DE HAAGSE HOGESCHOOL

Bachelor thesis

Implementation concept:

Implementing condition measurement, Shaft alignment

and on-site machining services in the Asia service stations

For obtaining the academic degree

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Preface

This thesis is submitted in partial fulfilment of the requirements for a bachelor in mechanical engineering degree at The Hague University of Applied Sciences. It contains work done from May to August 2015. This thesis has been made solely by the author, with text and philosophies based on the research and knowledge of others, for whom I have done my best to provide with proper reference.

During my previous internship and working experience at SKF Machine Support in Ridderkerk I have had the pleasure to meet and work with Mr. Schnäckel, who has commissioned this research. The idea for the research was to create an overview of the requirements to share the knowledge and experience between all the service stations.

At the end of May I have had the honour to travel to one of their Asian service stations in Shanghai, China. Here I have conducted research on the requirements for that office in order to implement the services performed by SKF Machine Support. I have had the pleasure to experience the work ethics and work methods of the Chinese culture.

The actual writing of the thesis has been done at the head office of SKF Blohm+Voss Industries, where I had all the resources I required to come to a sufficient result.

The writing of this thesis has been a difficult yet satisfying process, in which I have learned a great deal in both theory and life experiences.

Since this text has been written as the final thesis of the bachelor's degree in mechanical engineering, the text is aimed at teachers in mechanical engineer at The Hague University of Applied sciences in Delft. But I hope it will be of interest and support for the future SKF Marine business group and will support in future choices to be made.

Acknowledgements

I would firstly like to thank Mr. Schnäckel for creating the possibility for me to gain this amazing experience, and for the ideas, guidance and support given during my project.

Off course I want to thank all of the BVI Shanghai personnel for welcoming me with open arms and guiding me through the hectic world of Shanghai. With special regard to Mr. Kudruz with whom I have shared many fruitful conversations during the delicious Chinese lunches.

Thanks also towards my very companionable colleges at the Quality department in Hamburg, with special thanks to Mr. Meinhardt for keeping me motivated and laughing throughout the entire project.

Finally I would like to thank Mr. van der Vlugt for helping me get started and giving me direction for my project, without this proper goal in mind I would have never been able to finish this research.

Abstract

In this report a description is given of two implementation concepts for the implementation of shaft alignment, vibration measurement and on site machining in the Asia market. The entire analysis process has been described including an actor analysis, process analysis and market analysis.

The two concepts are based on two different business cases; the main concept is based on the concept off full implementation of all services and knowledge. The alternative concept is focussed on implementing the services that directly support the current services, mainly consisting of on-site machining supported with geometric measurements.

The first concept would take approximately 9 months to fully implement, of which a total of one month consists of training. The remaining months are planned for marketing, sales and building experience. The planning for the stages is summarized in Table 0-1: Overview planning main concept. *(Days are workdays without weekends and holidays)*

Table 0-1: Overview planning main concept

Main concept planning	Duration
Total	**150 days**
Stage 1	**10 days**
Stage 2	**40 days**
Stage 3	**40 days**
Stage 4	**20 days**
Stage 5	**40 days**
Stage 6	**0 days**

The costs for the main concept range between 241.729,00 € and 244.229,00 € depending on the choice of equipment supplier. The costs have been summarized in Table 0-2: Investment costs main concept

Table 0-2: Investment costs main concept

Current suppliers		**Alternative suppliers**	
Description	Costs	Description	Costs
Stage 1	1.395,00 €	**Stage 1**	1.395,00 €
Stage 2 *No investment required*	0	**Stage 2** *No investment required*	0
Stage 3	31.240,00 €	**Stage 3**	101.240,00 €
Stage 4	1.795,00 €	**Stage 4**	1.795,00 €
Stage 5	207.299,00 €	**Stage 5**	139.799,00 €
Stage 6	0	**Stage 6**	0
Total investment:	241.729,00 €	**Total investment:**	244.229,00 €

The alternative concept would require approximately 6 months to implement with an equal amount required for training. Most of the extra time required is for introducing new personnel and waiting time for equipment. The planning for this concept is summarized in Table 0-3: Overview planning alternative concept

Table 0-3: Overview planning alternative concept

Alternative concept planning	Duration
Total	**145 days**
Stage 1	**20 days**
Stage 2	**40 days**
Stage 3	**5 days**
Stage 4	**40 days**
Stage 5	**40 days**

The costs for the implementation of the alternative concept range between 179.939,00 € and 240.939,00 € these costs are summarized in Table 0-4: Investment costs alternative concept.

Table 0-4: Investment costs alternative concept

Current suppliers			**Alternative suppliers**		
Description		Costs	Description		Costs
Stage 1		195.499,00 €	**Stage 1**		134.499,00 €
Stage 2	*No investment required*	0	**Stage 2**	*No investment required*	0
Stage 3		1.395,00 €	**Stage 3**		1.395,00 €
Stage 4		15.545,00 €	**Stage 4**		15.545,00 €
Stage 5		28.500,00 €	**Stage 5**		28.500,00 €
Total investment:		240.939,00 €	**Total investment:**		179.939,00 €

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Abbreviations

ABS	American Bureau of Shipping
CAD	Computer aided drafting
CBM	Condition based maintenance
Class NK	Class Nippon Kaiji Kyokai
CSCL	China Shipping Container Lines
DNV	Det Norske Veritas
FEM	Finite elements method
FFT	Fast Fourier Transform
HRDD	Huarun Dadong Dockyard China
IMO	International Maritime Organization
ISO	International Standards Organization
LR	Lloyds register

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Introduction

The ship building industry has changed significantly over the last few decades. With the rising demand for products from far away countries, the demand for mass transportation has increased. Due to this demand the size of transport ships has increased substantially.

The demand for larger ships results in the installation of larger more powerful propulsion systems. This propulsion power is in effect transferred over longer distances. Shaft alignment is becoming more important in order to keep vibration and wear of equipment to a minimum.

The current marine service market has limited knowledge and experience in the field of shaft alignment. During the design phase an immense amount of research and thought is put in the proper alignment of the propulsion line. During the lifetime of a ship the alignment of components changes due to wear in parts and hull deflection.

A regular inspection of the alignment will increase the efficiency of the ships and will lower the amount of wear of all the components in the drive train. This is a main concept that follows the philosophy of planned maintenance and condition based maintenance. Both of these philosophies are already the standard in most industrial situations and will soon enter the marine maintenance world.

With the acquisition of SKF Machine Support, a significant amount of knowledge on shaft alignment, condition monitoring and on-site machining has been added to the SKF Blohm+Voss Industries service portfolio. In an effort to expand their service offset market and knowledge on this service field SKF Blohm+Voss Industries is searching to invest in the implementation of these service fields in the Asia market.

The implementation plan will consist of a multiple stage implementation aimed towards full knowledge transfer. The implementation plan has been divided in stages in order to keep flexibility in the implementation process, and to minimize the risks. For each stage of the implementation plan a time planning and financial overview is created based on estimated training times and costs based on offers by supplier and the local market.

The goal of the research is to provide the reader with a basic knowledge on the three main services, and give a clear description of the requirements to implement these services into a new business environment.

1 Research description

In this chapter the task and foundation of the project will be described. De project will be defined by a question schematic consisting of a central question, which will be supported by background questions and core questions. The questions defined in the schematic will be answered and elaborated in the further chapters.

1.1 Question schematic

The starting point for the question schematic will be provided by the main subject of the project and research. The project subject will lead to the central question, followed by the background and core questions.

Subject

The implementation of a new expertise in the service department, and the creation of the associated secondary conditions. The expertise will consist of condition measurement, shaft alignment and on-site machining

Central question

“What is the best method to implement shaft alignment, condition measurement and on site machining in the Asia service stations?”

Background questions

- What methods of shaft alignment exist?
- How is shaft alignment applicable to the current services?
- What methods of vibration measurement exist?
- How is vibration measurement applied to the services?
- What methods of on-site machine are applicable?
- What types of service jobs are currently executed?
- What is the level of expertise on the new service subjects?
- What are the restrictions of this new field of expertise? (*Laws, regulation societies etc.*)

Core questions

- Can the service jobs be combined?
- What materials/tools are used for this method?
- How much time is required to implement this concept?
- What are the implementation costs?

1.2 Motivation

A part of understanding the end goal of the project, is to ask why this project is a topic.

This paragraph will elaborate the main motivation for this research. The motivation will be a definition of why this project is of importance and will help the research to fit the needs of the commissioning party.

Background

The problem lying at the basis of this project comes forth out the recent addition of the SKF Machine Support office to the SKF Blohm+Voss Industries (*Hereafter referred to as SKF BVI*) portfolio. SKF Machine Support has specialized in the field of shaft alignment and vibration measurement since their establishment; therefore a great deal of experience is present in this part of the newly acquired office.

SKF BVI wants to start the implementation of this field of expertise in the BVI Shanghai Ltd. office. The execution of this implementation however has not been fully researched and the application of these techniques will be different for the Chinese market.

Problem

The definition of the problem is that the experience on shaft alignment and vibration measurement is available, but not yet transformed to a concept that can be utilized by the Asia service stations.

The research will focus on the requirements for the implementation of the knowledge and expertise in the Asia service stations, starting with the BVI Shanghai Ltd. office

2 Business profiles

In this chapter the business profile of the concerned parties is described. The reason for this is to give insight in the connection between each actor. This will also serve as a foundation for the actor analysis performed to define the demands and wishes for this project.

All of the connections of the parties are visually represented in Figure 2-1: Business connections, visible here is that all three parties are part of SKF Marine with SKF BVI GmbH as a controlling structure for SKF Machine Support and BVI Shanghai Ltd.

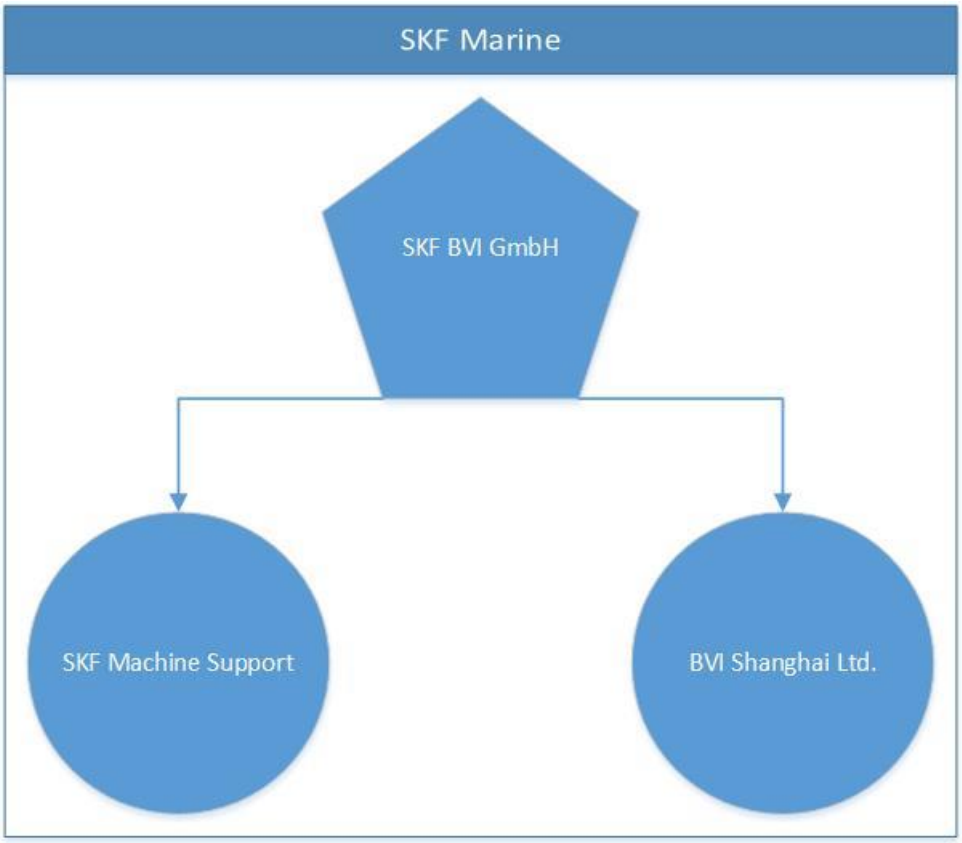


Figure 2-1: Business connections

2.1 SKF Blohm+Voss Industries GmbH[1]

SKF BVI is the main investor for this project. SKF BVI has been acquired by the SKF Global concern in order to open the marine market for SKF products.

SKF BVI is a worldwide renowned producer of ship parts producing:

- Intermediate shaft bearings
- Stern tube seals
- Oily water separators
- Stabilizers

SKF BVI will be the main controlling office for all of the recently acquired business subsidiary in the field of marine products. Starting September 2015 SKF BVI and all marine subsidiaries will become part of the new business group SKF Marine.

2.2 Blohm+Voss Industries Shanghai ltd.[2]

Blohm+Voss Industries Shanghai ltd. (*hereafter referred to as BVI Shanghai*) is a subsidiary office for SKF BVI. The BVI Shanghai office operates as a service station for the Asia market. They are currently the largest service station in Asia performing over 500 service jobs yearly with a team of 17 field engineers.

Their main activities consist of the repairing and commissioning of the SKF BVI products with a yearly account of nearly 200 stern tube seal services.

Besides working as a service station for the SKF BVI products they also function as a service support hub for the Fuchs[3] marine cranes and Hatecke[4] life-boats.

[1] http://www.bv-industries.de/
[2] http://bv-industries.com/company/locations/china.cfm
[3] http://www.fuchs-cranes.de/en/
[4] http://www.hatecke.de/

2.3 SKF Machine Support[5]

SKF Machine Support is a specialized company on the field of drive train services, with their main field of expertise consisting of three topics:

- Shaft alignment
- Condition monitoring
- On-site machining

Having 30+ years' experience in this service field they have acquired a large amount of knowledge and experience on these topics. Having a team of approximately 15 field engineers they currently offer their services all over the world.

With the start of SKF marine they will become a service station to the likings of the BVI Shanghai office and will share the knowledge of the BVI field as well as the knowledge of the SKF group.

2.4 SKF Marine[6]

The SKF marine group is the future marine segment consisting of all the business offices with their main focal point on the marine segment. SKF BVI will become the controlling office for the business unit marine.

With the official coupling under the SKF Marine business unit the former described companies will start sharing their knowledge and therefore expand the total offset market for their marine services and marine focused product.

The process has currently been set in motion by the SKF BVI group by training engineers from all subsidiary offices in the field of sealing service etc. And the SKF Machine Support crew has started training some of the service engineers from the SKF BVI team in the field of shaft alignment.

[5] http://www.machinesupport.com/contact/ridderkerk.html
[6] http://www.skf.com/group/industry-solutions/marine/index.html?alias=www.skf.com/marine

3 Demands and wishes

Because we are dealing with a multiple actor project, it is important to map and analyse each actors influence on this project. The influence of each actor will support the definition of their demands and wishes and will give a better image of the variables that influence the implementation.

3.1 Actor analysis

Before executing the actor analysis a visual overview of all the actors has been created as is shown in Figure 3-1: Actor diagram. In this image each party influencing the eventual product/service is shown in respect to their actor group.

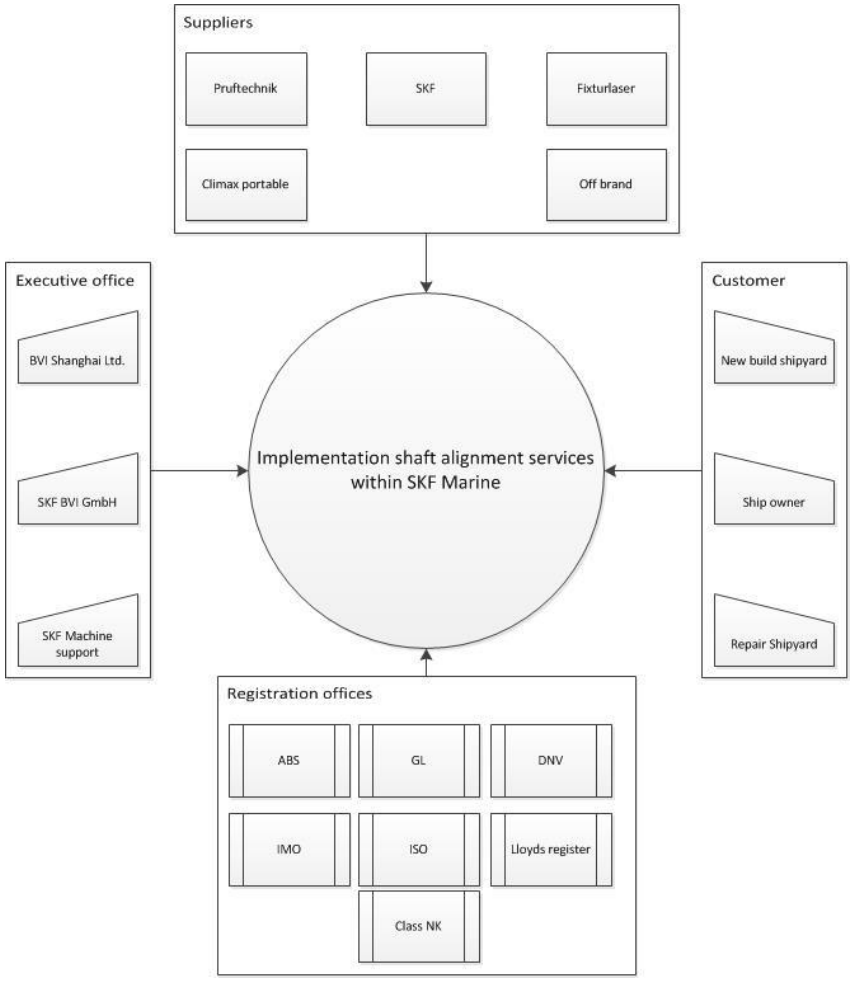


Figure 3-1: Actor diagram

The customers and executive offices are each describes as individual actors because they have differing influence on the project. The suppliers and registration office are defined as singular actors because their influence on the process is equal.

After defining the different actors their position in the project has been defined using the actor analysis as shown in Table 3-1: Actor influence table.

Table 3-1: Actor influence table

Actor	Role				Attitude				Contribution		
	Leading	Using	Provide work & resources	Execution	+	0	-	?	Indispensable	Important	Unimportant
SKF BVI GmbH	x		x		x					x	
BVI Shanghai		x		x	x					x	
SKF Machine Support			x				x		x		
New build shipyard		x				x				x	
Ship owner		x						x	x		
Repair shipyard		x				x					x
Suppliers			x			x				x	
Registration offices	x		x		x					x	

After stating all the actors and their position and role in this project their separate demands and wishes can be described.

3.1.1 Executive office

The executing offices are the main parties in this project; they request the research to be pursued and its outcome to be taken as an advice for the further progress. Because the different actors take different roles in the end product/project their individual demands are different.

SKF BVI GmbH

The SKF BVI GmbH office is the most influential actor in this project. Their role is that of the managing and controlling party; they are the ones who requested this research.

Their demands and wishes for this project are the red line in the project as the project is executed in their request.

Demands:

- This project will provide a clear concept for the integration of the new service business
- This project can be used to start the new project
- This project provides a better insight in the capabilities of the actors involved
- This project describes all necessities for the service to be executed

Wishes:

- This research will create a better understanding on the new service field
- The project will lead to new opportunities in the current service market
- This research will provide better understanding of the shaft alignment and on site machining service market

BVI Shanghai Ltd.

BVI Shanghai will be the first service station to start catering the Asia service market with the new services. Therefore they will serve as a trial stage in order to see what the possibilities are and what the market value will be for this new service field.

As they have the executive role in this project but no previous experience their demands and wishes are the following.

Demands

- A clear overview of the capabilities
- A well-defined training and implementation plan
- Defined theory and training material
- Proper support structure

Wishes

- To become a self-supporting service station
- To expand their capabilities and market
- To expand knowledge

SKF Machine support

The role that SKF Machine support fills is the role of teaching and training support office. They have to provide in the training and sharing of knowledge as well as support for the fresh starting offices.

They have the following demands and wishes.

Demands:

- To not lose their market or projects
- To keep control of their knowledge
- To use the tools they are familiar with

Wishes

- To have BVI Shanghai as a sales channel for their services
- To improve and expand their market and business

3.2 Customers

A customer is defined as the beneficiary of the service. In the business case handled in this research this will always be the ship-owner. However the service can be performed in request of other parties with the end beneficiary being the ship owner. Therefore we define the customer as one of the following parties:

- Repair shipyard
- New-build shipyard
- Fleet manager
- Ship owner

The customers have a very direct influence on the project. The main goal of offering any product is to cater to the needs of the customer. This is one of the driving factors for any research or investment in new products and services.

Because of this the customer has a lot of influence on the eventual outcome of the research/ product. As their wishes and demands shape and affect the product.

The customer defines the following parts of project:

- Possible off set market
- Installation size
- Project potential

Demands

- Fast service
- High quality service
- Service on demand

Wishes

- Cheap service
- Experienced service engineers

The wishes and demands have been estimated at the start of the research, during the research the visits to the repair shipyards and multiple conversations with the general manager of the BVI Shanghai office have confirmed these expectations.

3.3 Suppliers

The suppliers can be seen as one actor consisting of several stakeholders. The suppliers have influence on the project in the following fields:

- Investment costs
- Product support
- Training and knowledge support

The investments costs are directly affected by the investment price into the product bought by the suppliers. But besides the purchasing cost the training and knowledge transfer can also influence the investment costs.

Because of this the initial investment costs are just as important as the support covered by the different suppliers.

3.4 Registration/legislation offices

The registration offices have a large influence on the execution and the desired results linked to the project. The registration offices have the influence to change requirements for currently sailing ships and new build ship in the following areas:

- Maximum allowed vibrations
- Maximum allowed misalignment
- Required machinery checks
- Allowed wear on support structures
- Etc.

Due to their influence on the legislation for the ship owners they can influence the offset market for this service. When the registration and legislation offices adjust requirements for the shipping industry it will not affect the working process.

(Enserink, 2010)

4 Law and legislation

Every large ship in the world has to be classified by a classification bureau. These bureau's test the vessels according to several rules which are set by the IMO, Classification bureau's and the national organisations for shipping law and legislation.

As there are many classification offices it would mean a research on its own to check all of the laws and guidelines for the services. In this research the 4 most important classification bureaus have been used as a basis for the guidelines and laws for the three main service activities being:

- DNV
- Class NK
- ABS
- Lloyds register

Additional references are made toward the rules set by the IMO and standards according to ISO as global organisations defining the requirements.

4.1 Shaft alignment

For the execution of shaft alignment of marine vessels there are nearly no documents or rules that state the process or the requirements. The reason for this is the fact that shaft alignment procedures differ extremely per vessel. The guidelines for the alignment are therefore usually defined on the basis of allowed vibration and noise in a vessel.

Class NK and ABS have created guidelines for the execution of shaft alignment, in these guidelines it is assumed that the alignment is tested during the design phase. With the goal to deliver service on existing ships the guidelines don't fully apply to the executed services but still serve as an important reference.

The guidelines are described in the following publications:

- Class NK, June 2006, Guidelines on Shafting Alignment
- American Bureau of Shipping, APRIL 2006 (Updated February 2014), Guidance Notes on Propulsion Shafting Alignment
- DNV, July 2008, Rotating Machinery Power Transmission, Pt.4 Ch.4 Sec.1 – Page 20, F400

4.2 Vibration measurement

On the field of vibration measurement and condition monitoring there are a substantial amount of rules and regulations. Each of these rules applies to a different part of the ship and thus are not relevant for all the services that are to be executed on the ship.

Out of all the regulations the following are of interest for the services to be performed:

- IMO, 19 November 1981, Resolution A 468 (XII) Code on Noise Levels on Board Ships
- ISO, 05 December 1996, ISO 2923 acoustics – measurement of noise on board vessels
- ISO, 15 December 2000, ISO 6954:2000 Mechanical vibration -- Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships
- ISO, 01 June 2014, ISO 10816: Mechanical vibration -- Evaluation of machine vibration by measurements on non-rotating parts
- Class NK, July 2011, Noise and Vibration Guideline
- Lloyds register, July 2006, Ship Vibration and Noise Guidance Notes
- DNV, January 2011, Newbuilding Special equipment and systems – additional class Vibration class
- ABS, April 2006 (Updated February 2014), Guidance notes on Ship vibration

The abovementioned publications all describe the guidance notes and requirements for the vibration measurement. There are however separate publications for the field of condition measurement in the marine world some of the publications of interest for this field are:

- Lloyds register, February 2010, Condition monitoring of marine machinery
- DNV, October 2008, Guidance for Condition monitoring

4.3 On site machining

As on-site machining covers a vast amount of work procedures executed on board, there is no specific publication or rule prescribed for this type of service. When performing machining operation on board, it is important to have safety certified handling of equipment.

In Germany this is described by the SCC and in the Netherlands a VCA is required for all the operations. Each country normally has its own safety instance controlling the risk management for machining operations.

A standard reference point for the portable machining is to follow the ISO regulations. The various regulations can be found under:

- ISO/TC 39 conditions.
- ISO standards catalogue 25.080.01: Machine tools in general.

5 Service operations

In this chapter the service operations are described. The description is based on the standard procedure that is followed when currently performing the services. The service operations are followed in chronological order to have a logical overview.

Every step of this process is described and the requirements and methods will be described in each of the steps.

5.1 Service request

Every service project start with a service request by a customer, any of the three main services can be requested but usually the request is a combination of all capabilities. The root cause to request the services can come forth out of several situations off which the following are the most common:

- New build situation
- Drive train adjustment
- Planned maintenance
- Critical failure

These situations are based on the description of situations as discussed with the SKF Machine Support team as well as the descriptions made in:

- (K.H. Low, 2003)
- (Piotrowski, 2007)

In order to cover as much of the required methods and possibilities, planned maintenance will be the type of request described in the further service process. In this case an existing set-up shows signs of oncoming failure, or is scheduled to undergo standard maintenance.

The request starts with a definition of the installed machinery and a situation description. Usually a blueprint of the ships machine room is sent providing with the necessary information. In some situations a blueprint is not available in those cases a standard form is filled in by the customer describing the situation.

An example of this information is shown in Appendix D: Service data sheet.

5.2 Planning and modelling

In order to plan a service job properly the actual situation and optimal situation for the installation has to be defined. The current situation will be modelled based on the information provided by the customer during the request. This information preferably consists of:

- Ship blue print
- Optimal situation (*Design stage*)
- Component age and state
- Complaints and current errors
- Previous maintenance reports
- Repair/ Service planning (*Time in dry dock, anchorage etc.*)

With the use of this information a current state model is usually created by the back office support engineer. With the use of CAD software package an overview image can be created of the current situation. An example of such an image is shown in Figure 5-1: CAD situation model.

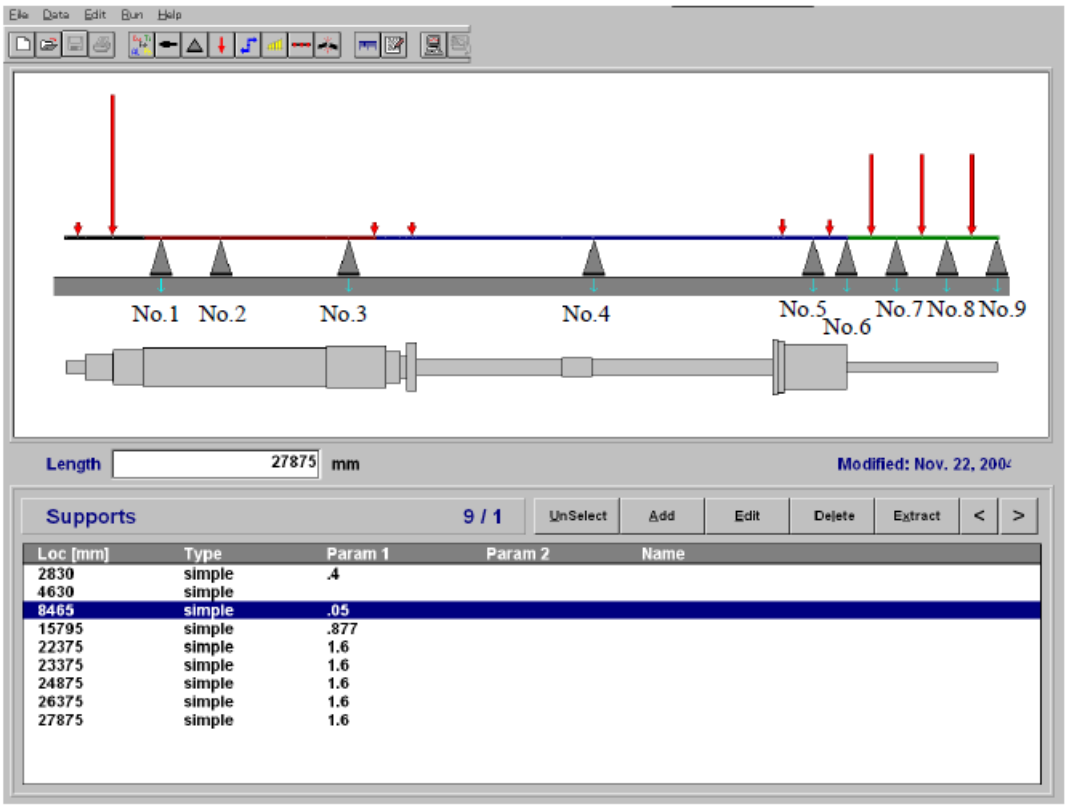


Figure 5-1: CAD situation model (NK, 2006)

When dealing with an emergency situation a quick sketch can be made by the field engineer using graph paper. However dealing with high tolerances a CAD situation is preferred.

After creating the current model showing each component in respect to one another the optimal situation will be modelled in order to set the goals for the field engineers.

The goal of the service is to create a properly aligned drive train. Because a properly aligned drive train will give the least vibration and have the best running condition. However creating a properly aligned drive train on a ship is dependent on many variables of which the greatest variable is the hull deflection.

The hull of a ship will deform and change shape under different conditions. A visual representation of this phenomenon is shown in Figure 5-2: Hull deflection.

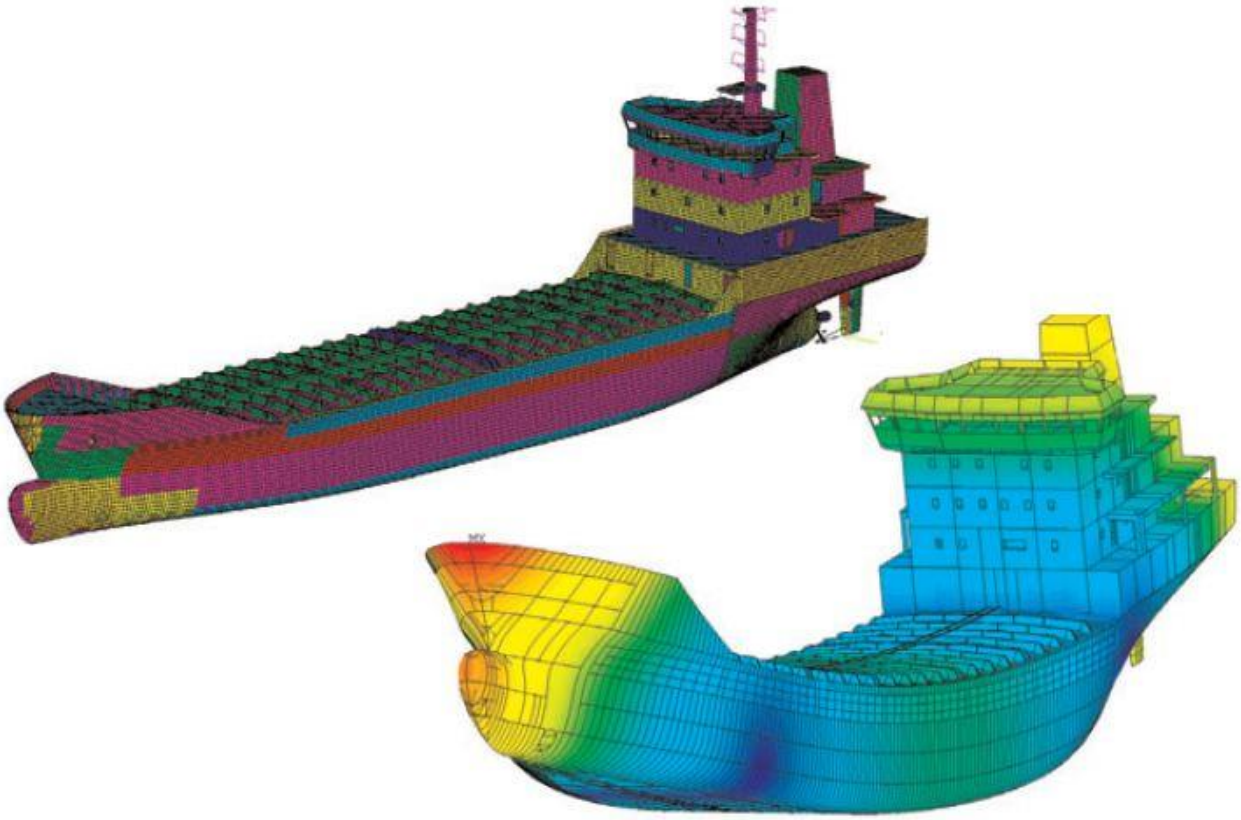


Figure 5-2: Hull deflection (Naval, 2015)

In order to reach acceptable alignment in standard conditions the hull deflection is usually calculated during the design phase. And in many conditions the actual hull deflection is measured and recorded during the sea trial.

However in many cases this information is not provided by the customer and therefore these values have to be defined by the back office engineer. In order to create this data a FEM (*Finite Element Method*) software package is used to model the hull deflection based on the technical data. An example of such software is the SKF owned Shaft designer or the ABS hull inspection software.

With the use of this software the vertical and horizontal movement of the drive train components can be modelled and recorded.

With the use of the SKF Shaft designer software more variables can be modelled in order to provide with a full alignment plan this software can model:

- Hull deflection
- Thermal growth
- Shaft deflection
- Shaft whirling

When the required data is prepared an alignment plan is provided to the field engineer. An example of an alignment plan is shown in Figure 5-3: Alignment plan.

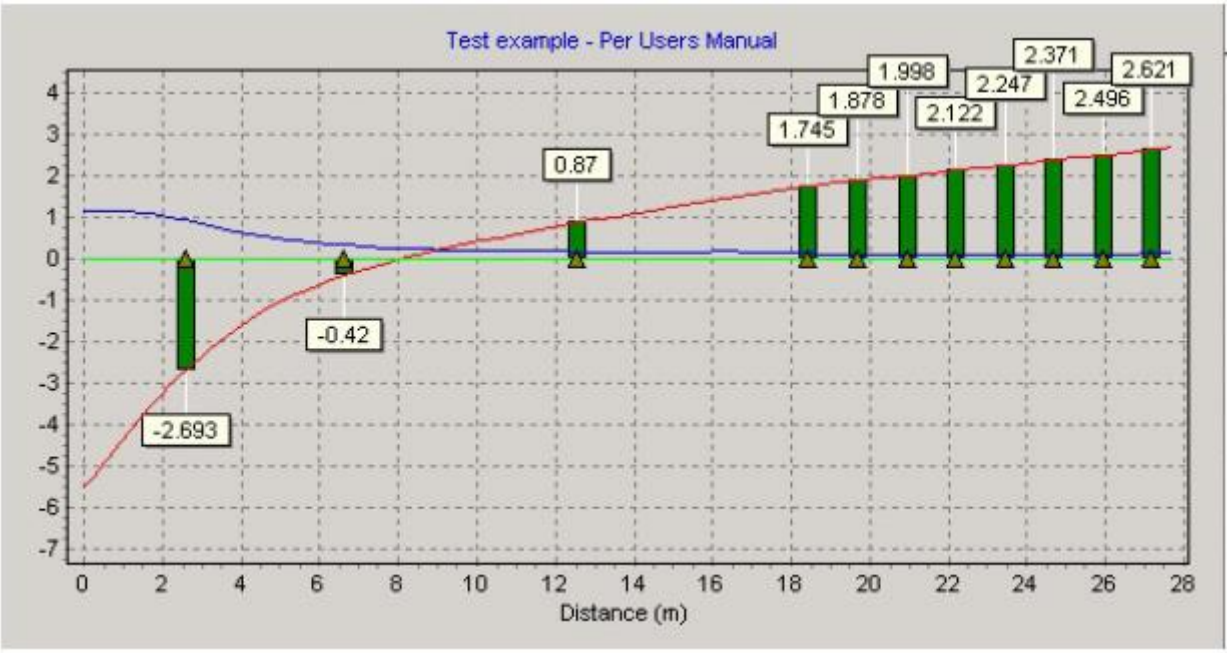


Figure 5-3: Alignment plan (ABS, GUIDANCE NOTES ON PROPULSION SHAFTING ALIGNMENT, 2006)

In this plan each node shown on the graph is a component, where the red line represents the shaft line, the green line the reference line for the foundation, the blue line the hull deflection influence and the green beams represent the required movements to have the best support for the shaft.

With such an alignment plan the required gap and sag values for the offline alignment can be defined and the service can be performed resulting in proper alignment.

(NK, 2006) (Piotrowski, 2007) (K.H. Low, 2003)

5.3 Work preparation

Before actually performing the service the field engineer has to assess the situation on board. This has to be done in order to ensure a good starting position resulting in the most precise measurements and efficient work flow. To ensure a proper starting situation the engineer performs the following checks:

- Situation check
- Component check
- Run-out check
- Shaft deflection check
- Foundation and base plate check

5.3.1 Situation check

When arriving at the location a first situation check is of high importance not only to check whether or not the previously described situation is correct but also to check if the ship is in laden condition or empty and if the ship is currently bunkering etcetera.

Then when the ships situation is familiar, the engineer will have to assess the situation on board measuring the distance between the components and referencing this with the alignment plan. Due to the fact that after several years in use the ships components tend to be altered and installations changed a new situation sketch might be required and the alignment plan has to be altered to the actual situation.

If anything in the installation has changed a new situation sketch will be made and the optimal alignment will have to be calculated again using the FEM software package.

(*This process is based on standard procedures as performed by the SKF Machine Support team. References can be requested in the form of the work instructions at SKF Machine Support)*

5.3.2 Component check

The components themselves can cause many problems both on the alignment and the vibration levels of the machinery which will be discussed in later chapters. In order to perform an effective measurement all possible deviations have to be found and taken in account.

When checking the components it is important to check for signs of excessive wear due to vibration or wrong operations. Such as leaking seals, tears in component housings, cracked welds or worn out bolt holes.

All these sign are to be noted and reported to the superintendent, and preferably resolved before the actual alignment job.

(Piotrowski, 2007)

5.3.3 Run-out check

When dealing with shafts and flanges the field engineer is dealing with seemingly round objects that have a centre of rotation. However it can never be assumed that the round objects are actually perfectly circular. Due to several factors a flange or shaft can in fact be slightly asymmetrical a phenomenon than will cause false measurements.

The definition of shaft run out defines this phenomenon:

> *"Run out is defined as the degree to which a shaft or coupling deviates from the true circular rotation"* (Riddle, 2013)

Before starting the actual measurement the run-out of the shaft, flange or coupling has to measured and noted. And if possible the run-out situation has to be fixed before performing the actual alignment procedure.

The shaft run out is measured using dial gauges in a setup as is shown in Figure 5-4: Run-out measurement set up. In Figure 5-5: Visual representation of run-out a theoretical measurement of run-out is shown.

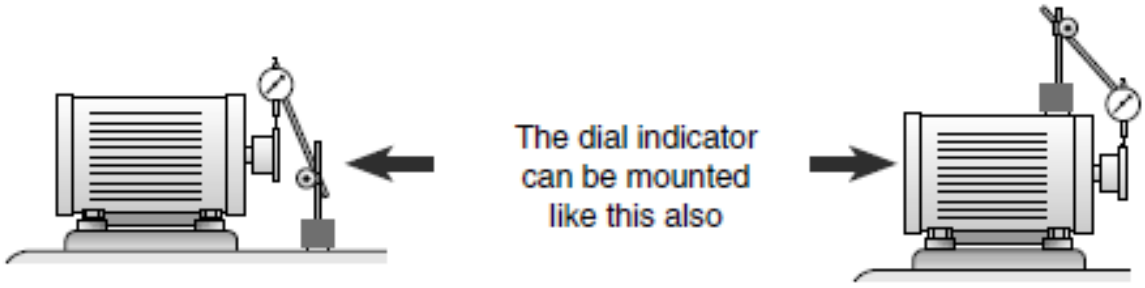


Figure 5-4: Run-out measurement set up

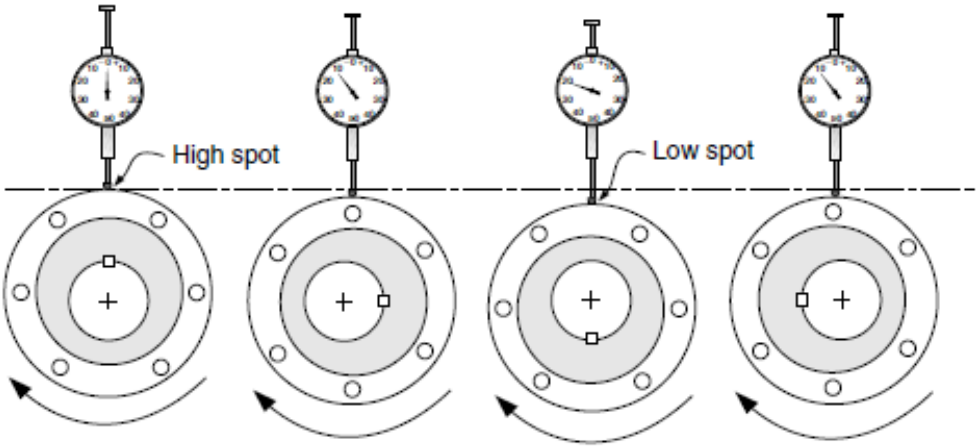


Figure 5-5: Visual representation of run-out

(Piotrowski, 2007) (Riddle, 2013)

5.3.4 Shaft deflection check

When dealing with longer shaft lines, the shaft is influenced by gravity, which causes the shaft to bend. Due to this phenomenon the measured alignment could deviate from the actual occurring alignment. In order to measure the shaft deflection a similar method is used as is used when run-out is measured.

One measures shaft deflection by measuring the run out on several points over the length of the shaft as is shown in Figure 5-6: Shaft deflection measurement.

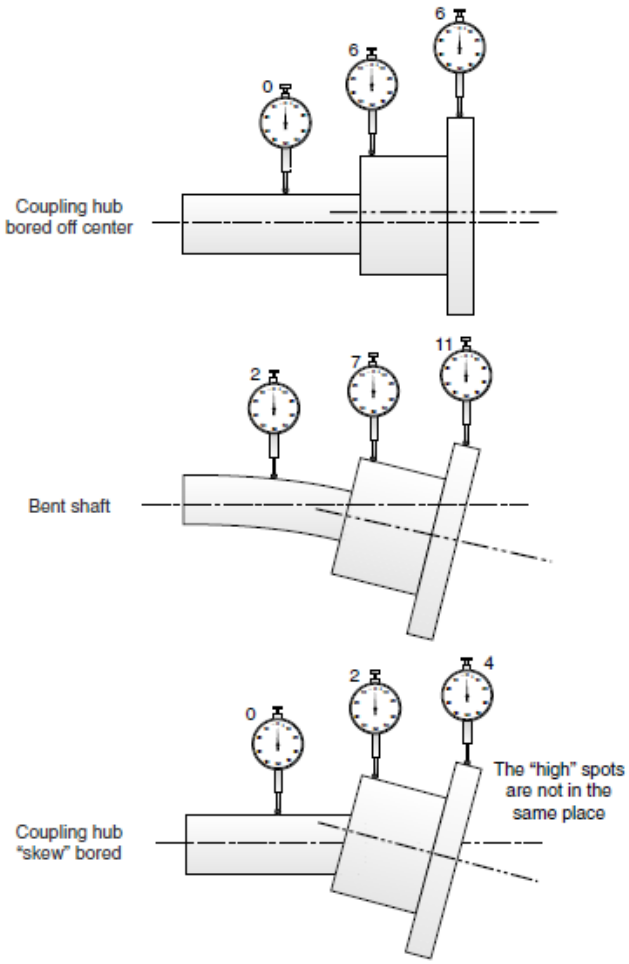


Figure 5-6: Shaft deflection measurement

Only by measuring the run-out on several points over the length of the shaft the actual deflection can be measured in Figure 5-6: Shaft deflection measurement several shaft deflections are shown each with a different outcome in the actual alignment measurement.

It is important to note the shaft deflection in order to adjust the alignment plan to these deviations.

(ABS, GUIDANCE NOTES ON PROPULSION SHAFTING ALIGNMENT, 2006) (Piotrowski, 2007)

5.3.5 Foundation and base plate check

The foundation and base plates can have a large effect on the components. When dealing with so called soft-foot the machine has a foundation that is not fully connected to the supporting structure. Soft foot is the cause of excessive stresses, vibration and misalignment in drive trains.

When starting the alignment it is important to check whether the components foundations show no signs of corrosion. A flatness measurement is recommended in order to ensure a straight fully supportive foundation.

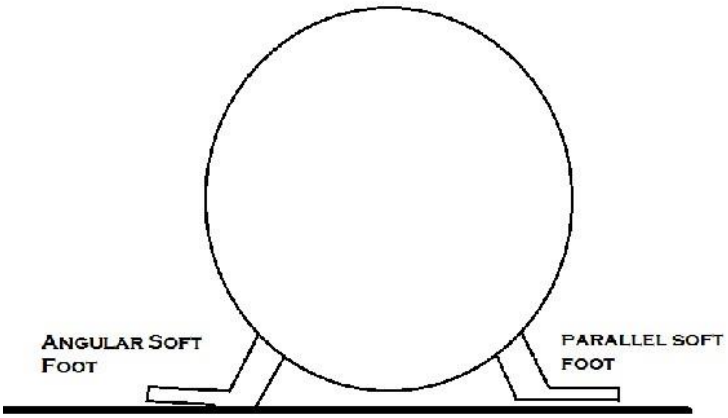


Figure 5-7: Soft foot (Case, 2010)

The soft foot has to be taken in account when chocking the component especially in the case of angular soft foot in which case the chock has to be adjusted to the angle of the soft foot. An example of both types of soft foot is shown in Figure 5-7: Soft foot.

(Piotrowski, 2007) (Case, 2010)

5.4 Vibration monitoring

"Vibration monitoring involves the acquisition of vibration data which can then be compared over a period of time" (LR, 2013)

Vibration measurement is a preferred and proven method for finding mechanical for rotating equipment. With the use of vibration analysis and the search for common vibration signatures a lot of root causes for machinery failure can be recognized and resolved.

It is also possible to identify shaft misalignment without interrupting the ships normal operation with the use of vibration analysis. This makes it a great tool in order to support the shaft alignment service.

The vibration measurement is mostly part of a CBM approach and is therefore not part of the regular service process. It is however a great tool to be used, and assists in offering a complete service to the market.

There are several solutions for measurement of vibrations, the most important being:

- Permanently installed systems
- Semi-permanent systems
- Portable monitoring systems.

For this project only the portable monitoring is covered, due to the fact that the other measurement options are not to be performed by a field engineer.

(LR, 2013)

5.4.1 Measurement process

The vibration is measured with the use of accelerometers combined with portable analysing equipment. Measurements are performed on the supporting structures of the drive train. The accelerometers can either be connected to the components with the use of a magnetic base or they can be connected with the use of special connection points. The accelerometers output can be processed to provide with the acceleration, vibration and displacement of the vibrating component. This makes them ideal for the analysing process of vibrations

There is also the possibility to measure the vibration with the use of non-contacting proximity probes these come in handy when the measurement points are hard to reach. They can however only measures the relative displacement between the rotating and non-rotating elements of the machine.

The actual process of placing the vibration sensors and performing the measurement is described in Appendix A: Work instructions.

(LR, 2013)

Requirements

The requirements for this type of measurement consist of:

- Accelerometers
- Signal converter
- Analysing software*(Optional but recommended)*
- Portable vibration analyser

There are enormous amounts of suppliers of accelerometers, signal converters, software and vibration analysers on the market. SKF is one of the world leaders in this equipment and being part of the SKF concern it would be logical to use this equipment.

Prüftechnik offers a competing range of vibration analysis equipment and might serve as an alternative to the vibration measurement equipment.

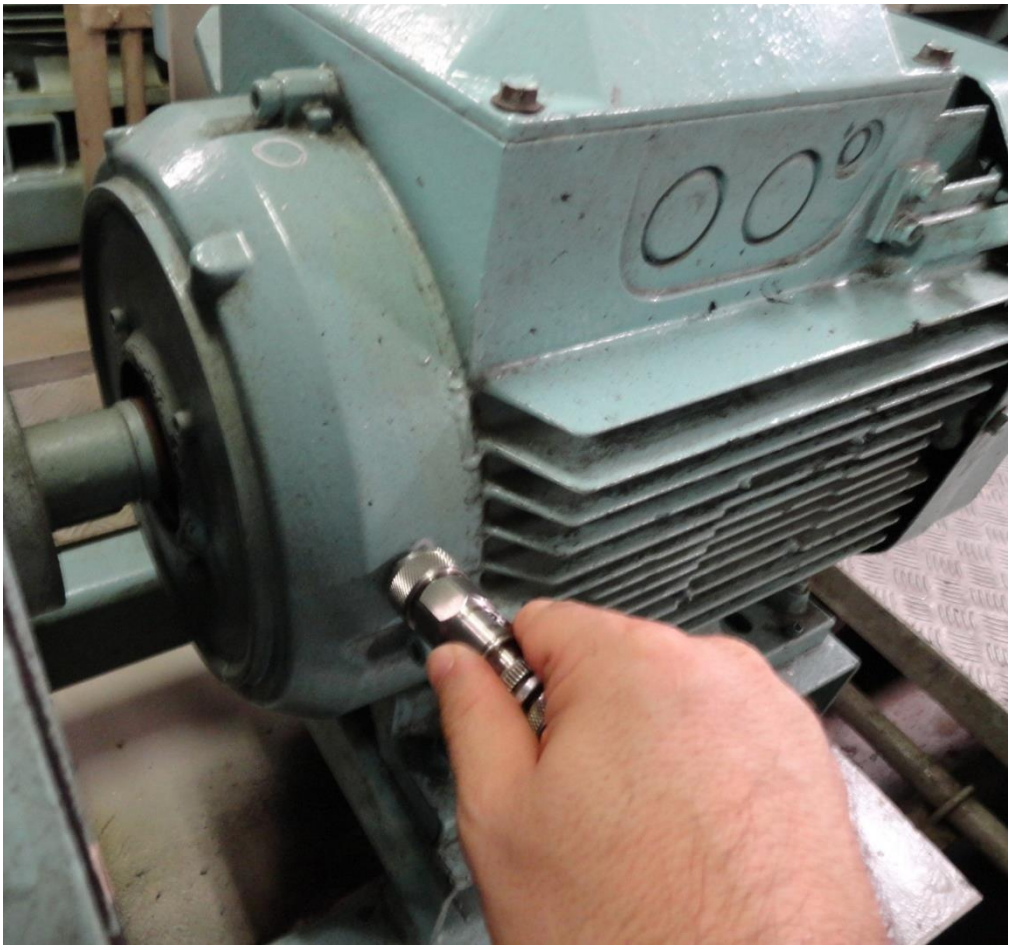


Figure 5-8: Vibration measurement (Staykov, Accelerometer mounting, 2014)

5.4.2 Measurement analysis

The analysis of vibrations and vibrations is a wide field of expertise and has been subject of research for many years. The offering of vibration analysis is on its own an entire service field to the industrial and marine market.

In this project the vibration analysis serves a support function therefore only the recognition of certain vibrations as an effect of misalignment are described. A common misconception of vibration caused by misalignment is that the vibration increases due to the misalignment. This however is not always the case normally the signature of the vibration changes but the vibration level itself does not increase.

The vibrations are measured as is described in Paragraph 5.4.1 these measurements are to be transformed into a format that can be analysed. A standard format for this is the Fast Fourier Transform (*FFT*) in this format the amplitude is set out to the vibration frequency. With the amplitude of the higher order frequencies can be analysed. A theoretical example of the Fourier transform is shown in Figure 5-9: Fourier transforms.

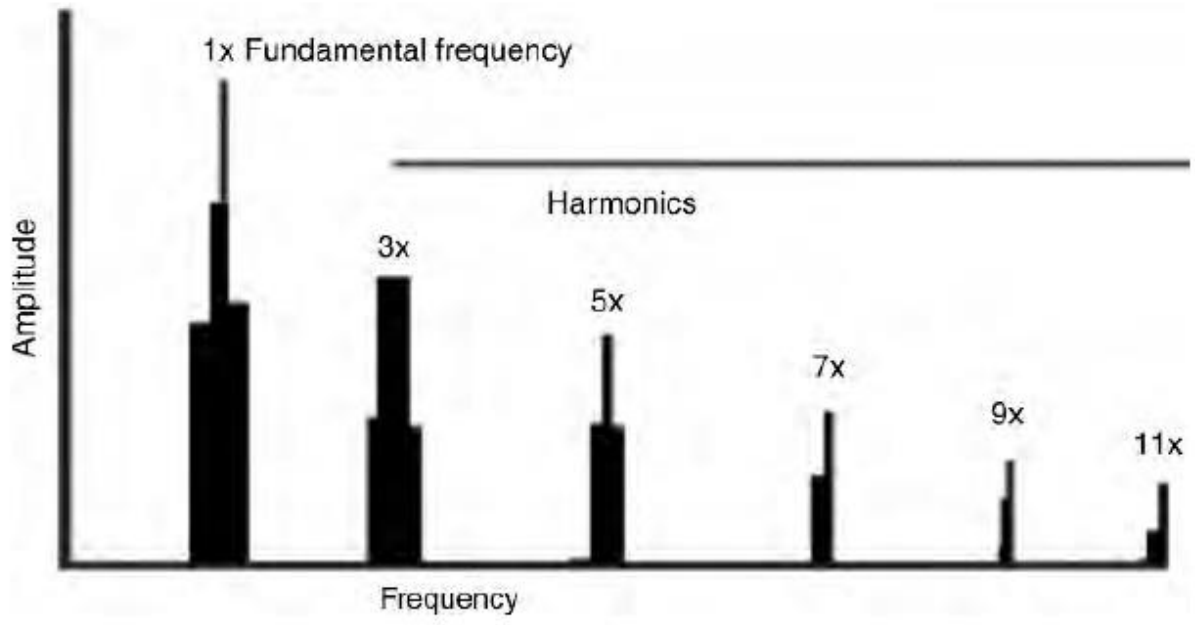


Figure 5-9: Fourier transforms (Cornelios Scheffer, 2004)

(LR, 2013) (Cornelios Scheffer, 2004)

When a theoretically perfect situation occurs the vibration signature would display only the fundamental frequency of the driving component. To translate this to the real life situation when a drive train is driven by a diesel engine running at 600 RPM, a perfectly aligned and constructed drive train would show a vibration of 600 Hz with small amplitude. Such a perfect situation is depicted in Figure 5-10: Vibration signature ideal.

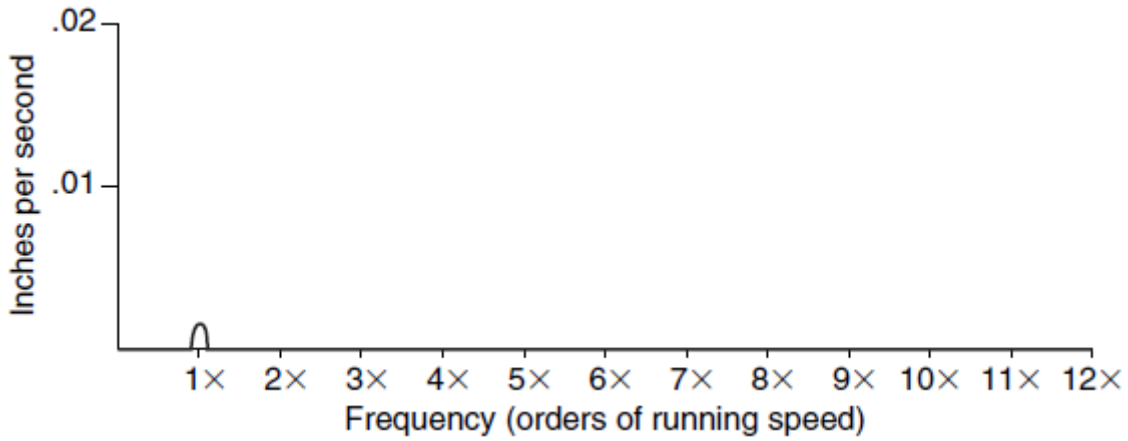


Figure 5-10: Vibration signature ideal (Piotrowski, 2007)

When dealing with misaligned shafts the forces acting on the shaft force the shaft to bend. As an effect the amounts of nodal points on the shaft increase due to the bending. When the amount of nodal points increase the frequency is amplified, this result in a vibration signature as shown in Figure 5-11: Vibration signature misaligned.

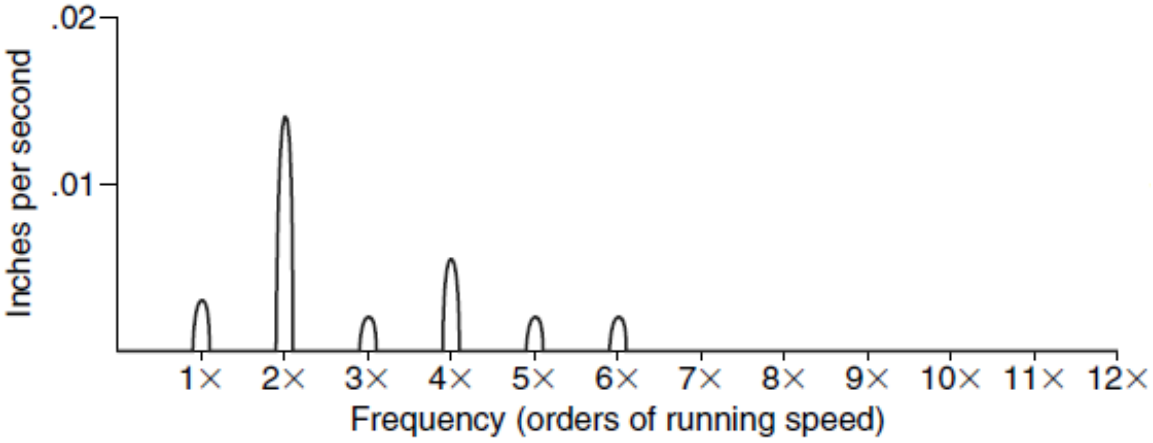


Figure 5-11: Vibration signature misaligned (Piotrowski, 2007)

With this knowledge the analysis of vibration signatures can be used to identify misaligned machinery. When searching for misaligned situations the vibration signature would show increased amplitude on the higher harmonic frequencies. The heightened amplitudes are a result of resonation of the components and surroundings

The previously depicted signatures are theoretical approximations of real life vibrations. The vibration signatures of real life measurements often show more white noise and are set out over time. This makes the analysis somewhat more difficult, but as is shown in Figure 5-12: Real life vibration signature the higher harmonics are clearly visible and the white noise is rather limited.

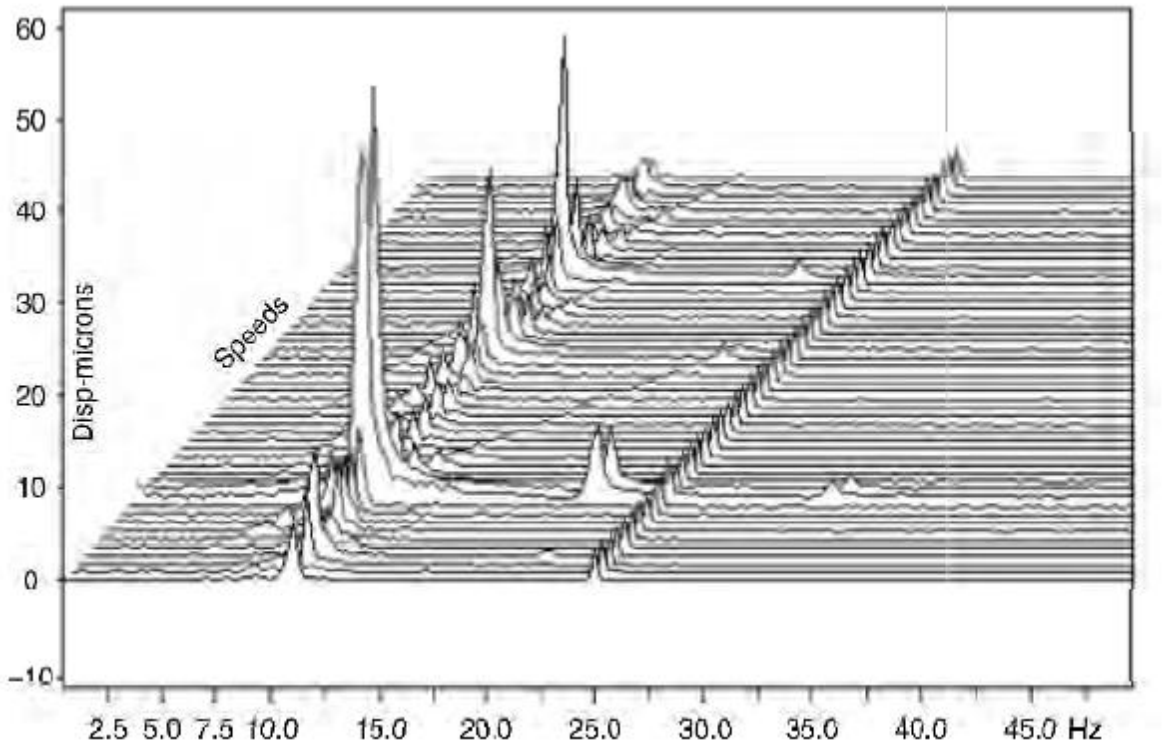


Figure 5-12: Real life vibration signature (Cornelios Scheffer, 2004)

Lloyds register has released a standard table in which the typical interpretations of causes for vibration levels are listed. This interpretation tool is a good method of analysing the occurring vibrations. This table is shown in Table 5-1: Vibration interpretation.

(Cornelios Scheffer, 2004) (Lei Shi*, 2010) (LR, 2013)

Frequency of vibration	Order	Most likely cause	Amplitude	Other possible causes and remarks
1 x Rotor RPM	1st	Unbalance	Proportional to unbalance; largest in radial direction	Most common cause of vibration; Eccentric journals, bent shafts
1 x Rotor RPM (2 & 3 x RPM sometimes)	1st	Misalignment of couplings or bearings	Large in axial direction	
2 x Rotor RPM	2nd	Mechanical looseness	Radial direction	Usually accompanied by unbalance and/or misalignment Could also be rubbing effects
3 x Rotor RPM	3rd			Rare. Could be a combination of misalignment and looseness
1/2 x Rotor RPM or less	1/2	Oil whip or whirl		Occurs on high or medium speed pressure lubricated machines with plain bearings
Many times RPM	nth	Gear noise Aerodynamic forces Blade defects	Low	Gear teeth x RPM of gear wheel Blades x RPM of rotor

Table 5-1: Vibration interpretation (LR, 2013)

5.5 Bearing load measurement

The loads on and reactions forces of the bearings are good indications for many machinery conditions. High loads on bearings can be an indication of improperly installed shafts and misaligned components. The standard for measuring the bearing loads is to perform a bearing reaction measurement with the jack-up method.

The jack-up method basically means that the shaft is lifted from the bearing. Considering the basic laws of physics the required force to lift the shaft out of the bearing is equal to the force that the shaft exerts on the bearing.

In reality the situations are often not as simple as more forces come into play such as the suction force of the used oil film between the bearing and shaft, or the amount of force that shaft will take up due to bending.

Process

The process of measuring the bearing load is basically setting up the hydraulic jack as near to the bearing as possible. With the use of a load cell or calculation table that converts the hydraulic pressure to force, the amount of force exerted to lift the shaft is measured.

This force is set out to the vertical movement of the shaft, this results in a so called Jack-up curve as is shown in Figure 5-13: Jack-up curve.

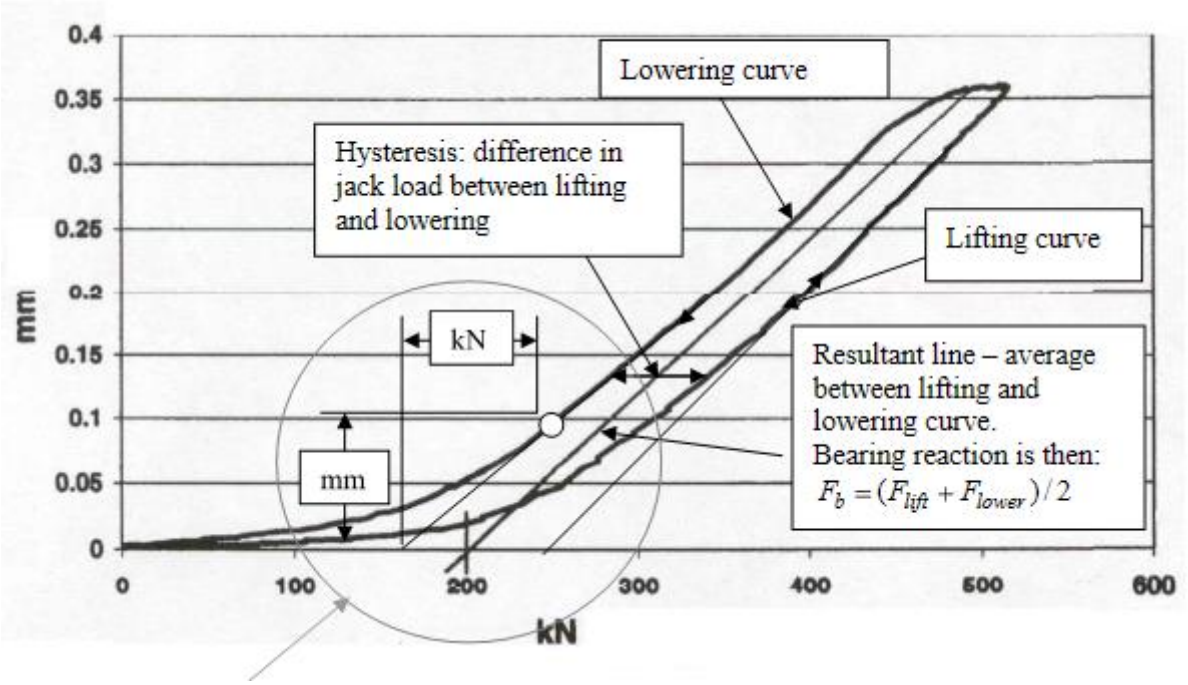


Figure 5-13: Jack-up curve (ABS, GUIDANCE NOTES ON PROPULSION SHAFTING ALIGNMENT, 2006)

With the use of such a Jack-up curve the forces acting on the bearing can be calculated and analysed.

Another option is to use strain gauges in order to measure the bending moments of the shaft near each bearing. The bending moment is measured during each point of rotation of the shaft. These forces can then be transformed to the bearing loads with the use of analysing software.

The shaft designer software is capable of analysing and processing these loads.

Requirements

The requirements to perform a bearing load test are:

- Hydraulic jack (*at least 50t capacity*)
- Load cell
- Strain gauge set
- Analysing software (*Not required but recommended*)

(ABS, GUIDANCE NOTES ON PROPULSION SHAFTING ALIGNMENT, 2006) (Murawski, 2005) (Piotrowski, 2007) (NK, 2006)

5.6 Measuring the alignment

When a proper starting point is ensured by performing all the on-site checks the actual measurement of the alignment can be performed. There are several methods to perform alignment measurements which will all be described in this chapter.

In this report a basic description of the methods will be made, the actual processes are described in Appendix A.

The measurement of the shaft alignment is in fact the comparison of the centrelines of rotation of both shaft components. The proper definition of shaft alignment is:

"SHAFT ALIGNMENT IS THE PROCESS WHEREBY TWO OR MORE MACHINES ARE POSITIONED SUCH THAT AT THE POINT OF POWER TRANSFER FROM ONE SHAFT TO ANOTHER, THE AXES OF ROTATION ARE COLINEAR IN NORMAL RUNNING CONDITIONS" (Piotrowski, 2007)

The shaft alignment is measured using several techniques all differing in execution and outcome. The method used is chosen depending on de situation and on the required tolerance.

The following methods are the most common, sorted from least precise to most precise measurement.

- Sight through measurement
- Feeler gauge measurement
- Dial gauge measurement
- Laser measurement

Each of these techniques has a different process and all have different requirements and outcomes. Which will be described in the following paragraphs.

(Piotrowski, 2007)

5.6.1 Sight through measurement

The sight through measurement is performed by defining the centrelines of rotation of the beginning of the component line and the ending of the component line. In this case this means that a straight line is being defined between the engine and the stern tube. The straight line can be made using several methods.

In short lines a piano wire or other wire type is tensioned between the two components in order to indicate the centre line. In longer set ups however a laser is normally used to indicate the centreline as a laser has no influence by gravity and will not sag over longer distance.

Each component will be placed with its consecutive centreline of rotation concentric to the straight line. Using this method each component can be placed within range of perfect alignment.

Pros

- Quick method
- Low labour intensity

Cons

- Low accuracy
- Only new building or retrofit situation

Process

The process of performing a sight through measurement is started by defining the centreline of the stationary component. In the case of marine vessels the stern tube will be the stationary component.

The laser will be placed in the centre of the stern tube projecting a straight line towards the main engine. This line will act as the reference line to align the components to. This reference line has been described earlier in the chapter planning and is shown in Figure 5-3: Alignment plan.

Requirements

For this method the shaft should not be installed therefore this method is only useful when dealing with new built situations or complete overhauls.

In order to perform this method of alignment the following equipment is needed:

- Laser transmitter
- Laser receiver
- Centreline bracket

These can be bought separately, or the transmitter and receiver from the laser alignment set (*As described in Appendix F*) can be used in order to perform this method.

(LR, 2013) (Piotrowski, 2007) (NK, 2006)

5.6.2 Feeler gauge method

Using the feeler gauge method to measure the shaft alignment is normally used as a method to make rough alignment. This is not a useful method of performing the end alignment but essential in preparation for alignment. With the feeler gauge alignment the components can be placed in positions close to the alignment, thus checking if the required machine movements are possible.

Feeler gauge alignment is also good for use in situations where accuracy is not of highest priority and minor misalignment is allowed. Usually this method is used when flexible couplings are used or in case of cardan drives as these types of coupling have a greater tolerance and can disperse more force.

Pros

- Quick
- Low labour intensity
- Minor knowledge required
- Works in small spaces
- Low costs

Cons

- Low accuracy
- Human error
- Coupling alignment/not shaft alignment

Process

The process of measuring the alignment with the feeler gauges is to place the feeler gauges on top or between the coupling flanges in order to measure the distance between the flanges. A visual representation of this method is shown in Figure 5-14: Feeler gauge measurement.

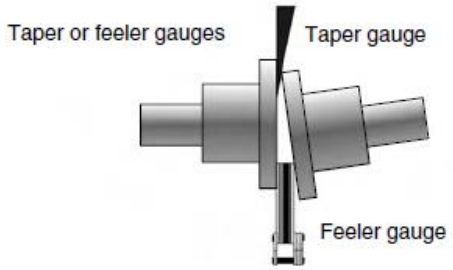


Figure 5-14: Feeler gauge measurement

Requirements

For this method of measurement only a set of feeler gauges is required.

(Piotrowski, 2007)

5.6.3 Dial gauge method

The dial gauge method is the method that is widely used for shaft alignment, most alignment jobs are still performed using this method. This method will correctly measure the differential in axial and radial direction of the shaft components.

Using some calculations the GAP and SAG of the shaft can be defined and with the proper training and experience the required adjustments can be calculated and executed.

Even though this method is widely practiced common, the execution requires a lot of knowledge and experience.

Pros

- High accuracy
- Cheap material
- Light weight tools

Cons

- Time consuming
- Requires extensive experience
- Requires intelligence (Relatively speaking)

Process

There are multiple methods of performing alignment measurement with dial gauges. Each of the methods applies to a different situation and with different calculation methods.

The reverse indicator is the most performed method of alignment as it provides both the angular as well as the parallel misalignment. Therefore the process of performing a face rim measurement is described. The dial gauges are to be installed as is shown in Figure 5-15: Reverse indicator measurement.

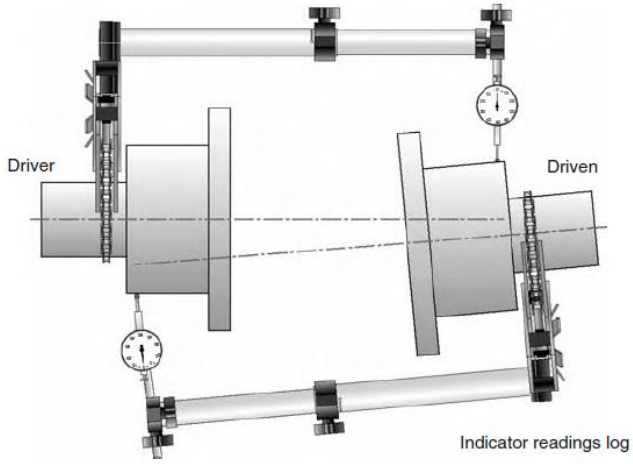


Figure 5-15: Reverse indicator measurement (Piotrowski, 2007)

The shafts are then to be rotated with 90° increments. At each increment the measurements are noted. With the use of the following calculations the alignment can be calculated.

VO = (S6-S0+SS)/2-(S6-S0+SS+M6-M0-MS)C/2D

VA = (S6-S0+SS+M6-M0-MS)/2D

HO = (S9-S3+SS)/2-(S9-S3+SS+M9-M3-MS)C/2D

HA = (S9-S3+SS+M9-M3-MS)/2D

Where:

VO	Vertical offset	**M0**	Right rim reading at 12 o'clock
VA	Vertical angle	**M3**	Right rim reading at 3 o' clock
HO	Horizontal offset	**M6**	Right rim reading at 6 o'clock
HA	Horizontal angle	**M9**	Right rim reading at 9 o'clock
S0	Left rim reading at 12 o'clock	**D**	Distance between left and right dial gauges
S3	Left rim reading at 3 o' clock	**C**	Distance between left dial gauge and coupling center
S6	Left rim reading at 6 o'clock	**SS**	Sag of left rim indicator
S9	Left rim reading at 9 o'clock	**MS**	Sag of right rim indicator

Requirements

For the dial gauge methods the following tools are required:

- 2 dial gauges
- 2 shaft brackets
- Set of mounting rods

(Piotrowski, 2007) (K.H. Low, 2003) (Prüftechnik, 2002)

5.6.4 Laser measurement

Laser measurement is a refined measurement method that has been based mostly on the dial gauge method. By rotating the shaft and measuring the differentials a linked computer performs the required calculations for the adjustments.

The laser method is the most user friendly method and requires the least training due to the easy GUI and the calculations performed by the computer.

Pros

- Fast method
- Highly accurate
- Immediate adjustment plan
- Efficient

Cons

- High cost

Process

The laser alignment kit consist two laser transmitter/receivers one for the stationary machine and one for the moveable machine. With the more advanced kits the laser transmitter/receivers are equipped with Bluetooth but usually the connection is made with cables.

The two laser units are placed on the shaft as is shown in Figure 5-16: Laser alignment set-up.

Figure 5-16: Laser alignment set-up

The shafts are then rotated while the laser units perform the measurement. This measurement is sent directly to the analysing computer.

The computer immediately analyses the alignment and shows the current alignment state in angular and axial misalignment. It also has the option to show the needed adjustments immediately.

An example of such a measurement is shown in Figure 5-17: Digital measurement.

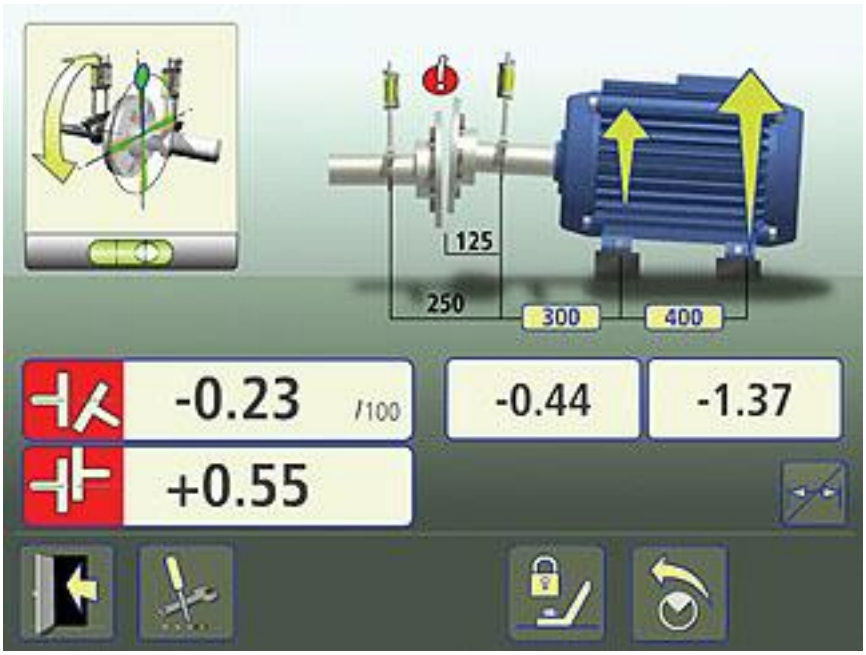


Figure 5-17: Digital measurement

Requirements

All that is needed for this type of measurement is a laser alignment tool kit.

The laser alignment toolkits come in complete packages ranging from very simple systems to fully stocked kits with alignment, vibration and geometrical measurement capabilities.

Some examples of such alignment kits are:

- Fixturlaser NXA
- Prüftechnik Rotalign
- SKF TKSA

A detailed description of these alignment sets can be found in Appendix F.

(Fixturlaser, 2014 (5th edition))

5.7 Correcting the alignment

When misalignment is measured using one of the described methods in paragraph 5.6, the next step is to correct the misalignment. In most cases an alignment goal is described before the service is executed.

In some cases however the amount of data presented is insufficient to prepare an alignment plan and the alignment has to be executed with the use of theoretical approximations for correct alignment. When encountering a liking situation it is important to execute the measurement and correction in conditions as close as possible to the standard operational situation.

With the use of the graph as shown in Figure 5-18: Alignment graph an approximation of the required alignment can be made.

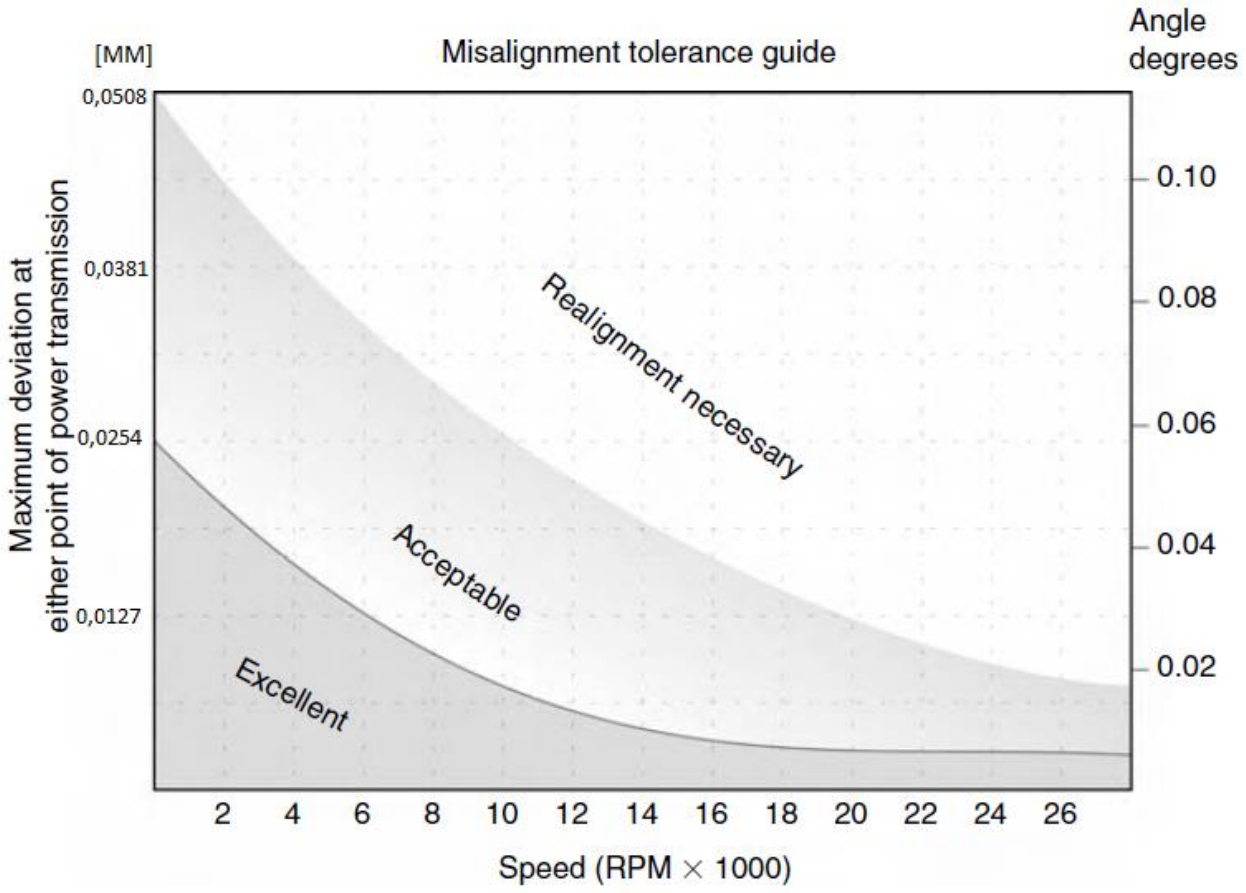


Figure 5-18: Alignment graph (Piotrowski, 2007)

5.7.1 Moving the machinery

The rule of thumb is to align the machinery starting with the stationary machinery and adjusting the movable components to align to the centreline of rotation of the stationary machinery.

When translating this rule of thumb to the marine situation one usually aligns from the motor to the stern tube, starting off course with aligning the motor to the stern tube. Normally the motor is already aligned to the stern tube starting from the new built situation.

When moving the machinery one must resolve two types of alignment the angular alignment and the axial alignment. Both require different actions and executions. Resolving the axial misalignment is the easier part resolving the angular misalignment is usually more difficult to execute due to the fact it requires more spatial awareness.

Process

In order to move the machinery it has to be lifted from its foundation. In most cases the machinery is already places on chocks from the first installation, these have to be removed and cleared before proceeding.

The lifting of the machinery is normally done with the use of on board cranes or with the use of hydraulic jacks. In the case of these service jobs the hydraulic jacks are favoured because the machinery can be moved on all support points with better precision than with the use of the crane. The hydraulic jacks system consists of multiple jacks powered by a hydraulic controller which disperses the pressure to the right jack in order to lift or lower the component at the respective support point.

After the component is placed in the right position the support bolts, or chocks are placed under the support feet of the component and the lifting equipment is removed from the machinery.

Axial adjustment

When adjusting the components axial alignment the entire machine is moved along the horizontal or vertical axis in order to adjust the alignment. A visual representation of these movements is shown in Figure 5-19: Machine movement.

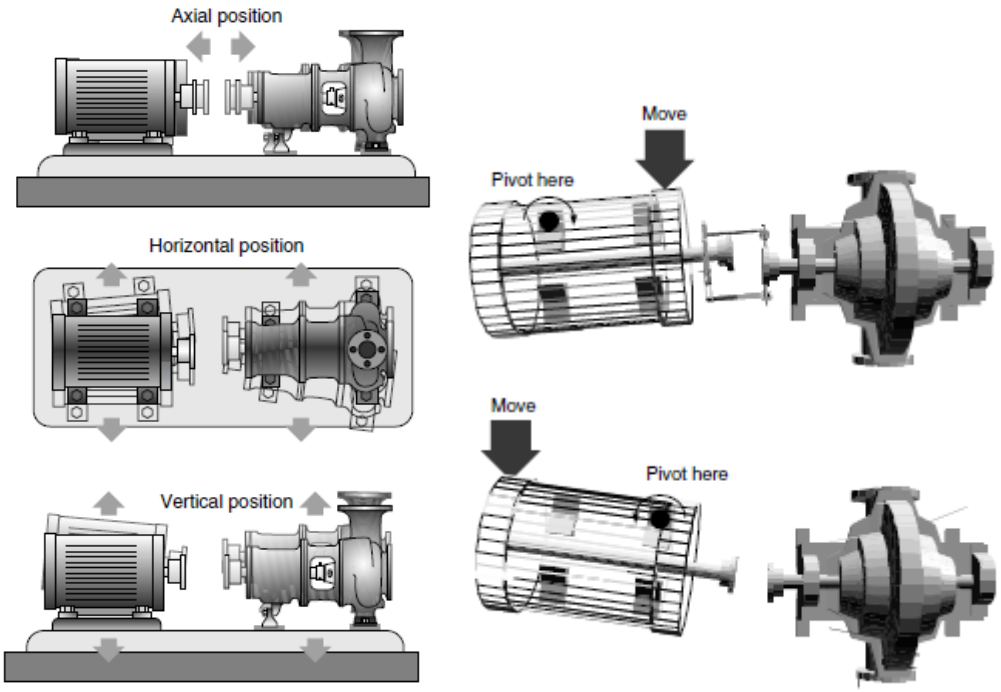


Figure 5-19: Machine movement (Piotrowski, 2007)

Angular adjustment

When adjusting angular misalignment one has to adjust the component around a chosen pivot point. One of the bolts connections to the foundation can be used as a pivot point in order to adjust the horizontal angle. And the vertical angle is adjusted by adjusting the height on only one side of the machine. A visual representation of these movements is shown inFigure 5-19: Machine movement .

Requirements

For the adjustment of the machinery the only requirement is proper lifting equipment to move the machinery. Usually the following equipment would suffice:

- 6 hydraulic jacks (*4 would suffice 6 are recommended*)
- Hydraulic pump + controller
- Component supports

5.7.2 Re-measuring and chocking

After the alignment situation has been corrected according to the correction plan the alignment should be re-measured as described in paragraph 5.6 in accordance to the appropriate procedure.

When the alignment is found to be within tolerance, the machinery is to be fixed into place. There are several products and methods used to chock the machinery some of which are:

- Steel blocks
- Shims
- Concrete(*Not used in the marine world*)
- Epoxy grout
- SKF Vibracon

In order to be able to cater the market with quick and responsive service it is recommended to have a small stock of steel shims and epoxy grout. The Vibracon can be ordered for the planned jobs as it can save a lot of time because of the easy adjustment.

When the component is chocked either proceed to the following component following the previous defined steps or finish up the alignment correction. And clear the machinery for operation.

(Appendix A) (Piotrowski, 2007)

5.8 On-site machining

In many the cases the service jobs performed require an adjustment of the components or other parts in order to reach proper alignment. It is also possible that parts have become damaged due to the improper working conditions and heightened vibration levels. In these cases the on-site machining tools and capabilities are used to perform these adjustments without having to move or extract the components.

The main required on-site machining operations consist of:

- Line boring
- Flange facing
- Milling

There are many more operations that can be performed with portable machinery, these four however cover most of the needs in order to provide a service package needed in this field.

(*As based on the service jobs that are currently being performed*)

5.8.1 Line boring

With the use of line boring equipment the inner diameter of any metal part can be machined. The main use for this method of machining is the machining of consecutive holes making them exactly concentric for example machining the holes for the rudder shaft to make them aligned and concentric.

Another possibility is to us the line boring bore out a worn circular part in order to fit in a replacement bushing or perform other repair operations requiring the increase in bore size. It is also possible to use the line boring equipment to weld on a new layer of material instead of placing a bushing; this is more suitable for quick fixes for tailor made solutions.

The final possibility is to us the line boring equipment to perform surface treatment, when pitting corrosion etc. forms on the inner diameter of parts, the line boring equipment can be used to smoothen the surface with the use of grinding equipment.

Figure 5-20: Line boring equipment (Redd, 2010)

5.8.2 Flange facing

Flange facing equipment is mainly used to machine the flanges in order to create a flat surface that will connect seamless to the connecting flange. Having flat flanges is highly important in order to prevent angular run-out on the shaft connection. When the shaft connection is not fully straight and an angular misalignment is caused by run-out, a proper alignment cannot be reached.

The main use for flange facing is to machine connection point in order to provide a fully seamless fit; this is off high importance with closing connections between the water and the vessels bilge. The seal covers of the stern tube seals have to be equally seamless in order to keep the lubricating oil in the system and prevent it from leaking into the environment.

Figure 5-21: Flange facing equipment (SKF, 2013)

5.8.3 Milling

The used milling equipment for on-site machining is basically the same as regular milling equipment with the main difference being the flexible and modular set-up. The equipment can be set up and used in basically any space and situation in order to perform basic milling operations.

The milling is often used in order to create perfectly flat surfaces to support the components on. Another application for the milling would be the machining of steel block chocks on site. This creates the opportunity to make quick adjustments to existing machinery foundations.

Figure 5-22: Portable mill (Safetech, 2015)

5.8.4 Other applications

Besides these large machining operations the following support capabilities are also part of the machining and support package offered in the service portfolio:

- Drilling
- Bolt tensioning (*Hydraulic bolt tensioning*)

These applications are not specific to any of the services provided but are however normal part of the on-site machining jobs and therefore worth mentioning.

Each of these methods is specifically adjusted for the marine market and required application for example the drilling equipment is capable of drilling holes up to 100mm requiring heavy and powerful equipment. The same goes for the hydraulic bolt tensioning, with bolts exceeding diameters of 85 mm and required torques of 145 Nm and higher the demand off the equipment is higher than regular applications.

5.8.5 Requirements

The required tools and knowledge to offer the on-site machining options is dependent on the situations in which the tools will be used and what is required of the tools.

In order to figure out which tools are required, an analysis of the performed seal services in shanghai has been conducted. Out of this research came forth that the minimum seal size and therefore shaft size serviced has been one of 400 mm the largest seal size is one of 1000 mm. the most common size is that of 500mm.

This means that for the circular machining tools the range has to go between 400 and 1000 mm but in order to perform most of the jobs a machine capable of machining 500mm would be sufficient.

For the line boring equipment this means that the following tools would suffice:

- Climax bb5000
- Climax bb6100
- Hydratight 8200

For the flange facing equipment:

- Climax ff5000
- Climax ff6300
- Hydratight MM1000i

For the milling:

- Climax PM4200
- Hydratight portable mill

Extended information on the equipment can be found in Appendix G.

5.9 Additional services

Besides the main service offered in the form of the drive train maintenance, SKF machine support currently offers several extra services. These services have been added as a support for the alignment and CM service.

These services are:

- 3d measurement
- Foundation calculation
- Geometric measurement

5.9.1 3d measurement

The 3d measurement is performed with a 3d laser scanner; this machine uses specific reference points and a laser to create a 3d image of a space. This technique is often used to create an image of the ship engine room of another important space.

With the use of the acquired data in the form of a 3d image, a research can be done to several topics. But the main research is the checking of the space for new components or to check the current spacing between components in order to create an alignment model.

It can also be used to measure the hull deflection in different situation which is a great support for the alignment service.

5.9.2 Foundation calculation

Because of their extensive experience and knowledge on machine foundation, SKF Machine Support acts as a consulting partner on machine foundation.

With the use of proven calculation models they calculate the required tightening of the bolts and projected compression of the chocks due to the acting forces. With this data a shipyard can service the machines foundation. Or a design for the foundation can be made.

5.9.3 Geometrical measurement

The geometrical measurement is a service that is part of the capabilities of the laser alignment system. With the use of special attachments the following geometrical measurements can be performed:

- Flatness
- Concentricity
- Parallelism
- Distance
- Angle

With the use of these measurements a lot of data can be acquired on the machines operational environment. When the operational environment is improved the aligned and serviced situation will be preserved longer and the services will be easier to execute.

5.9.4 Requirements

For these additional services the main requirement is knowledge on the situations. As they come as a support for the main service they have to be utilized in the proper manner, elsewise they become an unnecessary investment.

For the geometrical measurements and 3d measurements the following tools are required:

- Sokkia 3d scanner
- Fixturlaser NXA Ultimate or,
- Prüftechnik Optalign advanced

The investment costs for these types of equipment are high and therefore recommended for when they are specifically required or can improve the quality of the offered service.

6 Market research

In order to offer the right method for the implementation of the new service activities it is important to adjust the advice toward the current and potential market. As described in the demands and wishes the customer has a significant influence on the eventual product/service.

In order to create an image of the market the following has been researched:

- Current customer/market
- Potential market
- Competition
- Potential partner

Each of the subjects has been researched during the 2 months in Shanghai, and is mainly based on the experience during the service jobs as well as the experience of the local colleagues.

6.1 Current market

BVI Shanghai is a service station as has been described earlier. It is of importance to analyse their current market in order to create a fitting solution to start offering the new services to the market.

The BVI Shanghai office currently offers the following services to the market:

- New build sealing (*installation + commissioning*)
- Sealing repair/service
- OWS commissioning
- Fuchs cranes (*commissioning + repair*)
- Hatecke life boat service

The percentage of yearly job per service is shown in Figure 6-1: Service spread diagram.

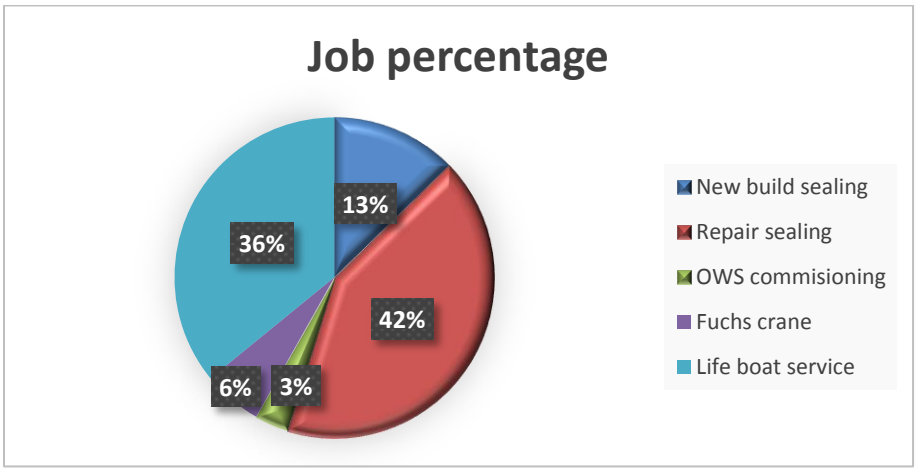


Figure 6-1: Service spread diagram

6.2 Potential market

In order to research the potential market visits to the biggest repair shipyards have been planned and several service jobs have been attended. These visits are described in Appendix C.

During the visits to the repair shipyards it became clear that alignment, condition monitoring and on site machining isn't part of the regular businesses performed during repair services. With an approximated maximum of 15 to 20 liking service jobs performed yearly the current market for these types of service is rather limited. All the services are currently performed on request of the ship owner and are not part of the regular overhaul job such as the seal repair business.

Knowing that the repair shipyards do not perform these services nor get requests for it, it can be concluded that the services have to be sold directly to the ship owner. This is where the current customers become important for the implementation and potential market.

Currently the following 15 companies are the biggest customers for BVI Shanghai:

1 Hapag-lloyd AG
2 CMA Ships
3 Clipper fleet management A/S
4 MISC BERHAD
5 MSC Shipmanagement ltd
6 Norddeutsche reederei H schuldt GmbH
7 Offen reederei
8 Peter Doehle schiffarts KG
9 Reederei Nord GmbH
10 Onetech Services
11 Thome Sip management Pte
12 V. Ships
13 F.H. Bertling Reederei GmbH
14 Columbus ship management
15 Hyundai heavy industries

Each of the current customers either owns a fleet of ships or has responsibility on the maintenance of a fleet. Having a combined total of over 1000 ships under their responsibility the potential of selling the services to one of these companies is rather high.

The optimal situation for the new market is when a full service contract is formed with the current customers. This ensures a constant amount of service requests.

More information on the market research can be found in Appendix C.

6.3 Competition

The current competition is small but consists of firmly represented companies in the service market. The two main competing companies are:

- Wärtsilä
- Goltens

Both offer full service and maintenance services to the market and research has shown that they are the most renowned companies in the field of on-site machining, shaft alignment and condition monitoring. Besides these companies some local companies, Prüftechnik and metal machines also offer some competition these companies however do not have significant influence on the BVI/SKF marine market.

Wärtsilä

Wärtsila is a company that forms a direct competitive position for both the BVI and SKF marine companies as they offer both the same products and services with the same target customers. They currently have a service contract with the HRDD shipyard which means they get first choice on service jobs performed in the HRDD shipyard.

Even though they have a firm position in the market they have only one alignment service mechanic working in the Shanghai region. This can be interpreted in some ways off which the following are most likely:

- There are little to none service jobs to be performed
- Their goal is to offer service mainly for their product, offering this service as a secondary option
- The service is performed by mechanics from elsewhere

(Appendix C)((Wärtsilä, 2015)

Goltens

Goltens us a company offering services on diesel engines and drivetrain for the worldwide marine market. They have service stations all over the world and are internationally renowned for their services. They offer many types of support and solutions that are alike to the services offered by SKF Machine Support.

Their workforce based in Shanghai consists of 5 engineers which is a rather small group, but as they are represented by small local crews all over the world they cater a big market which makes them market leader in this field of service.

(Appendix C) (Goltens, 2014)

6.4 Potential partner

A partner with knowledge and experience in the local market could be a fast method of implementation of the new services. This research however was quickly concluded as the local companies where not fully known to the colleagues of the BVI Shanghai office.

A possibility could be to form a partnership like Wärtsila and HRDD have formed, this would mean setting up a contract with a repair shipyard in order to receive all requests for the corresponding service possibilities and therefore expanding the market.

A potential partner would be CSIS for they have their own shipping fleet, and they offer repair services to a lot of ship owners. With an approximated amount of 300 ships in repair yearly of which approximately 180 ships require repair jobs on the drive train the potential market could be increased by offering a condition check as an option.

(Appendix B/C)

7 Concepts

Two concepts have been made for the implementation. Each of them with a different starting point and each constructed from a different philosophy. The main concept is constructed as a direct solution to implement all service fields and the alternative concept constructed towards the BVI Shanghai office capabilities.

The idea for the implementation construction has been formed with the use of several meetings and dialogues with the general manager of BVI Shanghai. Besides these dialogues the opinion SKF Machine Support has discussed on this matter has been taken in account.

As a disclaimer for the concepts counts that the market research has not given an unambiguous answer for how many jobs may be performed. Thus all of the time estimates are made based on the approximations of the market by the sales team of BVI Shanghai.

7.1 Main concept

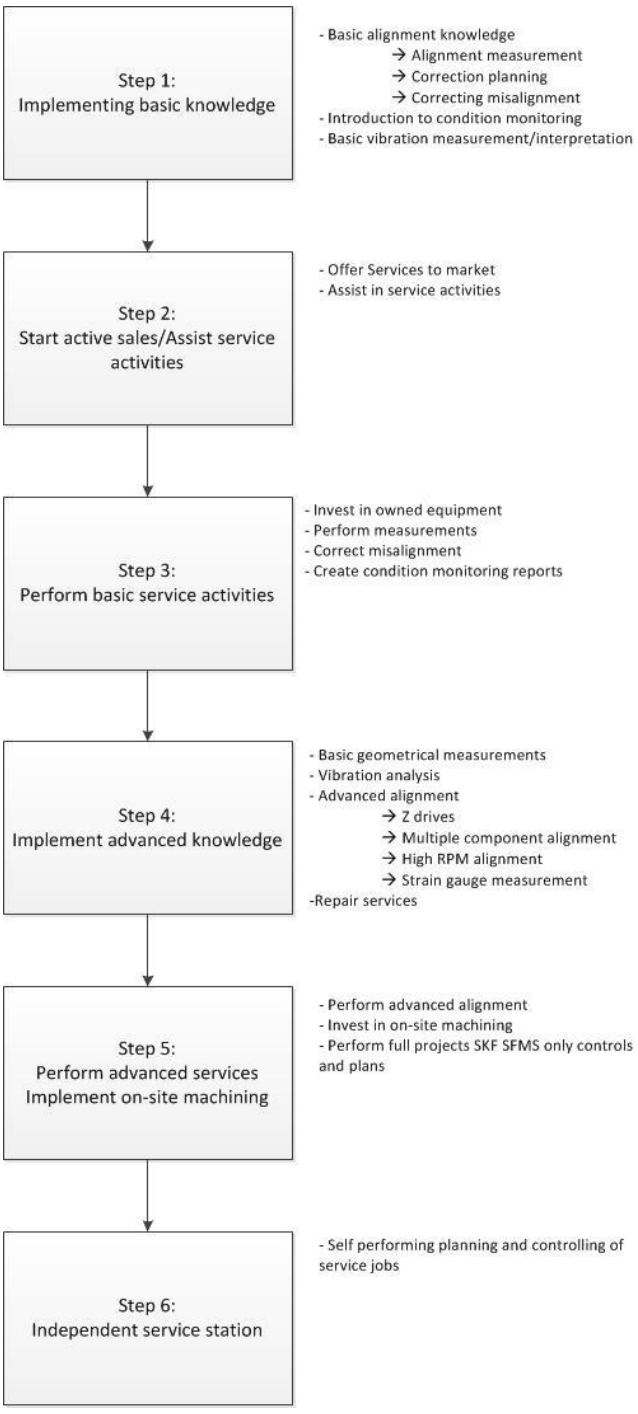


Figure 7-1: Implementation plan

The main concept for the implementation of the new service applications is based on the research performed in the BVI Shanghai Ltd. office. For the main concept the current knowledge of the BVI Shanghai personnel and the current offset market have been analysed

Using the knowledge acquired during the research on shaft alignment, vibration measurement and on-site machining an implementation plan is created.

Due to the fact that the Shanghai office has zero to none knowledge on any of the three main service applications (General Manager Mr. Kudruz excluded), the knowledge has to be taught and implemented starting with the basics.

A plan has been constructed consisting of six steps of implementation; this plan has been visually represented in Figure 7-1: Implementation plan.

7.1.1 Stage 1

During step one the knowledge on shaft alignment and CM is to be transferred to the Shanghai office, in this stage the actual execution of the service will not be performed yet.

The first step is mainly to arrange training for the personnel and share knowledge. The choice to do this comes forth out of the knowledge that the BVI Shanghai team is inexperienced in this field of service, but also out of the fact that the SKF Machine Support team has shown to be reluctant in providing the training.

The knowledge fields to be shared are:

- Basic alignment
- Condition measurement

Each of these subjects has its own requirements which will be described in the following paragraphs.

Basic alignment

The sharing of the knowledge on shaft alignment will have to start at the basic principle of alignment and the consequences that misalignment has on your machinery. Following by training in how to recognize situations where misalignment occurs, specifically how to recognize it with the products that are currently being services; being the Simplex seals and intermediate bearings.

The basic measurement of shaft alignment will be covered as well in order to present a basic knowledge on how to perform a proper situation check and be capable to recognize misalignment using the following techniques:

- Feeler gauge measurement
- Dial gauge measurement
- Laser measurement
- Bearing load measurement

These techniques have been chosen as a reference because they are the basic progression of used techniques starting with the most basic method. The time required to teach and train the theory and technique for these methods has been based on the amount of theory and personal experience in the amount of training.

The estimated amount of time required for the training in basic alignment:

→ 2 to 3 days of full time training

Condition measurement

Condition measurement effectively covers the entire analysing procedure for the drive train components. This analysing procedure lies at the basis of all the service jobs to be performed, it is therefore of high importance to train the personnel that will perform the services in the field of condition measurement.

For the training of the basic knowledge on condition measurement a choice can be made between the official training with certification and the in house training at SKF Machine Support. With the goal of executing the services in mind the certification of the personnel is highly recommended.

The estimated time for regular training is estimated on:

→ 4 to 5 days full time

The time required for cat. I certification:

→ 4 days training including exam

→ 6 months execution according to ISO regulations

7.1.2 Stage 2

In step two of the implementation offering the service to current customers is important in order to find out the actual yearly demand. As described in the Chapter Market analysis the current Asian market for shaft alignment service is not yet sure in yearly offset market.

Therefore the offering of the service to current customers with SKF SFMS as executing office and BVI Shanghai as support is a good method in to opening the market and researching the possibilities without mayor investments.

In order to start this step in the implementation previously described knowledge has to be in place and at least one executive worker has to be capable of performing basic support. Currently a service salesman has been assigned to actively offer the simplex service to market. This person has to be trained and informed on the possibilities in order to open the sales channels.

The second step is more of a scanning situation in which the Shanghai office can seek out the possibilities and adjust to the new sales.

The recommended time for the second step would be:

→ 2 to 3 month depending on the demand (*Starting directly after step 1*)

7.1.3 Stage 3

When a sustainable amount of jobs have been generated during the second stage and sufficient experience has been gathered by the field engineers. The services can be executed by the Shanghai engineers without the support of the SKF Machine Support engineers.

With the start of this phase own measurement equipment is required. The investment in this equipment will be done during the third phase.

Standard shaft alignment

With standard shaft alignment a standard condition is assumed where the goals and situation are clear before the start of the measurement and alignment process. When inadequate data and preparation is in place the jobs cannot be performed in short time without sufficient experience. In this case the jobs are best performed by the SKF Machine Support engineers, with the support of the BVI Shanghai team.

In this case the earlier taught techniques can be applied with minor experience and with the most basic of tools. The required tools for the shaft alignment will consist of the following equipment:

- Feeler gauges
- Dial gauge set
- Laser alignment set
- Hydraulic jacks
- Jack-up bearing load set

Vibration measurement

The vibration measurement is part of the condition measurement and in this stage they represent the same thing. The engineer has to go on board in order to perform a vibration measurement and perform a situation check in order to collect the data required to make a service report.

This data collection will then be sent towards the controlling office. In this stage of implementation SKF Machine Support will still control the data and plan the work to be executed. The engineer will need to be able and certified to perform the measurement in the correct methods and will need at least Cat.I vibration analysis at this stage of the implementation.

The required equipment for this service:

- Complete vibration measurement set (*SKF microlog + sensors & cables)*

7.1.4 Stage 4

During the execution of basic service activities the required experience for more advanced techniques is acquired. When proficient experience is acquired the knowledge of CM and alignment can be expanded toward more advanced techniques.

During the fourth step more advanced measurement techniques are to be learned and implemented mainly consisting of:

- Geometrical measurement
- Advanced alignment

With these advanced techniques some more controlling capabilities are required from the supporting office employees this includes:

- Situation modelling
- Alignment modelling
- Vibration analysis

Geometric measurement

The method of performing geometrical measurement is shortly covered in Paragraph 4.9 the main measurements to be performed are:

- Straightness measurement
- Flatness measurement
- Parallelism measurement

Each of these measurements can be performed using the more advanced laser alignment kits and therefore no extra equipment is required. The training for this is rather straightforward and should be covered in 2 to 3 days.

Advanced alignment

The performing of advanced alignment is basically the performing of alignment in non-standard situations such as multiple machinery drive trains and the aligning of high RPM shafts.

For the advanced alignment more experience and extended knowledge is required. This can basically only be implemented by performing the basic alignment techniques and gaining insight and experience in aligning machinery.

However training on the theory of advanced alignment is needed in order to understand the differences and requirements in order to perform the service in a right manner.

Controlling

As the service activities advance in difficulty the required level of control has to improve as well. The personnel providing support and planning from the office require more knowledge on the service jobs performed.

The main goal of the training of the controlling personnel is to improve their analytical capabilities in order to support the service personnel as much as possible. The controlling personnel would preferably have knowledge at a state of Cat.II vibration analyst.

The amount of time required for the Cat.II training is the same as the time required for the Cat.I training:

➔ 4 day training required for Cat.II

7.1.5 Stage 5

Include on-site machining

During the fifth step the learned service methods are to be offered to the market and performed by the service personnel. This includes the implementation of on-site machining; this however is dependent on the capabilities of the personnel.

For the on-site machining knowledge on metal working is essential, the current personnel has no knowledge on metal working and therefore acquiring new personnel with previous experience in machining workshops would be recommended.

It is also possible to start training in the field of on-site machining in this step this is not recommended due to the required time to train and gain experience which would extend the roll out time for the new services.

7.1.6 Stage 6

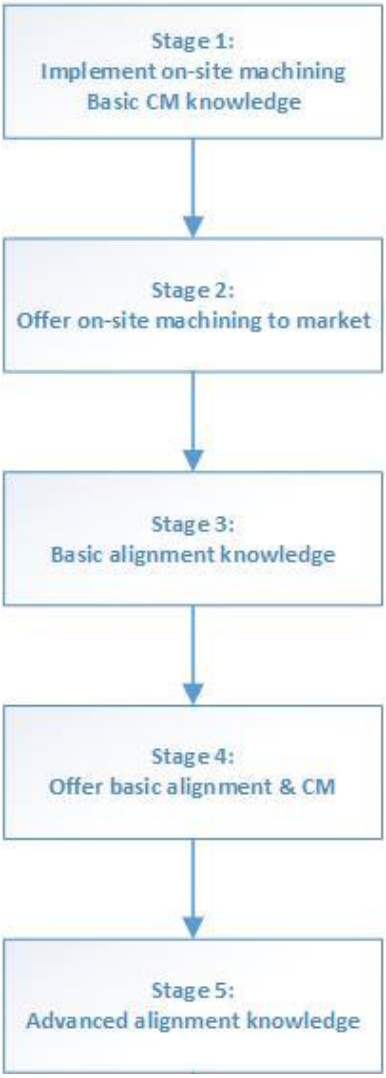
When all previous steps have been completed all the necessary equipment and knowledge should be in place and the company would be ready to start selling, controlling and executing the service jobs without support of the SKF Machine Support office.

This would mean that the office has the following skills:

- Full shaft alignment knowledge
- Full vibration measurement and analysis capabilities
- On-site machining capabilities for shaft components
- Geometrical measurement
- Offline to online alignment modelling
- Condition monitoring

The office personnel is capable of supporting their field personnel on these jobs and has acquired both knowledge and experience of all the subjects. The jobs can be performed with the guarantee that the end product will be a qualitative and fast service and full service on the drive train can be provided.

7.2 Alternative concept



The main concept as described in chapter 6 is a concept created in order to fully implement all the services offered by the SKF Machine Support. In the previous concept the investment risks are slowly increased during the project and the personnel and office is slowly prepared for the new services.

An alternative to the main concept is to implement only a part of the service activities. The part that has been chosen for this concept is the on-site machining, as the on-site machining has the most market potential to be implemented and offered quickly.

This requires greater investments and new personnel to be hired. However the projected time to market and therefore income is a lot faster.

A visual overview of this concept is shown in Figure 7-2: Alternative concept.

Figure 7-2: Alternative concept

7.2.1 Stage 1

For the first stage of the alternative concept the on-site machining business is to be offered as soon as possible. The on-site machining will be offered as support for the current services performed mainly concentrated on the commissioning of the BVI products.

At first the investment will be in the following on-site services:

- Line boring
- Flange facing
- Drilling
- Bolt tightening

These services can be easily offered to the current customers, and knowledge on machining is currently in place due to the knowledge of Mr. Kudruz (General Manager) and Mr. Sun (Service manager).

In order to offer it consistently however a proper trained machine worker would have to be hired and instructed on the use of the equipment.

This step will approximately take 3 weeks to fulfil with the main time consuming step being the delivery time for the equipment.

7.2.2 Stage 2

During the second stage the on-site machining service will be offered to the market, in the first step the preparations have been made to make it possible. The second step is mainly focused on the sales and controlling of the services.

The requirements for this stage are mainly the support of the back office and a good sales team to offer the services.

An estimate of the time required to bring this service to the market has been set at 3 to 4 months based on the current progression of the active sales and investments.

7.2.3 Stage 3

In stage 3 three the basic knowledge on alignment is implemented as is described in paragraph 5.1. The knowledge transferred will consist of the basic background of shaft alignment and CM. And further knowledge on vibration measurement.

The third step is only to be taken if there is sufficient market offset. The goal of the alternative implementation concept is to ease into the market and allow for more research to be done on the potential offset market.

7.2.4 Stage 4

The fourth stage would consist of offering the alignment services to the market. The idea for this is to offer the service to the market commissioned and controlled by the SKF Machine Support office. This means that the sales of the CM and alignment jobs are to be controlled on a different location.

For the execution of measurements only basic alignment equipment is required and the reports are to be created by the field engineers. The back office at SKF Machine Support will analyse and process the measurement in order to provide the customer with an alignment correction plan.

7.2.5 Stage 5

In the fifth stage the alignment knowledge is to be expanded in order to create a bigger support for the SKF machine support team. Being capable of performing more advanced alignment and geometrical measurements as well as offering solutions would be the next step.

In this stage a supportable amount of service jobs should be arranged, the investment cost in knowledge and equipment would be useless elsewise.

As described in paragraph 5.4 the amount of support required for the advanced measurement and analysis services require expensive training and require a significant amount of time and experience to execute.

7.3 Planning

In this paragraph the planning for both concepts is covered. The planning has been based on the required time to fulfil each stage of the implementation.

7.3.1 Main concept planning

In order to implement the new services some time is required to implement each part and plan the training. The following planning has been made on the estimated time required for the training and experience.

The planning as a whole can be used as a guideline, and is off course highly dependent on several variables encountered during the implementation such as:

- Learning curve personnel
- Amount of jobs sold and performed
- Budget
- Delivery time equipment

Because of all these influences the planning has been made using MS project making it flexible and easy to adjust to the reality.

At first a global planning has been made in order to define each stage of the implementation as described in the chapter: Main concept.

The stages where the different jobs are executed and experience is gathered are estimated at 2 months and the training times are estimated on the amount of theory and training time provided by SKF Machine Support.

Table 7-1: Planning main concept

Task Name	Duration
Total	**150 days**
Stage 1	**10 days**
Alignment training	3 days
CM training	3 days
Vibration training	4 days
Stage 2	**40 days**
Start active sales	2 mons
Assist services	2 mons
Create/collect service reports	2 mons
Stage 3	**40 days**
Invest in basic equipment	5 days
Condition monitoring start	5 days
Perform alignment jobs	2 mons
Stage 4	**20 days**
Advanced alignment training	3 days
Advanced vibration training (CAT II)	4 days
Geometrical measurement training	3 days
On site machining training	10 days
Stage 5	**40 days**
Invest in on-site machining products	5 days
Invest in advanced alignment equipment	5 days
Invest in advanced software	5 days
Perform advanced alignment	2 months
Perform on site machining	2 months
Sell expanded services	2 months
Stage 6	
End of implementation	

7.3.2 Alternative concept

The alternative concept is based on offering the service to market as soon as possible. Therefore the choice has been made to start the implementation with the on-site machining business. Based on the provided offers for the equipment as shown in Appendix E

Table 7-2:Alternative concept planning shows the actual performing of the services can be implemented rather quickly. However the difference in time to executing the combined services does not differ a lot from the main concept.

Table 7-2:Alternative concept planning

Task Name	Duration
Total	**145 days**
Stage 1	**20 days**
Invest in machining tools	4 weeks
Hire new personnel	4 weeks
Stage 2	**40 days**
Start active sales	2 months
Perform machining jobs	2 months
Collect service reports	2 months
Stage 3	**5 days**
Alignment training	5 days
Investment basic alignment equipment	5 days
Stage 4	**40 days**
Advanced alignment training	5 days
Geometric measurement training	5 days
Offer alignment to market	2 months
Stage 5	**40 days**
Invest in advanced equipment	5 days
Invest in software	5 days
Perform advance alignment	2 months

7.4 Equipment comparison

In the previous paragraphs multiple choices for the suppliers of equipment have been mentioned. As has been stated each of the suppliers has their own advantages. Usually this chapter is used to make a choice between suppliers and give a definitive statement on which supplier is best.

Because SKF Machine Support already has the equipment range of both Fixturlaser and Climax portable they will be taken in consideration for the further project regardless of the outcome of the comparison. This comparison will act as a recommendation and as an argument to possibly use different equipment by different suppliers.

The comparison is performed based on a grading system grading the equipment on several topics. The grading is done on a scale of 1 to 5, where five is the highest grade and one being the worst grading. Each topic has its own weighing factor based on the amount of influence on the eventual usability of the equipment for this project.

7.4.1 Line boring equipment

Table 7-3: Comparison chart line boring

Line boring equipment								
	Price *(5x)*	Support *(2x)*	size range *(3x)*	Flexibility *(2x)*	Dimensions *(3x)*	Accuracy *(4x)*	Transportability *(2x)*	**Total**
Climax bb 5000	4	3	2	2	4	4	4	3,43
Climax bb 6100	4	3	4	2	3	3	3	3,29
Hydratight 8206	3	4	5	4	3	3	3	3,48

7.4.2 Flange facing equipment

Table 7-4: Comparison table flange facing

Flange facing equipment								
	Price *(5x)*	Support *(2x)*	size range *(3x)*	Flexibility *(2x)*	Dimensions *(3x)*	Accuracy *(4x)*	Transportability *(2x)*	**Total**
ff5000	4	3	2	2	4	4	3	3,33
ff6300	4	3	4	3	3	3	3	3,38
Hydratight MM1500i	3	4	5	4	3	3	4	3,57

7.4.3 Portable milling tools

Table 7-5: Comparison table portable milling

Portable milling								
	Price *(5x)*	Support *(2x)*	size range *(3x)*	Flexibility *(2x)*	Dimensions *(3x)*	Accuracy *(4x)*	Transportability *(2x)*	**Total**
Climax PM 4200	3	3	5	4	4	3	4	3,57
hydratight 6T mill	3	4	5	2	3	5	5	3,71

7.4.4 Laser alignment

Table 7-6: Comparison table laser alignment

Laser Alignment						
	Price *(5x)*	Support *(2x)*	Capabilities *(4x)*	Ease of use *(2x)*	Accuracy *(4x)*	**Total**
Prüftechnik Optalign Standard	2	4	4	4	5	3.18
Prüftechnik Optalign Advanced	2	4	5	4	5	3.41
Fixturlaser NXA Pro	5	3	3	4	4	3.59
Fixturlaser NXA Ultimate	4	3	4	4	4	3.53
SKF TKSA	5	3	1	2	3	2.65

7.4.5 Vibration measurement

Table 7-7: Comparison table vibration analysers

Vibration analysers						
	Price *(5x)*	Support *(2x)*	Capabilities *(4x)*	Ease of use *(2x)*	Accuracy *(4x)*	**Total**
Prüftechnik	3	4	5	5	4	3.59
SKF Microlog CMXA 75	4	5	5	5	5	4.12

7.4.6 Conclusion

For the on-site machining the tools by Hydratight score the highest, mainly due to the fact that they are capable of covering the entire required range with one machine. Increasing the flexibility of the field engineers with multiple machines to cover the same range of services.

For the measurement tools the Fixturlaser equipment has the best ratings in this case the price performance ratio is what makes them the best for the project. In the case of the vibration measurement the SKF equipment is the best, scoring high on all topics making them the best choice for this project.

7.5 Finance

To implement the new services several investments have to be made, in this chapter a summary of all the costs has been made. Expenses such as travel cost, pay rates and personnel accommodation during training have not been calculated.

An investment plan for both of the implementation concepts has been made. In order to give multiple options for the investment a cost estimate with different suppliers has been made. Each of these plans has different pros and cons which will be described in the investment description.

7.5.1 Main concept

In this paragraph the investments for the main concept will be described. Starting with the costs for the equipment as is used by the SKF Machine Support team. An overview of these costs is shown in Table 7-8: Main concept investment Current.

SKF Machine Support tools

The main advantage for the use of the same equipment as is used by SKF Machine Support is the fact that the experience with this equipment is already in place. This means that when encountering problems there is always a support line.

A second advantage is the fact that there is already a longstanding contract with the suppliers which gives the possibility of special offers when buying more equipment. The long standing contract has the extra advantage of extensive support.

The disadvantage for this equipment is the fact that the on-site machining equipment consists of multiple tools in order to perform a single job. The line boring and flange facing equipment does not have a size range capable of catering the current requirements.

The biggest disadvantage is the fact that different suppliers are used or different tools Climax portable does not offer an extensive range capable of performing all the service required. The same applies with the Fixturlaser equipment they only supply measurement equipment for the geometrical measurements.

Table 7-8: Main concept investment Current

Current suppliers		
	Description	Costs
Stage 1		1.395,00 €
	Training	
	Vibration cat I.	1.395,00 €
Stage 2	*No investment required*	0
Stage 3		31.240,00 €
	Alignment equipment	
	Fixturlaser NXA Pro	15.000,00 €
	Strain gauge set	695,00 €
	SKF microlog (CMXA 75)	15.000,00 €
	Bearing load kit	545,00 €
Stage 4		1.795,00 €
	Training	
	Vibration cat II.	1.795,00 €
Stage 5		207.299,00 €
	Alignment equipment	
	Upgrade NXA ultimate	6.500,00 €
	On-site machining equipment	
	Climax bb 5000	27.000,00 €
	Climax bb6100	60.000,00 €
	Climax ff 5000	39.000,00 €
	Climax ff 6200	65.000,00 €
	Euroboor 100	699,00 €
	Hytorc hydraulic tensioners	3.800,00 €
	Cylinder jacks	2.800,00 €
	Hydraulics controller	2.500,00 €
Stage 6		0
Total investment:		241.729,00 €

Alternative suppliers

When researching the local suppliers in Shanghai alternate suppliers for both the on-site machining equipment as well as for the laser alignment and vibration measurement have been found. The suppliers are respectably:

- Prüftechnik
- Hydratight

Both suppliers offer a full range that can cater to the demands of the service jobs, providing with a wider range of capabilities.

The main advantage for this equipment is the fact that less equipment is needed to perform the same jobs, making the field engineers more versatile. An extra advantage for these suppliers is the fact that their large product line makes it possible to expand the service possibilities in the future.

The disadvantage for these suppliers is the fact that their products are currently unknown and all knowledge has to be reacquired. This will also mean that the offered support and the prices will be less preferable than to use the same equipment.

Table 7-9: Main concept investment alternative

Alternative suppliers		
	Description	Costs
Stage 1		1.395,00 €
	Training	
	Vibration cat I.	1.395,00 €
Stage 2	*No investment required*	0
Stage 3		101.240,00 €
	Alignment equipment	
	Prüftechnik Centralign	55.000,00 €
	Strain gauge set	695,00 €
	Prüftechnik Vibxpert II	45.000,00 €
	Bearing load kit	545,00 €
Stage 4		1.795,00 €
	Training	
	Vibration cat II.	1.795,00 €
Stage 5		139.799,00 €
	On-site machining equipment	
	Hydratight 8206	80.000,00 €
	Hydratight MM600i	50.000,00 €
	Euroboor 100	699,00 €
	Hytorc hydraulic tensioners	3.800,00 €
	Cylinder jacks	2.800,00 €
	Hydraulics controller	2.500,00 €
Stage 6		0
Total investment:		244.229,00 €

7.5.2 Alternative concept

As described in chapter 6 the alternative concept is based on the implementation of the services starting with the implementation of the on-site machining business. This means that the largest investment will have to be done in the beginning of the project.

However the investments in the field of condition monitoring and vibration measurement are lower and extended measurement training is not required.

Table 7-10: Alternative concept investment current

Current suppliers		
	Description	Costs
Stage 1		195.499,00 €
	On-site machining equipment	
	Climax bb5000	27.000,00 €
	Climax bb6100	60.000,00 €
	Climax ff5000	39.000,00 €
	Climax ff 6200	65.000,00 €
	Euroboor 100	699,00 €
	Hytorc hydraulic tensioners	3.800,00 €
Stage 2	*No investment required*	0
Stage 3		1.395,00 €
	Vibration cat I.	1.395,00 €
Stage 4		15.545,00 €
	Alignment equipment	
	Fixturlaser NXA Pro	15.000,00 €
	Bearing load kit	545,00 €
Stage 5		15.000,00 €
	Alignment equipment	
	SKF microlog (CMXA 75)	15.000,00 €
Total investment:		227.439,00 €

Alternative suppliers

For the alternative concept the choice for alternative suppliers has been limited to merely the on-site machining tools. Measurement tools have been added to this concept but because the requirements for this equipment are low, therefore a basic Fixturlaser package will be sufficient for this cause.

The total overview of the costs is shown in Table 7-11: Alternative concept alternative

Table 7-11: Alternative concept alternative

Alternative suppliers		
	Description	Costs
Stage 1		134.499,00 €
	On-site machining equipment	
	Hydratight MM600ie	80.000,00 €
	Hydratight 8206TI	50.000,00 €
	Euroboor 100	699,00 €
	Hytorc hydraulic tensioners	3.800,00 €
Stage 2	*No investment required*	0
Stage 3		1.395,00 €
	Vibration cat I.	1.395,00 €
Stage 4		15.545,00 €
	Alignment equipment	
	Fixturlaser NXA Pro	15.000,00 €
	Bearing load kit	545,00 €
Stage 5		15.000,00 €
	Alignment equipment	
	SKF microlog (CMXA 75)	15.000,00 €
Total investment:		166.439,00 €

8 Conclusion

In this chapter the main research questions are reviewed and concluded based on the research and thesis.

Central question

"What is the best method and execution to implement shaft alignment, condition measurement and on site machining in the Asia service stations?"

- There is not a best method of implementing the service knowledge into the service stations. However based on the experience in Shanghai and the research done, the main concept suits the requirements in the most logical way.

Background questions

- **What methods of shaft alignment exist?**

- There are many methods of performing shaft alignment. However the real question that became important is which method suits the requirements for the current market. For this both the laser alignment and the method based on the bearing loads are the best methods. Where the laser alignment gives a direct view on the actual alignment, the bearing load alignment gives the possibility to align towards the best spread of loads in order to minimize the wear of components.

- **What methods apply to the current services?**

- Basically all methods apply to the current services, as each method has its own specific application in the entire service field. However dial gauge and therefore consecutively laser alignment are the best applicable to this situation.

- **What methods of vibration measurement exist?**

- The basic two measurements are performed with either strain gauges or with the use of accelerometers. Both methods suit the requirements. The use of accelerometers is however the recommended method due to the basic ruggedness of the equipment used.

- **What methods apply to the current services?**

- In basis the Fast Fourier transform analysis will be sufficient for the goals set. The strain gauge measurement and advances vibration simulation will not be required.

- **What methods of on-site machine are applicable?**

- Basically all types of metal machining are applicable to the drive train maintenance. Line boring and flange facing however are methods of machining that are a direct support for the BVI products. The investment in these techniques is therefore most recommended.

- **What is the level of expertise on the new service subjects?**

- The knowledge on condition measurement and therefore shaft alignment is currently very limited. The knowledge on machining is already in place as both the general manager as the service manager has knowledge and experience in this field.

- **What are the restrictions of this new field of expertise? (*Laws, regulation societies etc.*)**

- The services are restricted to the same rules and restrictions as the currently executed services. Only the field of vibration measurement is subject to different expectations and rules.

Core questions

- **Can the service jobs be combined?**

- In basic understanding the services have no direct connection; however the improving of the conditions of the drive train serve as a direct support for the services executed on the stern tube seals. After the seal installation or service a general condition check can be added as a supporting service thus improving the total state of the drive train.

- **What materials/tools are used for this method?**

- An overview of all the required materials is described in the finance chapter.

- **How much time is required to implement this concept?**

- The amount of time required for the implementation is stated in the planning of both concepts. These are however estimates and the actual required time for full implementation is dependent on a large amount of variable which are difficult to calculate therefore a specific answer to this question is not within the reach of this research.

- **What are the implementation costs?**

The total costs for the implementation are dependent on the chosen concept. They can range between approximately 200.000 euro and 250.000 euro.

9 Recommendations

Based on my experience in the BVI Shanghai office and in the Asia market overall, I would recommend to invest in a broad service package to be offered. The current competition is well represented and offers a wide range of drive train services.

Both Goltens and Wärtsila offer the full package of Diesel engine, shaft alignment, vibration measurement/analysis and on-site machining to the Chinese market. They are thoroughly represented which makes the competition more difficult.

The only way to compete fully is to offer an equally broad service, preferably invest in a more extended service capability. The investment in extended knowledge on drive train maintenance is a good start to develop a wide range of service capabilities with a large potential market.

My recommendation would be to first invest in the main concept of implementation, slowly offering the services to the market as a support for current services. After the basic services are familiar in the market to expand the service capabilities towards more advanced techniques.

The field of Condition Based Maintenance is a smart capability to develop, when you offer the condition measurement to the ship owners the required maintenance will result in on-site machining service jobs. Therefore the measurement and analysis is the basis for the further services.

As the investment in on-site machining is both expensive and requires new personnel with entirely new knowledge this implementation step can be taken at any time in the implementation process. I however recommend it at the end of the implementation, due to the fact that the market of maintenance and service has already been opened and extension of capabilities in line with these new service possibilities is easier.

10 Competences

As a part of the graduation process certain competences have to be developed and tested during the graduation process. During the process I have followed with this project I have developed the following competences:

- Professionalize
- Research
- Advise

Professionalization

I believe I have developed my professional competences to level three during this project. During this project I have worked in international environments where I had to work and perform research in foreign cultures.

I did my research and communicated in these environments without accompaniment in an unstructured project. I have given shape and direction to the research and utilized the local personnel in order to reach my end goal.

With this I have shown to be self-reliant in international work environments, capable of handling unstructured tasks and capable of working in unknown contexts and situations.

I believe that being capable of functioning in different cultures and adapting to different requirements shows a professional capability of a high level. Thus worthy of level 3.

Research

In order to define requirements for the implementation, I have performed literature research on the three fields of service as well as a research on the required laws and legislation. In Asia I have done field research in order to acquire a clear image of the requirements of the local market and what the local market has to offer.

I have interpreted the needs and capabilities of the foreign office and translated this into a concept for the implementation. The requirements and specifics of the Asia market and company where unclear and undefined at the start of the project.

All of the research has been performed independently with the use of new research methods; with this I have developed my research skill towards level 3.

Advise

As my project was mainly to give advice on how to handle the possible knowledge, and service exchange I have developed this competence to the highest level achievable by creating a well-rounded advice and concept for the implementation. The creation of the advice and the possibilities I have created are worth of level 3.

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Appendix A: Work Process

Vibration sensor mounting

Overview of threaded stud sensor mounting method (Table 0-1)

Stud mounting requires a tapped hole drilled directly into the structure. A threaded stud provides electrical and mechanical connection between the sensor and the machine. The sensor requires a flat spot faced surface with a perpendicular tapped hole. The spot face must be 1.1 times larger than the diameter of the sensor housing to ensure flush mounting. For measurements above 1,000Hz (60,000 CPM), the surface should be flat within 1 mil (0.025mm) and have a surface texture no greater than 32 micro inches (Ra0.8). In all cases burrs between the sensor and the machine must be eliminated. The center line of the tapped hole must be perpendicular within 1° of the mounting surface to ensure no gaps are present between the base of the sensor and the structure. The tap drill and spot face can be machined in one stop with the proper tooling.

Overview of sensor adhesive mounting method using mounting pads (Table 0-2**)**

This method uses pads that are glued to the machine surface and afterwards the sensor has to be mounted on the pad.

This method guarantees transmission of high frequency vibrations up to 30 kHz and very quick sensor dismounting and mounting again.

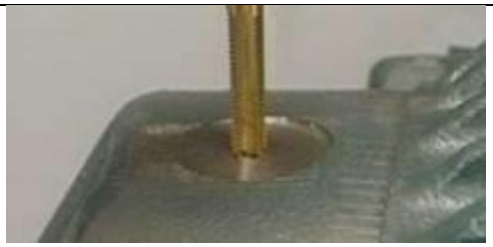
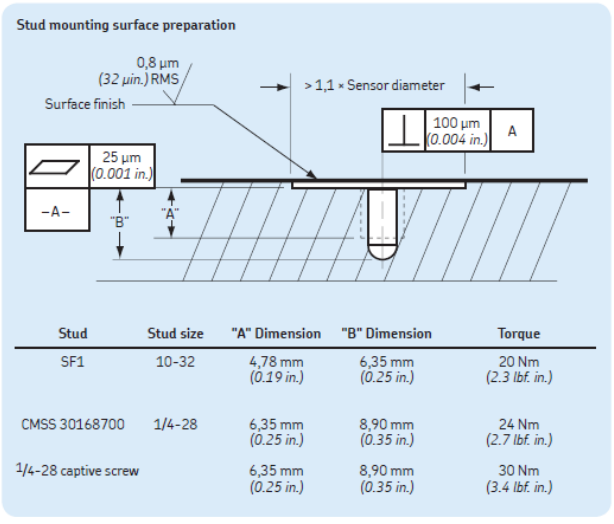
The key factor in this method is to use the right glue and strictly to follow glue manufacture procedure to guarantee good adhesion.

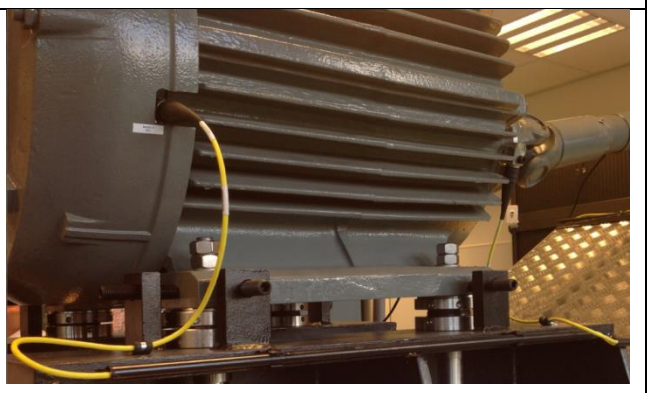
It is also possible to screw mount the pad. In this case you have to perform a similar procedure to that for stud mounting.

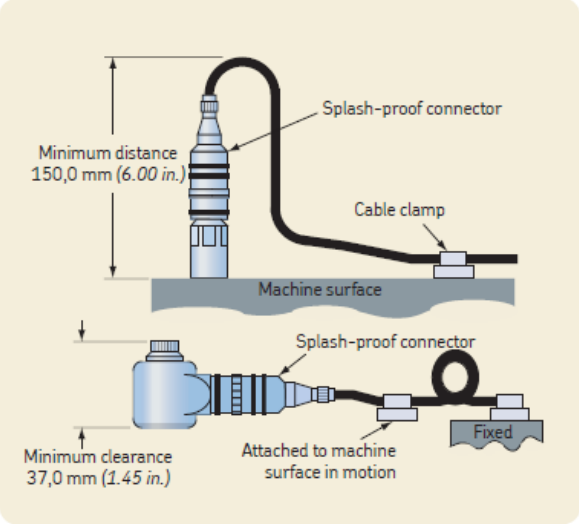
Threaded Mounting QWI

Table 0-1 Stud Mounted Accelerometer - Mounting Procedure - QWI

Step ID	Step	Note
010	Mark the sensor locations on the machine	
020	Clean the mounting area with DREMEL abrasive brushes	
030	Flatten the surface with a file	
040	Select ∅5 mm drill. Fix the drill depth to 9 mm.	
050	Mark hole's center with center tool and hummer.	
060	Drill initial hole with ∅3 mm drill. Drill main hole with ∅5 mm drill to 9 mm depth.	

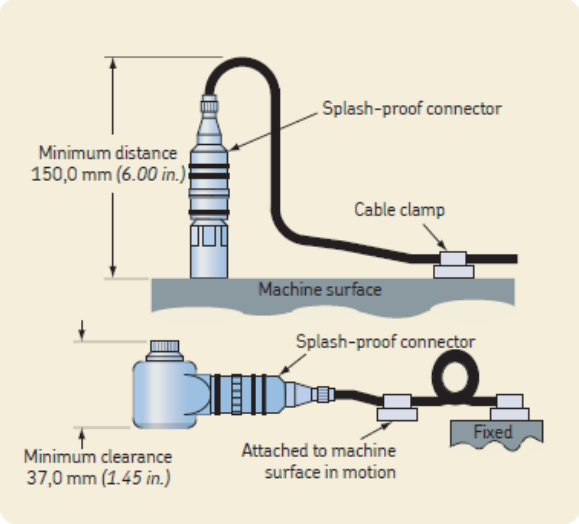
Step ID	Step	Note
070	Select Counterbore ∅*28* mm and mill the spot face. **IMPORTANT:** **See step 090 about requirements to surface**	
080	Using the tap stand, cut .250 inches (6.35 mm) of full thread (7 thread minimum). Use a bottom tap on holes less than .450 inches deep. Use cutting fluid.	
090	Check the surface requirements **If the sensor axis is not perpendicular to the spot surface this could cause a Ski-slope effect in the FFT**.	 **Stud mounting surface preparation** 0,8 µm (32 µin.) RMS Surface finish > 1,1 × Sensor diameter 100 µm (0.004 in.) A 25 µm (0.001 in.) –A– "B" "A" **Stud** / **Stud size** / **"A" Dimension** / **"B" Dimension** / **Torque** SF1 / 10-32 / 4,78 mm (0.19 in.) / 6,35 mm (0.25 in.) / 20 Nm (2.3 lbf. in.) CMSS 30168700 / 1/4-28 / 6,35 mm (0.25 in.) / 8,90 mm (0.35 in.) / 24 Nm (2.7 lbf. in.) 1/4-28 captive screw / 6,35 mm (0.25 in.) / 8,90 mm (0.35 in.) / 30 Nm (3.4 lbf. in.)

Step ID	Step	Note
100	**Clean the hole and mounting surface free of metal shavings and debris.**	
110	**Carefully test-screw the sensor in place, to ensure that good contact is made.**	**If the sensor does not fit flat on the surface, and thereby makes bad contact with it - Drill a new hole!!**
120	Apply coupling fluid to the spot face taking care to avoid the stud. Coupling fluids should be used between the sensor and mounting surface interfaces. Coupling fluids include: Silicone Grease Oil Petroleum Jelly/ Beeswax Apply a service removable threadlock such as **Loctite 2701** glue to the tapped holes in both the structure and the sensor. Screw the Sensor and tighten to **6 Nm**.	

Step ID	Step	Note
130	Fix and protect the integrated sensor's cable. Electrical cables attached to the sensor should not be excessively tight (under tension), nor left loose to flop around. In both cases, mechanical forces and contact resistance and coupling capacitance variations can result in unstable and inaccurate vibration response readings. It is recommended that the cable be firmly clamped to the mounting surface (tape, clamp, wax, epoxy, etc.) around six inches (15 cm) from the transducer; the cable run between the transducer and clamp should neither be very loose, nor under tension. Sealing the cable-to-transducer connector or attachment point with a silicone RTV type (or equivalent) sealant to prevent moisture intrusion may be advisable in some environments.	 The cable should not be bent into a radius less than approximately 50 mm (2.0 in.) and should be anchored to reduce stress at the cable terminations. When securing the cable, leave just enough slack to allow free movement of the accelerometer. Failure to leave enough slack will cause undue stress on the cable and dramatically influence the sensor's output When assembling any cable/connector to the vibration sensor, application of a small amount of silicone grease to the pin contacts is recommended to ensure reliable operation over a long period.
140	Glue close to the sensor a label with the CM Point ID.	
150	Document Sensor Installation in **A02_QWF101**	Take picture for each sensor and put in the report

Adhesive Mounting QWI

Table 0-2 Adhesive Mounted Accelerometer - Mounting Procedure - QWI

Step ID	Description	Note
010	Follow **A00_QWI102** to glue the stud for permanent sensor attachment	The procedure is the same as for Quick connect studs installation. Only the stud design is different.
060	Fix and protect the sensor's cable. Electrical cables attached to the sensor should not be excessively tight (under tension), nor left loose to flop around. In both cases, mechanical forces and contact resistance and coupling capacitance variations can result in unstable and inaccurate vibration response readings. It is recommended that the cable be firmly clamped to the mounting surface (tape, clamp, wax, epoxy, etc.) around six inches (15 cm) from the transducer; the cable run between the transducer and clamp should neither be very loose, nor under tension. Sealing the cable-to-transducer connector or attachment point with a silicone RTV type (or equivalent) sealant to prevent moisture intrusion may be advisable in some environments.	 The cable should not be bent into a radius less than approximately 50 mm (2.0 in.) and should be anchored to reduce stress at the cable terminations. When securing the cable, leave just enough slack to allow free movement of the accelerometer. Failure to leave enough slack will cause undue stress on the cable and dramatically influence the sensor's output When assembling any cable/connector to the vibration sensor, application of a small amount of silicone grease to the pin contacts is recommended to ensure reliable operation over a long period.
140	Glue, close to the sensor, a label with the CM Point ID.	

(Staykov, A02_QWI103, 2014 (A))

Epoxy grouting procedure

1. Planning:

Prepare a materials list of all the required components (grout, wood, bracing, pump, hose, water, mixing tools, vibrators, etc.).

Plan an adequate amount of time to perform the job. Instruct the personnel on the task at hand. Are there enough vent holes in the base or frame for venting trapped air? Has the concrete foundation cured completely? Is the machinery base in the position you want it in and is it leveled and not warped? Will the base lift up when grout is pumped under it?

2. Machinery base, frame: and concrete preparation

Insure that all contact surfaces on the undersides of the machinery base or frame are clean, rust free, and oil free. If possible, metal surfaces should be sand blasted and primed if you are using a cement-based grout. The concrete surface should also be clean, dust free, and oil free. If you are using a cement-based grout and do not plan on applying a concrete bonding glue to the top surface of the foundation, the concrete surface should be soaked with water for at least 24 h prior to grout placement to insure dry concrete does not extract the water in the grout mix at an excessive rate preventing proper cure. Prior to pouring grout, remove any puddles of water.

3. Building the form:

Construct a form (typically wood) around the perimeter of the machinery base or soleplate to be grouted (Figure 3.23). Insure that there is adequate clearance between the machinery base or soleplate and the form to allow for placement of grout and access for pumping or pushing the grout completely under the base. Build the form with a number of pouring points around the perimeter. Insure that there are numerous vent holes of adequate size (at least 1 in. diameter) to discharge trapped air during the pour. If you are using epoxy-based grouts, insure that there are at least two to three coats of paste wax on all of the wooden form surfaces that will be exposed to the grout so the form does not permanently bond to the grout. Insure that the forms are adequately anchored. It is suggested that the baseplate or soleplates be protected with plastic sheeting or masking tape.

4. Mix the grout:

Carefully follow the manufacturer's recommended mixing instructions.

5. Pour the grout:

Insure that the grout is flowing under all areas of the form removing entrapped air at all points. Vibrators can be used with most of the cement-based grouts but not on epoxy grouts.

6. Allow adequate time for the grout to cure.

7. Remove forms.

8. Torque the anchor bolts to their final value after the grout has cured completely.

9. Tap the top surface of the baseplate with a hammer to detect any voids that may have occurred.

Voids will have a distinctive hollow sound. There should be at least 80% adhesive surface contact. Voids larger than 3 in. in diameter should have epoxy injected into them. Define the perimeter of the void, drill, and tap a hole on one side of the void, and install a grease fitting. Drill a hole on the other side of the void perimeter to enable air to escape when injecting the void with an epoxy-filled grease gun or epoxy pump.

Bearing Reaction Measurements

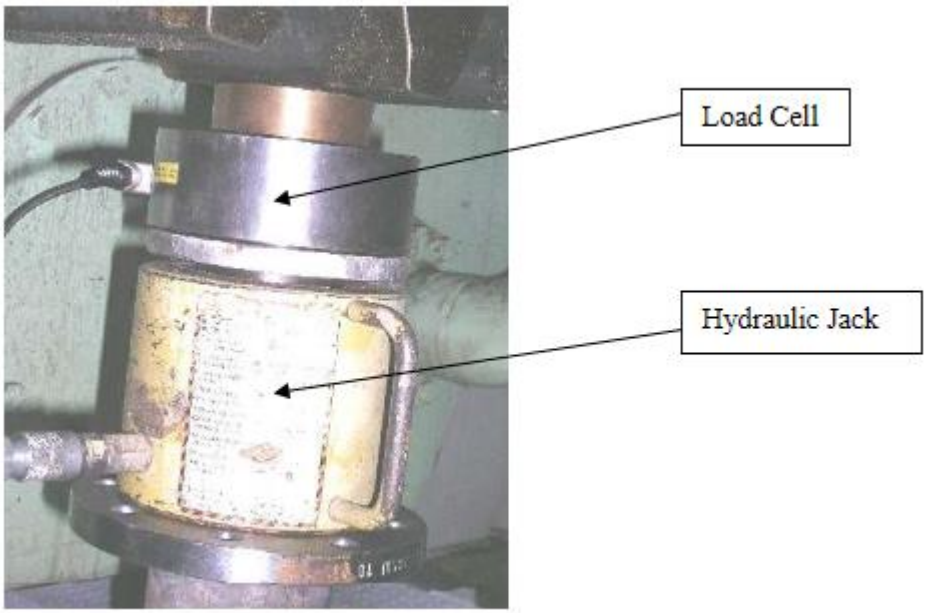
Bearing reactions are generally measured utilizing:

- Hydraulic jacks, or
- Strain gauges.

Jack up method

Step 1: Set up the jack and load cell

The hydraulic jack has to be placed under the shaft as close to the bearing as possible the load cell is to be placed between the shaft and hydraulic jack as is shown in the picture below. A dial indicator is to be placed on top of the shaft.

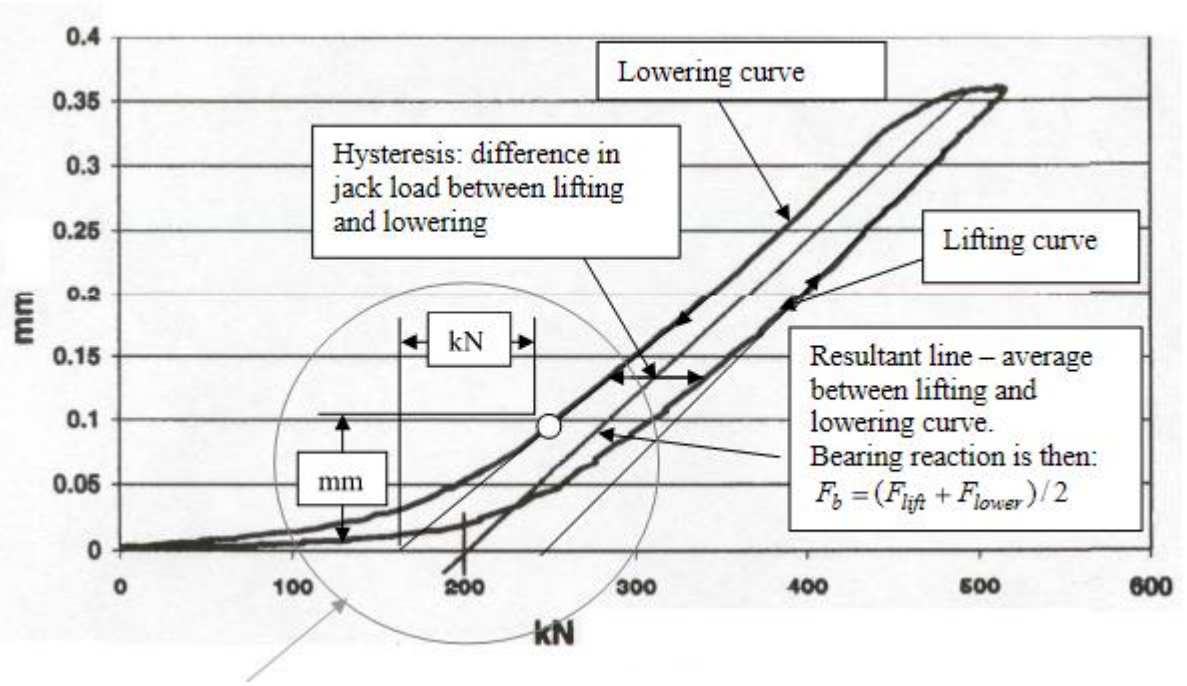


Step 2: Lift the shaft

The pressure in the hydraulic jack is to be increased until the shaft comes loose from the bearing shell. The top shell is preferably separated making it possible to move the shaft out of the bearing, if this is not possible movement of the shaft has to be monitored with the use of the dial gauge.

Step 3: Create jack up curve

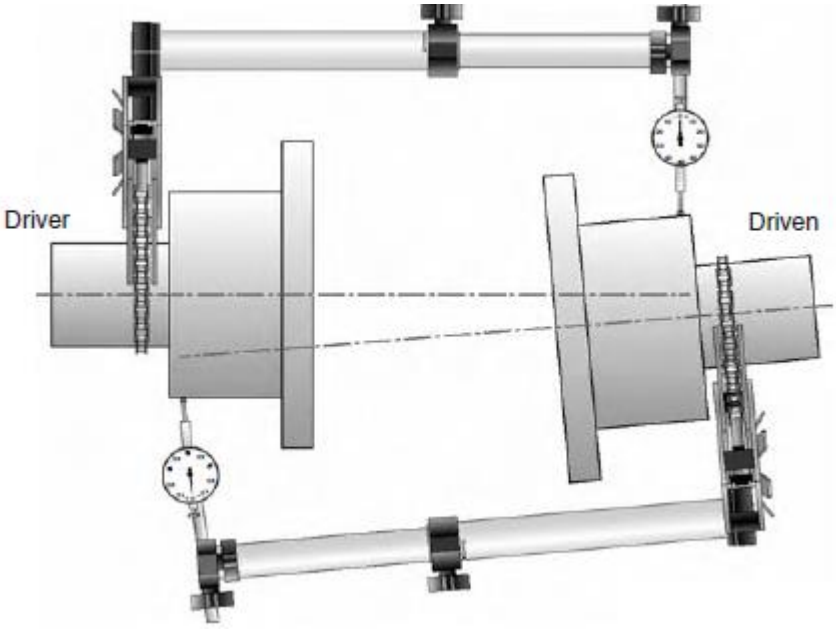
Create the curve using the load cell data and dial gauge movement readings. The requirements for the jack up curve are shown in the figure below.



(ABS, 2006)

Dial gauge alignment measurement

Step 1: Place dial gauges on shaft using the shaft brackets and support rods. Place the dial gauges on the shaft 180° apart as shown in the picture below.



Step 2: Set both dial gauges at zero

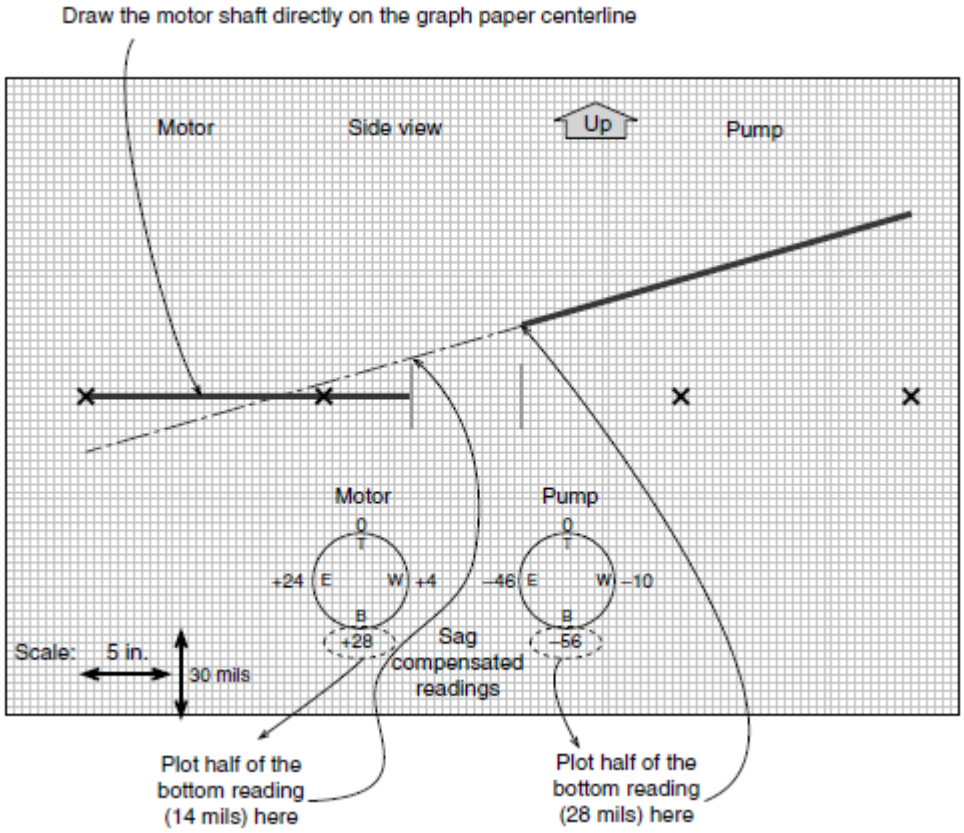
Step 3: Slowly rotate the shaft and bracket arrangement through 90 intervals stopping at the three, six, and nine o'clock positions. Record each reading (plus or minus).

Step 4: Note the dial gauge readings

Step 5: Return to the 12 ‘o clock position and check if the indicators show zero.

Step 6: repeat step two to 5 to verify first measurement.

Step 1: Select one of the two machinery shafts and draw one of those shafts on top of the graph centerline. Figure 10.14 shows an example where the motor shaft was initially placed on the graph paper centerline and the pump shaft position was plotted from the reverse indicator measurements. Figure 10.15 shows an example where the pump shaft was initially placed on the graph paper centerline and the motor shaft position was plotted from the same reverse indicator measurements.



Step 2:. Start with the top to bottom or side-to-side dial indicator readings on the other shaft (i.e., the one you did not draw on the graph centerline).

Step 3:. Plot the other shaft centerline position by starting at the intersection of the graph centerline and the point where the dial indicator was capturing the readings on the other shaft. If the bottom (or side) reading was negative, place a point half of the bottom(or side) readings from the graph centerline toward the top of the graph. If the bottom (or side) reading was positive, place a point half of the bottom (or side) readings from the graph centerline toward the bottom of the graph (the same as in the point-to-point modeling techniques).

Step 4: Next, start at the intersection of the graph centerline and the point where the dial indicator was capturing the readings on the shaft that was drawn on top of the graph centerline. If the bottom (or side) reading was negative, place a point half of the bottom (or side) readings from the graph centerline toward the bottom of the graph. If the bottom (or side) reading was positive, place a point half of the bottom (or side) readings from the graph centerline toward the top of the graph (opposite of the point-to-point modeling technique).

Step 5: These two points marked on the graph at the dial indicator reading points define the line of sight (i.e., the centerline of rotation) of the other shaft. Draw a straight line through these two points from the coupling end to the outboard end of the other shaft.

Appendix B: Service job reports

Bonding job on a COSCO ship

The job was a supposedly simple job consisting of basic knowledge and output. The seal had been in use for a long time and had started to leak due to unknown causes (Potentially wear and tear). A spare seal package was in place on the ship therefore the job ought to be an easy fix.

The spare part however had been on the ship for over 21 months far exceeding the 6 month time schedule and therefore the guaranty on the job could not be provided. Dealing with this situation required a time consuming back and forth between the superintendent and the engineer. After some troublesome waiting and time wasting. The superintendent accepted the situation and started the job.

The bonding was a straight forward job afterwards and did not demand a lot of time compared to the jobs as seen in Hamburg.

Knowledge perspective

The knowledge needed and used in this job was of basic systematic structure and it was visible that roughly the same procedure had been followed as it is followed by Hamburg engineers. Therefore the conclusion can be made that the short training done in Hamburg by the engineer Andy has been effective and that the knowledge of the engineer is sufficient to do the job required in this situation.

After concluding that the engineer fits within his current position the question for the willingness and the view towards improvement is the next step. Even though the engineer seemed interested in the subject of the studies, there was no further interest in developing their own knowledge on the subject and possibly grow within the company.

Situation description

The situation in the shipyard is rather simple this job had been described as a difficult place to enter for personnel however all that was needed was a trip to the immigration service with the right papers and my passport leaving me to be able to enter shipyard within half an hour. When the shipyard was entered the access was free and the possibility to enter all workplaces was not of an issue.

On this ship the foundation of the machinery was already done by the SKF SFMS crew in 2002, this means that a follow up check on the machinery might be an easy way in and provides the Shanghai ltd. with a nice starting contact towards the customers.

Retracted shaft seal placement

The job was a seal replacement on a ship where the shaft had been retracted, probably in order to do some work on the propeller. The reason for the retracting of the shaft however is not of importance to the job done.

On this job a seal could be placed over the shaft without the use of bonding and therefore it should be a quick fix. This was the case with only some minor hiccups as the engineer supposed to do the job was ill and therefore one of the shipyards workers placed the seal over the shaft.

The fact that an untrained engineer performed the job made the job different from normal situations.

Knowledge perspective

As the engineer involved was ill I had the opportunity to see the situation with Steven Sun in control this lead to a conversation on his knowledge and possibilities. The seal placement was done in a somewhat crude method and needed some influence from Steven which was fixed in a proper manner. Using wood blocks and cloth to protect the seal against damage during the placement.

After the placement I got to talk a little more, and came to find out that Steven is a competent man and has knowledge on machining and the service jobs to be executed. There is on the other hand the knowledge and trust in being a manager. On that topic Steven misses some strength and it became clear that from his point of view more stability and self-confidence is needed.

In this situation became clear that Steven Sun is lacking the confidence in control over the team as well as the oncoming possibilities in the service area. This is a minor limiting situation which should be easily fixed by proper training and some support from the ridderkerk crew base.

Situation description

The situation that was at this place was the thing that has he most interest for me, this is because of the fact that the shaft had been dropped and therefore realignment of the shaft line should be a critical point in the job. This however never crossed the minds of the engineers etc. If it is known to the office that a shaft is dropped. The simple and fast alignment analysis can be offered to the ship owner. This can then equally result in the alignment job to be carried out. And create quick turnover.

OWS commissioning

This job consisted of the commissioning of a BVI oily water separator, it was in a new build shipyard. And with that being said the job is mostly described, the shipyard installed the OWS and added the piping. The engineer only came by to check the installation and to properly set up the machinery.

In the description this sounds like an easy job the reality was slightly different though.

Knowledge perspective

The knowledge of the machinery was difficult to test and somewhat tricky to find out. However the way the engineer handled the gear showed that he had proper knowledge on the machinery and especially on the electronics. This should give a good opportunity for the more electrical steps in the shaft works such as:

- Bearing load
- Strain gauge measurement
- Etc.

Appendix C: Market research

HRDD

Answers according to question model

Shaft alignment

Laser alignment jobs per year:

10

Who performs the alignment?

- The shipyard performs basic alignment jobs, using feeler gauges and dial gauges. The claim is that approximately 500 workers can perform this type of alignment. (Personally I am sceptical about this number due to the required experience)

- If more precise alignment is to be executed, HRDD will call Wärtsilä with whom they have a contract for these jobs. Wärtsilä uses the Prüftechnik optalign laser alignment system. And a total of 1 expert engineer

Who request the laser alignment?

The request is always from the ship owner, if the shipyard finds a problem they tend to place all components in the same situation again. They align within visually acceptable state using feeler gauges and dial gauge.

This states that the overall precision in component alignment is low.

Is vibration measurement performed after repair/service?

No vibration measurements are specifically performed by the shipyard.

On site machining

How many times per year are on site machining required?

5 to ten times per year

Who performs the on-site machining?

Line boring/Milling and small flange facing is performed by:

- Wärtsilla
- Goltens

Large flanges are machined by:

- Metal machines

What tools does the shipyard have?

The shipyard has no tools for on-site machining themselves they cut out the part to be machined if necessary and machine it in their own machine shop.

Who orders the on-site machining?

Ship owner

HRDD basic info

Data	Amount	Percentage of total yearly jobs
Vessels per year in dock	300	
Amount retract the shaft	180	60%
Amount of alignment jobs	10	3%
Amount of on-site machining jobs	10	3%
Bearing retrofits	30	10%

CSIC

Shaft alignment

Laser alignment jobs per year:

Approximately 2

Who performs the alignment?

- Normally Goltens is the go to company for alignment which requires more precission

- Regular alignment is done by the shipyard using feeler gauges and dial gauges

Who requests alignment?

The ship-owner

Can the shipyard perform alignment?

The shipyard is capable of performing basic alignment with dial gauges, they however rarely execute this.

On site machining

How many times on-site machining is required?

10 to 20 times per year line boring jobs, flange facing maybe 2 times per year.

Who performs the on-site machining?

Line boring/Milling and small flange facing is performed by:

- Wärtsilä
- Goltens

Large flanges are machined by:

- Metal machines

Who performs the on-site machining?

Line boring/Milling and small flange facing is performed by:

- Wärtsilla
- Goltens

Large flanges are machined by:

- Metal machines

What tools does the shipyard have?

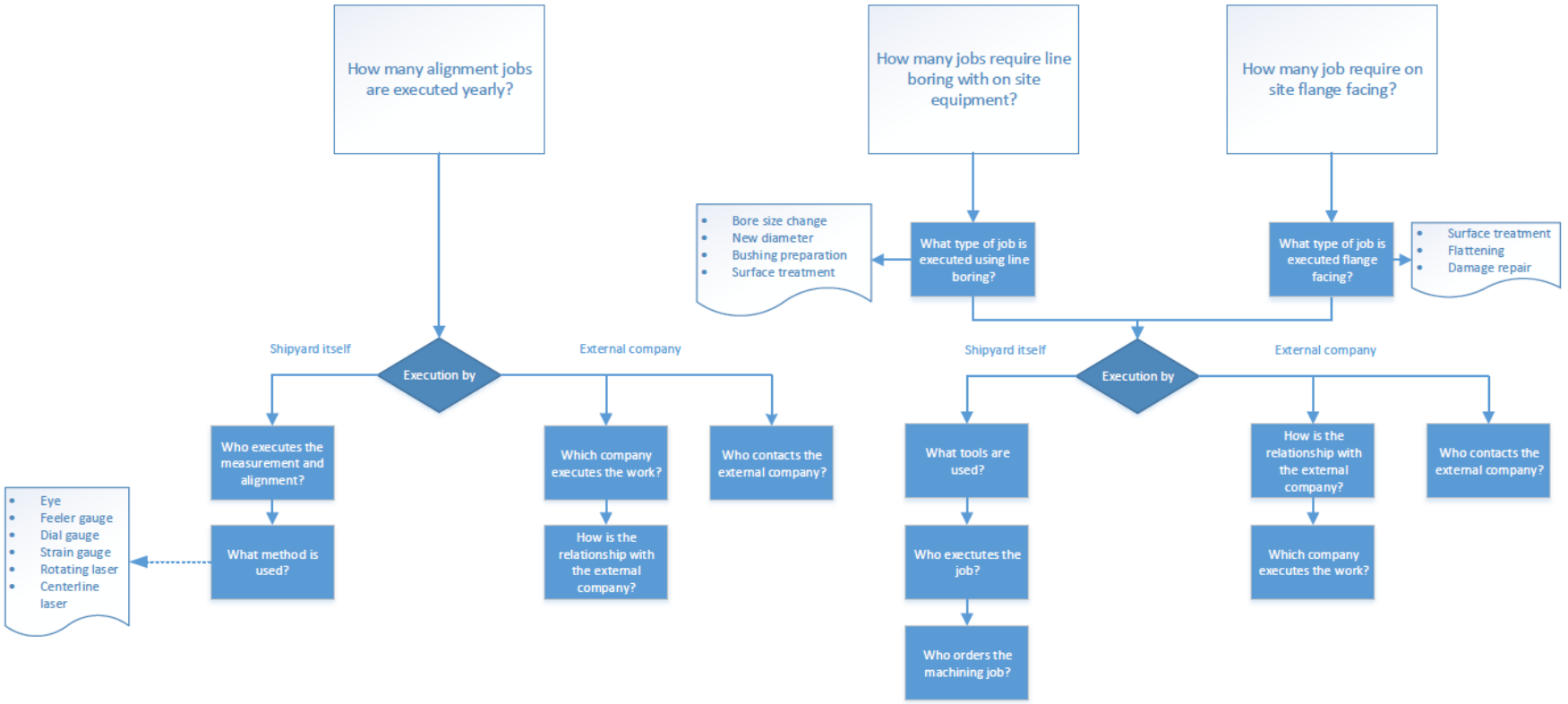
The shipyard has a line boring installation.

Who orders the on-site machining?

Always the ship owner.

CSIC basic info

Data	Amount	Percentage of total yearly jobs
Vessels per year in dock	380	
Amount retracted shaft work	100	26.%
Amount of alignment jobs	2	0.52%
Amount of on site machining	20	5%
Bearing retrofits	-	-


How many alignment jobs are executed yearly?
How many jobs require line boring with on site equipment?
How many job require on site flange facing?
Bore size change
New diameter
Bushing preparation
Surface treatment
What type of job is executed using line boring?
What type of job is executed flange facing?
Surface treatment
Flattening
Damage repair
Shipyard itself
Execution by
External company
Shipyard itself
Execution by
External company
Who executes the measurement and alignment?
Which company executes the work?
Who contacts the external company?
What tools are used?
How is the relationship with the external company?
Who contacts the external company?
Eye
Feeler gauge
Dial gauge
Strain gauge
Rotating laser
Centerline laser
What method is used?
How is the relationship with the external company?
Who exectutes the job?
Which company executes the work?
Who orders the machining job?

Visit Prüftechnik

During the research for local tool suppliers, the Prüftechnik office came up as a complete supplier for the alignment lasers as well as the vibration measurement and analysis tools. Because this supplier can provide a full solution for the measurement and analysis part of the service job it has the interest.

However during this meeting some interesting knowledge has been acquired on their market field and their customers.

First of all tools will be described including the practicality for the job and the possibilities, after this their market and market position will be described.

The tools

For the tooling they provide the alignment measurement as well as the vibration measurement and analysis. Next to the tangible products they provide a full service with product support and complete training.

This makes them a good partner and local solution for the alignment and monitoring business, and a good support structure for the jobs being executed.

Alignment

For the alignment they provide a wide range of laser alignment sensors and for this field of work they provide one analysing computer. This computer can analyze the following measurements:

- Shaft alignment
- Line bore straightness
- Component concentricity
- Basic parallelism
- Flatness
- Angular offsets

The basic set is the computer in combination with the sensors and brackets in order to measure and analyse shaft alignment, and the set can be expanded by upgrading the software and the addition of new sensors.

Besides the geometrical reference measurement the alignment computer is also capable of measuring and analysing basic vibration signatures. This analysis is only sufficient to check if the executed work is performed correctly and that any vibration problems have been solved.

Vibration measurement

The vibration measurement tools consist mostly out of several types of sensors, with at the core a analysing computer. The computers range from a basic model only showing a basic vibration scale with no analysis. However the more advanced computer provides a higher efficiency and more precise reading.

In the advanced system a analyzing logarithm show the parts in the vibration that are of interest and are not wanted. This analysis tool makes it faster and easier to analyze the machines situation and to implement an improvement.

the market position

With the above described tools, and the provided services Prüftechnik shows to be not only a very interesting partner for the execution of the work. But in the same way they are a direct competitor to the business.

They provide the same tools and analysis structure as SKF offers, and provide the same alignment services to the market as the goal is to provide ourselves. So the question leads if this is a smart business decision.

Even though they provide a nearby office and support section, I think that SKF can provide with the same knowledge and support in the vibration department.

A list of their main customers consists of:

- Goltens
- MAN
- Caterpillar
- Wärtsilä
- COSCO
- Siemens

Goltens in China is headquartered in Shanghai, with two sales offices in Guangzhou and Dalian.

Goltens Shanghai Co. Ltd. has a wide range of services, including in-situ machining, troubleshooting, overhaul and repairs of a variety of marine and land-based equipment systems, as well as reconditioning of diesel engines, mechanical, electrical and electronic components.

Goltens Shanghai Co. Ltd.

Block No.5,
No.533 Yuanzhong Road
Nanhui Industrial Zone,
Pudong New District,
Shanghai 201300

Phone: +86 21 5818 6828
Fax: +86 21 5818 6833
Email: shanghai@goltens.com
Repair: repair.shanghai@goltens.com
GMT +7 hours

Jesson Huang — Senior Sales Executive (Repair)
Mobile: +86 137 6131 2655
Email: jesson.huang@goltens.com

William Huang — Senior Sales Executive (Repair)
Mobile: +86 137 6131 9297
Email: william.huang@goltens.com

Alec Zhang — Sales Executive (Trading)
Mobile: +86 137 7438 4881
Email: alec.zhang@goltens.com

Chen Yefeng — Sales Product & Systems
Mobile: +86 133 1186 2856

Guangzhou Sales Office

Goltens Workshop
Four Hectares Industrial Zone
Miaotou Huangpu District
Guangzhou - 510730

Phone: +86 20 82088729
Fax: +86 20 82218869
Email: guangzhou@goltens.com

Dalian Sales Office

Room 534 Yue Tai ChengLi
No.227 YouHao Road
Zhongshan District
Dalian 116001

Phone/Fax: +86 411 8230 0582
Email: dalian@goltens.com

Authorized Service Agents for

- Mitsubishi UEC engines;
- HHI-EMD Engine & Machinery
- YANMAR Authorized Service Station
- STX engine, VDR
- ITW – Chockfast;
- ZJMD engine spare and service;

In-situ Machining Service

- Machining of crankshaft in-situ or in workshop;
- Line boring of engine bedplates/blocks in-situ or in workshop;
- Laser equipment for realignment of machinery;
- Annealing/Heat Treatment of hardened shafts/journals;
- Checking of machinery after realignment;
- Large scale flange facing and other surface machining and milling;
- Machining of stern tunnel or rudderstock tunnel
- Boring of all sizes coupling holes include taper holes.

Repair Service

- Main and auxiliary diesel engines;
- Steam turbines;
- Main propellers and tunnel thrusters;
- Shaft line, rudders
- Valves, pumps, COW machines;
- Deck machinery, winches, cranes, etc.
- Hydraulic systems;
- Electrical systems;
- Automation systems;
- Electric Motors (Rewinding)
- Governors;
- Ballast Water treatment upgrade service

Reconditioning Service

- Fuel injectors, nozzles, valves, pumps and timing;
- Centrifugal casting of White Metal Bearing & Stern tubes;
- Connecting rod;
- Exhaust valve spindle, seats and cages;
- Cylinder liner;
- Piston crowns and skirt;
- Cylinder head/covers;
- Heat exchangers;
- Cargo & Service pumps;
- Turbocharger Repairs & Balancing

Trading and supply of

- Goltens G-Pump;
- Goltens Test Unit for fuel Valves;
- 2 & 4 Stroke Diesel Engine Spare Parts;
- Bearing Metals, Std, Undersize as well as on special fabrication for most type of main and auxiliary engines;
- WENCON material (Denmark);
- Firber & Rope – Dyneema (Netherlands)
- Steering Gear/Deck Machinery – Yoowon (Korea)
- Pump – HYOSUNG (Korea)
- Boilers – SPP (Korea)
- Aluminium Helideck Systems – Marine Aluminium (Sweden)
- Grab – Cargotec (Sweden)
- Soot Cleaning System – Infrafone (Sweden)
- Alignment Resins - ITW Chockfast (USA);
- Marine Emissions Control System – STI-EMS(USA)
- Galley & Laundry Equipment – Beha Hedo/Berto's
- High Pressure Cleaner & Water Blaster – DENSIN (Denmark)
- Level Gauging system – Xtronica A. S. (Norway)
- Power Measurement system for rotating shafts – Metasystem(Norway)

Appendix D: Service Data Sheet

(Staykov, 2013)

GENERAL

Builder / year	[redacted]
Flag / POR	Bahamas / Nassau
Class	Lloyds Register of Shipping +100A1, IWS, +LMC, UMS, DP(AA). Offshore Support Vessel
Gross tonnage	2,990
Nett tonnage	1,573
Deadweight (summer)	4,709 tonnes

DIMENSIONS

Length OA	82.88 m
Breadth mld.	19.00 m
Draught (summer)	6.333 m

PERFORMANCE

Service speed	abt. 10-12 knots

CARGO DECK

Sheathed deck area	58.5 m x 16.0 m = 936 m^2
Deck strength	5 tonnes / m^2
Deck load	3,000 tonnes

CARGO CAPACITIES

	Approx. at 100%
Fuel oil cargo	1,138 m^3
Potable water	1,010 m^3
Drill water	1,056 m^3
Dry bulk @ 80 psi.	8 x 50 m^3 = 400 m^3 (14,400 ft^3)
Liquid mud @ 2.5 sg	2 x 165 m^3 - (2,080 bbls)
Liquid mud @ 2.5 sg	2 x 141 m^3 - (1,774 bbls)
Brine @ 2.5 sg	2 x 159 m^3 - (2,000 bbls)
Brine @ 2.5 sg / Base oil	2 x 191 m^3 - (2,400 bbls)
Base oil	2 x 100 m^3 - (1,255 bbls)
Ships fuel oil	323 m^3 (IFO 40 or MDO)

CARGO PUMPING

Fuel oil cargo	2 x 150 m^3/hr @ 9 bar
Potable water	1 x 150 m^3/hr @ 9 bar
Drill water	1 x 150 m^3/hr @ 9 bar
Dry bulk compressors	2 x 30 m^3/m @ 80 psi
Liquid mud	2 x 100 m^3/hr @ 23 bar
Brine	2 x 100 m^3/hr @ 23 bar
Base oil	1 x 100 m^3/hr @ 9 bar

DP2 SYSTEM

DP / Joystick Control	IMO Class 2 DP System - Kongsberg K-Pos DP-21
Reference systems	Fan beam laser + 2 x DGPS

PROPULSION

Two Wärtsilä Vaasa 6R32E marine diesel engines each developing 3,300 BHP @ 750 rpm each driving 1,760 kW shaft alternator and CP propeller

Total developed power	4,920 kW (6,600 BHP)

GENERATORS

	440 / 3 / 60
Shaft alternators	2 x 1,760 kW
Main alternators	2 x 335 kW
Emergency alternator	1 x 167 kW

THRUSTERS

Forward tunnels	2 x 736 kW
Aft tunnels	2 x 736 kW

DECK MACHINERY

Deck/stores crane	3 tonnes @ 12 m radius
Tuggers	2 x 10t
Capstans	2 x 10t

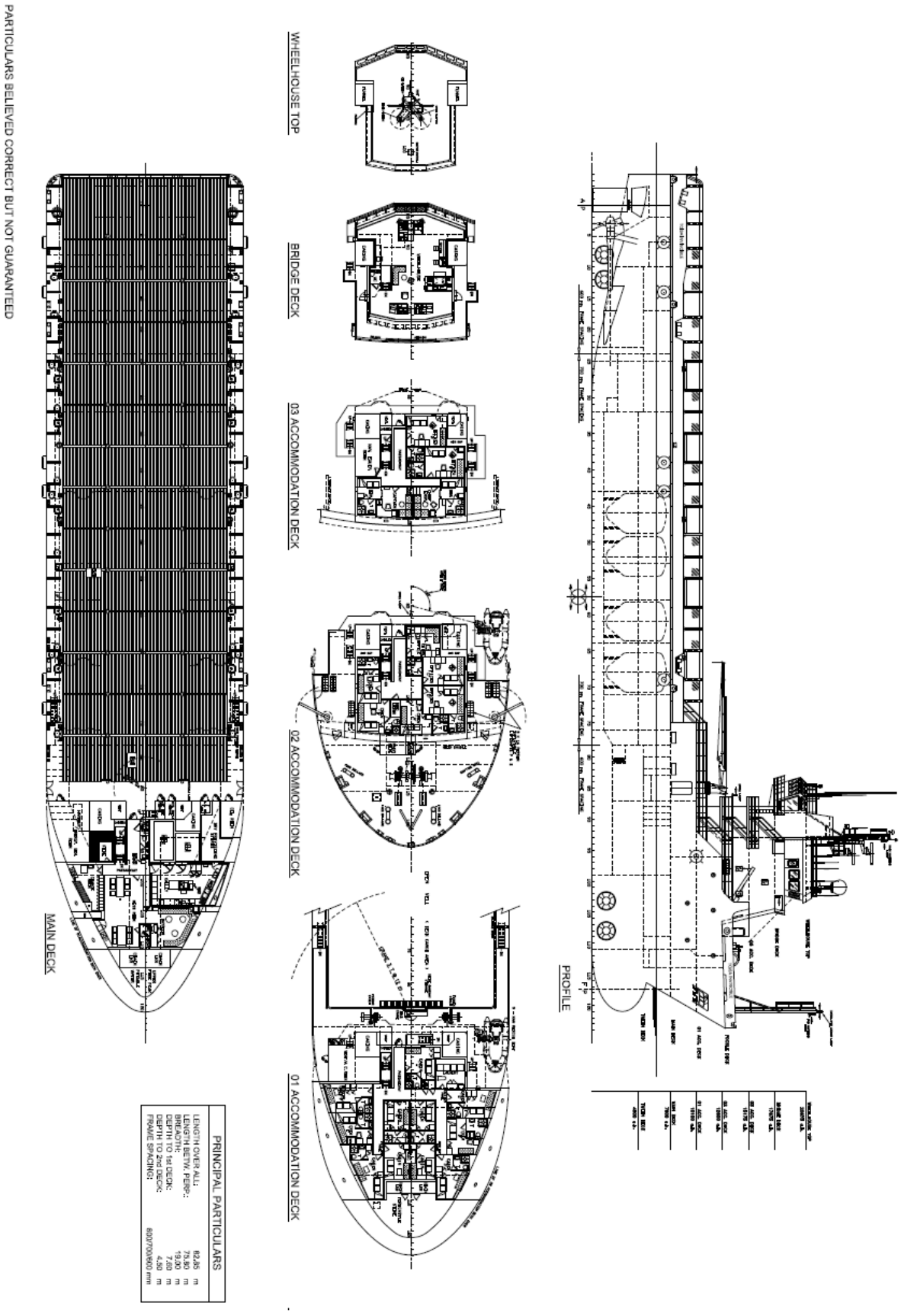
ACCOMMODATION

Wheelhouse and accommodation fully air conditioned

Single berth cabins	2 suites + 9 en-suite
Two berth cabins	6 cabins
Hospital	2 berth
Complement	27 persons

STABILISATION

Two passive roll reduction stabilisation tanks


PARTICULARS BELIEVED CORRECT BUT NOT GUARANTEED
WHEELHOUSE TOP
BRIDGE DECK
03 ACCOMMODATION DECK
02 ACCOMMODATION DECK
01 ACCOMMODATION DECK
MAIN DECK
PROFILE
PRINCIPAL PARTICULARS
LENGTH OVER ALL: 82,85 m
LENGTH BETW. PERP.: 75,80 m
BREADTH: 19,00 m
DEPTH TO 1st DECK: 7,20 m
DEPTH TO 2nd DECK: 4,50 m
FRAME SPACING: 600/700/800 mm

Appendix E: Tool quotations and offers

Quotation Prüftechnik

PRÜFTECHNIK

Our ref: PTC/2K15/BXF
Date: 2015-06-09

Customer: SKF Blohm + Voss Industries
To: Erwin Pieters
Email: erwin.pieters@bv-industries.com

About: Quotation for Laser alignment and Vibration analysis

Dear Sir,
Thank you for your interest in our Pruftechnik products. With pleasure I have enclosed our quotation and details of the products proposed. The following terms of delivery and payment shall apply for this quotation:

* Price : RMB,17%VAT DDP Shanghai
* Delivery : 4-6 weeks from date of full payment.
*Validity : 3 months
*Payment : Full payment in advance by T/T.
* Warranty : 12 months from date of invoice.

We trust our quotation is of interest to you and look forward to your order in the near future. In the event that you have further questions, please do not hesitate to contact us.

Yours sincerely,

Ramon Bai
Sales Manager
13918680898

Productive maintenance technology
PRUFTECHNIK Trading(Shanghai) Co. Ltd
21F,Room 03,04 Tower A , Hongkou Plaza
No.388 West Jiangwan Road, Hongkou Disrtict
Shanghai 200083, P.R. China
PRUFTECHNIK Trading(Shanghai) is a part of PRUFTECHNIK
Tel: +86(21)65075118
Fax: +86(21)65075115
www.pruftechnik.com.cn
普卢福贸易(上海)有限公司
上海市虹口区西江湾路 388 号
凯德龙之梦写字楼 A 栋 21 楼 03,04 室
邮编：200083

PRÜFTECHNIK

序号	定货号	描述	数量	单价
01	ALI 4.030/2-2F	CENTRALIGN Ultra stand alone package 120mm-810mm + non magnetic bores	1	390,000.00
02	ALI 4.035	ROTALIGN Ultra Shaft add-on package for CENTRALIGN Ultra	1	65,000.00
03	ALI 4.036	LEVALIGN Ultra Flatness add-on package for CENTRALIGN Ultra	1	140,000.00
04	ALI 4.037	Straightness (2 plane) add-on package for CENTRALIGN Ultra	1	55,000.00
05	ALI 2.893 SETIS	Cardan shaft bracket set	1	70,000.00
06	ALI 13.000-7	AC first device activiation for ROTALIGN Ultra	1	30,000.00
07	VIB 5.314-2	VIBXPERT II Advanced 2-channel +	1	316,000.00
08	VIB 8.830	VIBROTIP Trending package	1	53,000.00
09		Free of Trainning	1	

First set up: **01+02+06+08=538,000.00**

Basic alignment
line bore concentric measurement
minor bearing vibration measurement

Second set up:**01+02+03+04+05+06+08=803,000.00**

Full alignment (multiple components, cardan shafts etc.)
Line bore concentric measurement
Flatness measurement
Perpendicular and parallelism of planes
Minor vibration measurement

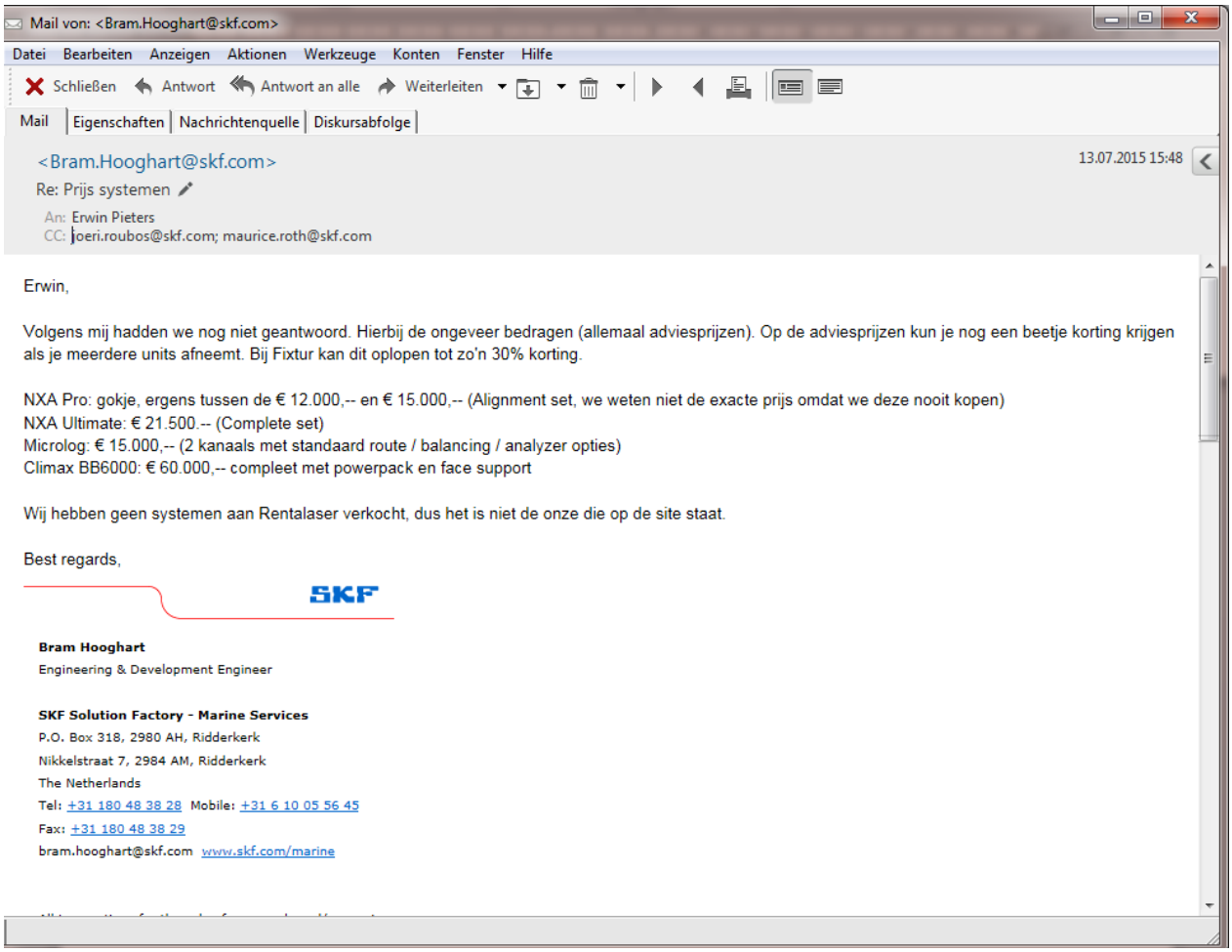
Third set up: **01+02+03+04+05+06+07=1,066,000.00**

Full alignment (multiple components, cardan shafts etc.)
Line bore concentric measurement
Flatness measurement
Perpendicular and parallelism of planes
Full spectrum vibration analysis(Suitable for cat II vibration engineer)

Productive maintenance technology
PRUFTECHNIK Trading(Shanghai) Co. Ltd
21F,Room 03,04 Tower A , Hongkou Plaza
No.388 West Jiangwan Road, Hongkou Disrtict
Shanghai 200083, P.R. China
PRUFTECHNIK Trading(Shanghai) is a part of PRUFTECHNIK
Tel: +86(21)65075118
Fax: +86(21)65075115
www.pruftechnik.com.cn
普卢福贸易(上海)有限公司
上海市虹口区西江湾路 388 号
凯德龙之梦写字楼 A 栋 21 楼 03,04 室
邮编：200083

Quotation Fixturlaser

Due to the fact that rental laser already offers to the SKF Machine Support team the prices have been requested directly from the SKF Machine Support team.



Mail von: <Bram.Hooghart@skf.com>

Datei Bearbeiten Anzeigen Aktionen Werkzeuge Konten Fenster Hilfe

Schließen Antwort Antwort an alle Weiterleiten

Mail | Eigenschaften | Nachrichtenquelle | Diskursabfolge

<Bram.Hooghart@skf.com> 13.07.2015 15:48

Re: Prijs systemen

An: Erwin Pieters
CC: joeri.roubos@skf.com; maurice.roth@skf.com

Erwin,

Volgens mij hadden we nog niet geantwoord. Hierbij de ongeveer bedragen (allemaal adviesprijzen). Op de adviesprijzen kun je nog een beetje korting krijgen als je meerdere units afneemt. Bij Fixtur kan dit oplopen tot zo'n 30% korting.

NXA Pro: gokje, ergens tussen de € 12.000,-- en € 15.000,-- (Alignment set, we weten niet de exacte prijs omdat we deze nooit kopen)
NXA Ultimate: € 21.500.-- (Complete set)
Microlog: € 15.000,-- (2 kanaals met standaard route / balancing / analyzer opties)
Climax BB6000: € 60.000,-- compleet met powerpack en face support

Wij hebben geen systemen aan Rentalaser verkocht, dus het is niet de onze die op de site staat.

Best regards,

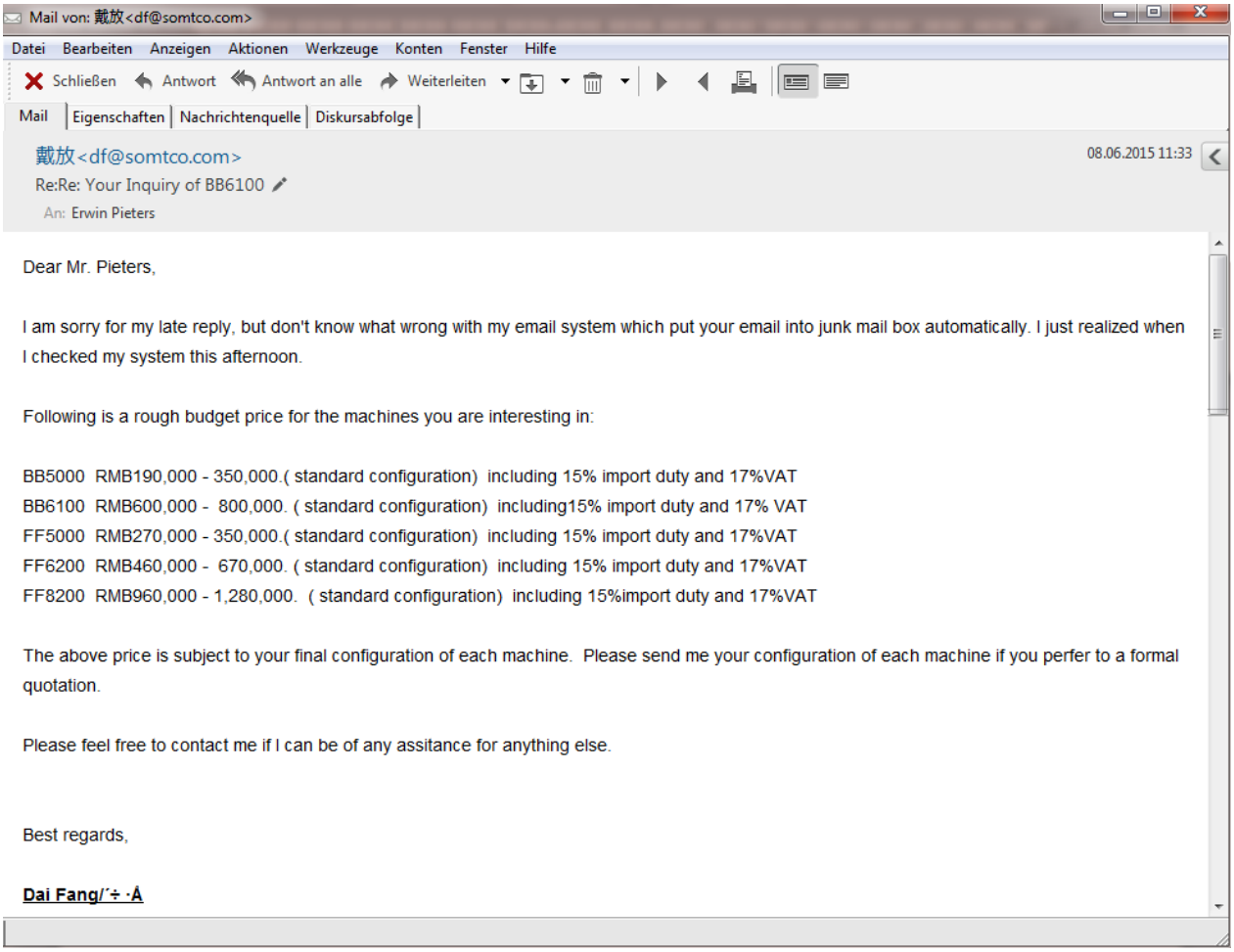
SKF

Bram Hooghart
Engineering & Development Engineer

SKF Solution Factory - Marine Services
P.O. Box 318, 2980 AH, Ridderkerk
Nikkelstraat 7, 2984 AM, Ridderkerk
The Netherlands
Tel: +31 180 48 38 28 Mobile: +31 6 10 05 56 45
Fax: +31 180 48 38 29
bram.hooghart@skf.com www.skf.com/marine

Quotation Climax portable

This quotation has been offered by the local dealer of Climax portable.



Mail von: 戴放<df@somtco.com>

Datei Bearbeiten Anzeigen Aktionen Werkzeuge Konten Fenster Hilfe

Schließen Antwort Antwort an alle Weiterleiten

Mail | Eigenschaften | Nachrichtenquelle | Diskursabfolge

戴放<df@somtco.com> 08.06.2015 11:33

Re:Re: Your Inquiry of BB6100

An: Erwin Pieters

Dear Mr. Pieters,

I am sorry for my late reply, but don't know what wrong with my email system which put your email into junk mail box automatically. I just realized when I checked my system this afternoon.

Following is a rough budget price for the machines you are interesting in:

BB5000 RMB190,000 - 350,000.(standard configuration) including 15% import duty and 17%VAT
BB6100 RMB600,000 - 800,000. (standard configuration) including15% import duty and 17% VAT
FF5000 RMB270,000 - 350,000.(standard configuration) including 15% import duty and 17%VAT
FF6200 RMB460,000 - 670,000. (standard configuration) including 15% import duty and 17%VAT
FF8200 RMB960,000 - 1,280,000. (standard configuration) including 15%import duty and 17%VAT

The above price is subject to your final configuration of each machine. Please send me your configuration of each machine if you perfer to a formal quotation.

Please feel free to contact me if I can be of any assitance for anything else.

Best regards,

Dai Fang/´÷ ·Â

Additional tools

13-8-2015 Strain Measurement Kit

OMEGA®

Your One-Stop Source for Process Measurement & Control!

Home » Pressure, Strain and Force » Strain Gages, Access... » Strain Gage Accessor... » SG1-KIT

Strain Gage Application Kit

SG1-KIT

Strain Measurement Kit

$695.00 SG1-KIT

- Tools
- Adhesives
- Coatings
- Strain Gage Assortment

Strain Gages, Accessories and Instrumentation - View related products

http://www.omega.com/pptst/SG1-KIT.html (*13-08-2015)*

See larger image

RSM Series Enerpac Flat Jack Hydraulic Jack Supplier

FOB Price:	US $20 - 200 / Set | Get Latest Price
Min.Order Quantity:	1 Set/Sets Flat Jack
Supply Ability:	10000 Set/Sets per Month Flat Jack
Port:	Shanghai
Payment Terms:	T/T,Western Union,Paypal
Quantity	1 Set/Sets

Please write your requirement here.

Recommend matching suppliers if this supplier doesn't contact me on Message Center within 24 hours.

I agree to share my **Business Card** to the supplier.

Contact supplier | Chat Now!

Start Order | Add to Inquiry Cart | Add to My Favorites

This supplier supports **Trade Assurance.**

With Trade Assurance, you'll enjoy:

- 100% product quality protection
- 100% on-time shipment protection
- 100% payment protection for your covered amount

Learn More ›

http://www.alibaba.com/product-detail/RSM-Series-Enerpac-Flat-Jack-Hydraulic_1709319112.html?spm=a2700.7724857.35.1.vDY44U (*13-08-2015)*

Hytorc Electric Hydraulic Pump Factory Price

FOB Price:	US $500 - 5,000 / Piece | Get Latest Price
Min.Order Quantity:	1 Piece/Pieces Hytorc Electric Hydraulic Pump
Supply Ability:	1000 Set/Sets per Month Electric Hydraulic Pump
Port:	Shanghai
Payment Terms:	T/T,Western Union,Paypal
Quantity	1 Piece/Pieces

Please write your requirement here.

Recommend matching suppliers if this supplier doesn't contact me on Message Center within 24 hours.

I agree to share my **Business Card** to the supplier.

Contact supplier | Chat Now!

Start Order | Add to Inquiry Cart | Add to My Favorites

This supplier supports **Trade Assurance.**
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- 100% product quality protection
- 100% on-time shipment protection
- 100% payment protection for your covered amount

Learn More ›

http://www.alibaba.com/product-detail/Hytorc-Electric-Hydraulic-Pump-Factory-Price_1975227758.html?spm=a2700.7724838.35.1.BQvSJO (*13-08-2015*)

Euroboor Eco.32 | kernboormachine + HCS.KIT kernborenset

Artikelnummer: Eco.32_HCS.KIT/8

Op voorraad: **Voor 22.00 = morgen in huis**

Euroboor Eco.32 | kernboormachine + HCS.KIT kernborenset. Koop nu snel online bij Toolmax! Betaal veilig en vertrouwd via uw eigen bank.

€ 659,00

Excl. BTW: € 544,63
(Adviesprijs: € 743,75)

1 In winkelwagen

Zet op verlanglijst | Toon in vergelijking

http://www.toolmax.nl/euroboor-eco32-kernboormachine-hcs-kit-8-kernborenset.html (*13-08-2015*)

See larger image

Single acting low height hydraulic lifting jacks 50 ton

FOB Price: US $100 - 800 / Piece | Get Latest Price
Min.Order Quantity: 1 Piece/Pieces
Supply Ability: 500 Piece/Pieces per Month
Port: shanghai
Payment Terms: L/C,D/A,D/P,T/T,Western Union,MoneyGram,T/T 50% in advanced
Quantity 1 Piece/Pieces

Please write your requirement here.

Recommend matching suppliers if this supplier doesn't contact me on Message Center within 24 hours.

I agree to share my **Business Card** to the supplier.

Contact supplier | Chat Now!

Start Order | Add to Inquiry Cart | Add to My Favorites

This supplier supports **Trade Assurance.**
With Trade Assurance, you'll enjoy:
- 100% product quality protection
- 100% on-time shipment protection
- 100% payment protection for your covered amount

http://www.alibaba.com/product-detail/Single-acting-low-height-hydraulic-lifting_1771668028.html?spm=a2700.7724857.35.1.USiLSO (*13-08-2015)*

See larger image

SC29FB Low profile disk typ load cell/wheel shaped load cell weight sensor 0.5-2000KN

FOB Price: US $25 - 450 / Piece | Get Latest Price
Min.Order Quantity: 1 Piece/Pieces bridge loadcell sensor
Supply Ability: 500 Piece/Pieces per Month
Port: shenzhen, Hongkong
Payment Terms: L/C,D/A,D/P,T/T,Western Union,MoneyGram,agreed by both parties
Quantity 1 Piece/Pieces

Please write your requirement here.

Recommend matching suppliers if this supplier doesn't contact me on Message Center within 24 hours.

I agree to share my **Business Card** to the supplier.

Contact supplier | Leave Messages

Start Order | Add to Inquiry Cart | Add to My Favorites

This supplier supports **Trade Assurance.**
With Trade Assurance, you'll enjoy:
- 100% product quality protection
- 100% on-time shipment protection
- 100% payment protection for your covered amount

http://www.alibaba.com/product-detail/SC29FB-Low-profile-disk-typ-load_60065030662.html?spm=a2700.7724838.35.1.wSlBbF(*13-08-2015)*

Vibration training

Work Identification

WI210
ISO Category I—
Vibration Analysis Entry Level

Recommended for
Plant personnel requiring an introduction to vibration analysis techniques and technologies used in a condition predictive maintenance program. Including maintenance supervisors, rotating machinery engineers, predictive maintenance technicians and coordinators, reliability engineers, and multi-skilled mechanics.

Course objective
Introduce a novice to basic vibration analysis by using a variety of PdM instrumentation and software. To find how vibration analysis and related technologies can best be integrated to successfully implement such programs from hands-on demonstration. Teach vibration terminology and measurement conventions needed, not only by coverage of seminar text material, but also by performing "button pushing" demonstration to maximize the learning experience.

2015 course schedule

January 20–23	Charlotte, NC
February 3–6	Miami, FL
February 24–27	Dallas, TX
March 17–20	New Orleans, LA
April 7–10	Seattle, WA
April 14–17	Charlotte, NC
May 12–15	Columbus, OH
June 2–5	St. Louis, MO
June 9–12	Myrtle Beach, SC
July 7–10	Charlotte, NC
July 21–24	Denver, CO
July 28–31	Myrtle Beach, SC
August 25–28	Philadelphia, PA
September 15–18	Charlotte, NC
September 29–Oct 2	Dallas, TX
October 13–16	Orlando, FL
October 27–30	San Diego, CA
November 3–6	Charlotte, NC
December 1–4	Houston, TX

Course description
The basics of performing vibration analysis to get started within a condition monitoring program. Various techniques used to understand machinery condition are introduced.

- Introduction to predictive maintenance and machine vibration:
  - Definitions of PdM and condition monitoring
  - How PdM compares with other maintenance systems
  - Goals of a PdM program
  - The critical role of vibration analysis in PdM
- Machine vibration – basic theory and analysis:
  - Characteristics of vibration (frequency and period)
  - Amplitude – magnitude of vibratory motion
  - RMS peak and peak-to-peak conversations
  - Frequency – how often the vibration occurs
  - Phase – how one machine component or support frame vibrates relative to another
  - Basics of a time waveform versus a spectrum
- Preparation for data collection:
  - Types of vibration transducers
  - Choosing the optimum transducer location
  - Effects of transducer mounting on it's performance, accuracy and repeatability
  - Choosing the optimum FFT data collector
- Introduction to data collection systems:
  - Setting up a PdM database (plants, trains, machines and points
  - Choosing the proper parameter (vibration, acceleration, velocity and/or displacement)
  - Selecting the proper parameters
  - Setting up the optimum PdM routes and schedules
  - Printing out the proper reports after uploading
- Introduction to problem recognition:
  - How to recognize abnormal conditions
  - How to identify hardware versus software faults
  - How to identify good versus bad data
  - How to detect common machine problems

2015 tuition

Public classes	$1,395
On-site	
per class	$10,595
# people	5
6+ people	$295 per person

3.5 days – optional certification exam on day 4

A written examination is available for this course. Test fee – $275 per person. Successful completion of the written exam results in ISO Category I Certification.

Basic machine maintenance skills and experience. General computer and calculating skills are helpful. Little or no previous vibrating experience required.

Pre-study*
WI100 Vibration basics
JM02001 Introduction Guide to Vibration Monitoring
JM02007 Vibration Principles

Post-study*
MB02006 Predictive maintenance
MB02005 SKF Condition Monitoring
KBA00276 Measuring with different SKF devices

* On-line learning material at skf.com/us/knowledge-centre.com

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http://www.skf.com/us/services/customer-training/classroom/WI211.html (*05-07-2015*)

Work Identification

WI212
ISO Category III—Vibration Analysis II

Recommended for
Plant personnel requiring a comprehensive understanding of vibration FFT and diagnostic techniques used to perform rotor dynamics analysis for increased performance of rotating machinery; including machinery specialists, predictive maintenance technicians, reliability engineers, and advanced mechanics.

Course objective
At the end of this course, participants should understand how to refine a condition monitoring program with diagnostic techniques that improve the performance of rotating machinery with rolling element or sleeve bearings. Participants will be taught to diagnose several malfunctions, from common to moderately severe, and to make recommendations for corrective action. In addition, participants will be taught to enhance condition monitoring programs with advanced measurement techniques, such as high frequency enveloping and time waveforms.

2015 course schedule

March 10–13	Dallas, TX
April 21–24	Seattle, WA
April 28–May 1	Charlotte, NC
June 16–19	St. Louis, MO
June 23–26	Myrtle Beach, SC
August 4–7	Denver, CO
August 11–14	Myrtle Beach, SC
September 29–Oct 2	Charlotte, NC
October 27–30	Orlando, FL
November 10–13	San Diego, CA
November 17–20	Charlotte, NC
December 15–18	Houston, TX

Course description
A comprehensive survey and in-depth study of vibration spectrum analysis and related condition monitoring techniques used to analyze rotating machinery, and to detect and correct machinery malfunctions. An overview of rotor dynamics is presented, along with the study of severe, but less common, machinery problems that frequently lead to catastrophic failure. An overview of acceleration enveloping and SEE™ Technology is also presented.

- Brief review of Vibration Analysis I course topics
  - Vibration instruments and sensors
  - Evaluating machinery condition with vibration analysis
  - Analog vs. digital overall vibration measurements
  - Spike energy, high frequency demodulation (HFD), and shock pulse techniques
  - Common pitfalls in vibration measurements
  - Time waveform and conversion to FFT spectrum
- Proper use of vibration severity charts
- Phase analysis techniques
- Concentrated vibration spectrum analysis for detecting 40 machinery problems
  - Mass unbalance, eccentric rotors, and bent shafts
  - Misalignment and coupling problems
  - Mechanical looseness
  - Balance resonance problems
  - Rotor radial rubs and sleeve bearing problems
  - Track rolling bearing condition using spectrum analysis
  - Flow-induced vibration (cavitation, surge, starvation)
  - Gear problems (wear, excessive backlash, eccentricity, tooth misalignment, cracked/broken teeth, hunting tooth, assembly phase problems)
  - Monitoring problems in AC and DC motors
  - Belt-drive and beat vibration problems
  - Soft foot and distorted frame problems
- Proven analysis procedure, including examples
- High frequency enveloping and demodulation spectral analysis. What is SEE Technology? How are these techniques used to detect problems with rolling element bearings, gears, lubrication, and contamination
- Real-world case histories are presented

2015 tuition

Public classes	$1,795
On-site	
per class	$12,995
# people	5
6+ people	$395 per person

3.5 days – optional certification exam on day 4

A written examination is available for this course. Test fee – $325 per person. Successful completion of the written exam results in ISO Category III Certification.

SEE™ spectral emitted energy signal processing technology is a trademark of SKF USA Inc.

Six to 12 months full-time condition monitoring program experience; SKF course ISO Category II—Vibration Analysis I (WI211) or commensurate field experience; knowledge of basic sensor and monitoring instrumentation.

Pre-study*
JM02012 Time domain analysis of vibration data
CM3068 Recommended initial alarm criteria for bearing condition assessment
JM03001 A balanced approach to acceleration and velocity monitoring

Post-study*
JM02019 Vibration analysis feature extraction techniques
MB01001 Low speed bearing monitoring
WI130 Thermography basics

* On-line learning material at skf.com/us/knowledge-centre.com

SKF

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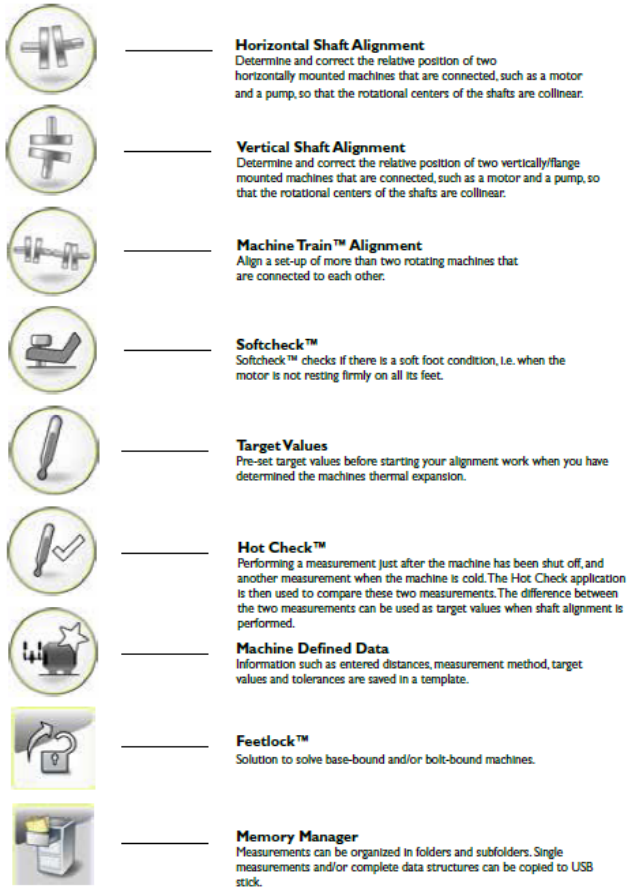
http://www.skf.com/us/services/customer-training/classroom/WI212.htm (*05-07-2015)*

Appendix F: Laser alignment sets

Fixturlaser

Fixturlaser NXA Pro System	
Weight including all standard parts:	7,7 kg (17 lbs)
Dimension:	415 mm x 325 mm x 180 mm (16 in x 13 in x 7 in)
Display Unit	
Weight:	1,2 kg (2,6 lbs) with battery
Dimensions:	124 mm x 158 mm x 49 mm (4,9 in x 6,2 in x 1,9 in)
Environmental protection:	IP 65 (Dust tight and protected against water jets)
Display size:	6,5" (165 mm) diagonal (133 x 100 mm)
Gyroscope:	6-Axis MEMS Inertial Motion Sensor with drift compensation and automatic field calibration.
Operating time	10 hours continuous use (with 50% LCD backlight)
Battery charging time (system off, room temperature):	1 hour charge – 6 hours operating time
TD Units	
Weight:	192 g (6,8 oz) with battery
Dimensions:	92 mm x 77 mm x 33 mm (3,6 in x 3,0 in x 1,3 in)
Environmental protection:	IP 65 (Dust tight and protected against water jets)
Measurement distance:	Up to 10 m
Detector:	2nd generation Ultra HD CCD
Detector length:	30 mm (1,2 in)
Detector resolution:	1 µm
Measurement accuracy:	0,3% ± 7 µm
Gyroscope:	6-Axis MEMS Inertial Motion Sensor with drift compensation and automatic field calibration
Operating time:	17 hours continuous use (measuring)
Shaft Brackets	
Shaft diameter:	Ø 20-450 mm (3/4"-18")
Rods:	4 pcs 85 mm and 4 pcs 160 mm (extendable to 245 mm)

Fixturlaser NXA Pro Application



Horizontal Shaft Alignment
Determine and correct the relative position of two horizontally mounted machines that are connected, such as a motor and a pump, so that the rotational centers of the shafts are collinear.

Vertical Shaft Alignment
Determine and correct the relative position of two vertically/flange mounted machines that are connected, such as a motor and a pump, so that the rotational centers of the shafts are collinear.

Machine Train™ Alignment
Align a set-up of more than two rotating machines that are connected to each other.

Softcheck™
Softcheck™ checks if there is a soft foot condition, i.e. when the motor is not resting firmly on all its feet.

Target Values
Pre-set target values before starting your alignment work when you have determined the machines thermal expansion.

Hot Check™
Performing a measurement just after the machine has been shut off, and another measurement when the machine is cold. The Hot Check application is then used to compare these two measurements. The difference between the two measurements can be used as target values when shaft alignment is performed.

Machine Defined Data
Information such as entered distances, measurement method, target values and tolerances are saved in a template.

Feetlock™
Solution to solve base-bound and/or bolt-bound machines.

Memory Manager
Measurements can be organized in folders and subfolders. Single measurements and/or complete data structures can be copied to USB stick.

Figure 0-1: Fixturlaser NXA Pro (1)

Fixturlaser NXA Pro System	
Weight including all standard parts:	7,7 kg (17 lbs)
Dimension:	415 mm x 325 mm x 180 mm (16 in x 13 in x 7 in)
Display Unit	
Weight:	1,2 kg (2,6 lbs) with battery
Dimensions:	124 mm x 158 mm x 49 mm (4,9 in x 6,2 in x 1,9 in)
Environmental protection:	IP 65 (Dust tight and protected against water jets)
Display size:	6,5" (165 mm) diagonal (133 x 100 mm)
Gyroscope:	6-Axis MEMS Inertial Motion Sensor with drift compensation and automatic field calibration.
Operating time	10 hours continuous use (with 50% LCD backlight)
Battery charging time (system off, room temperature):	1 hour charge – 6 hours operating time
TD Units	
Weight:	192 g (6,8 oz) with battery
Dimensions:	92 mm x 77 mm x 33 mm (3,6 in x 3,0 in x 1,3 in)
Environmental protection:	IP 65 (Dust tight and protected against water jets)
Measurement distance:	Up to 10 m
Detector:	2nd generation Ultra HD CCD
Detector length:	30 mm (1,2 in)
Detector resolution:	1 µm
Measurement accuracy:	0,3% ± 7 µm
Gyroscope:	6-Axis MEMS Inertial Motion Sensor with drift compensation and automatic field calibration
Operating time:	17 hours continuous use (measuring)
Shaft Brackets	
Shaft diameter:	Ø 20-450 mm (3/4"-18")
Rods:	4 pcs 85 mm and 4 pcs 160 mm (extendable to 245 mm)

Fixturlaser NXA Pro Application

Horizontal Shaft Alignment
Determine and correct the relative position of two horizontally mounted machines that are connected, such as a motor and a pump, so that the rotational centers of the shafts are collinear.

Vertical Shaft Alignment
Determine and correct the relative position of two vertically/flange mounted machines that are connected, such as a motor and a pump, so that the rotational centers of the shafts are collinear.

Machine Train™ Alignment
Align a set-up of more than two rotating machines that are connected to each other.

Softcheck™
Softcheck™ checks if there is a soft foot condition, i.e. when the motor is not resting firmly on all its feet.

Target Values
Pre-set target values before starting your alignment work when you have determined the machines thermal expansion.

Hot Check™
Performing a measurement just after the machine has been shut off, and another measurement when the machine is cold. The Hot Check application is then used to compare these two measurements. The difference between the two measurements can be used as target values when shaft alignment is performed.

Machine Defined Data
Information such as entered distances, measurement method, target values and tolerances are saved in a template.

Feetlock™
Solution to solve base-bound and/or bolt-bound machines.

Memory Manager
Measurements can be organized in folders and subfolders. Single measurements and/or complete data structures can be copied to USB stick.

Figure 0-2: FIxturlaser NXA Pro (2)

Horizontal Shaft Alignment
Determine and correct the relative position of two horizontally mounted machines that are connected, such as a motor and a pump, so that the rotational centers of the shafts are collinear.

Vertical Shaft Alignment
Determine and correct the relative position of two vertically/flange mounted machines that are connected, such as a motor and a pump, so that the rotational centers of the shafts are collinear.

Machine Train™ Alignment
Align a set-up of more than two rotating machines that are connected to each other.

Softcheck™
Softcheck™ checks if there is a soft foot condition, i.e. when the motor is not resting firmly on all its feet.

Target Values
Pre-set target values before starting your alignment work when you have determined the machines thermal expansion.

Hot Check™
Performing a measurement just after the machine has been shut off, and another measurement when the machine is cold. The Hot Check application is then used to compare these two measurements. The difference between the two measurements can be used as target values when shaft alignment is performed.

Machine Defined Data
Information such as entered distances, measurement method, target values and tolerances are saved in a template.

Feetlock™
Solution to solve base-bound and/or bolt-bound machines.

Memory Manager
Measurements can be organized in folders and subfolders. Single measurements and/or complete data structures can be copied to USB stick.

Circular Flatness
A laser plane is used as reference in the circular flatness application. The deviation in distance between the laser plane and the measurement object is measured in one or more positions with the use of the receiver.

Rectangular Flatness
The rectangular flatness measurement program uses a laser plane as reference. The deviation in distance between the laser plane and the measurement object is measured in one or more positions with the use of the receiver.

Straightness
With the straightness application, straightness can be measured in two axes. The laser beam is used as reference and the deviation in distance between the laser beam and the measurement object is measured in two or more positions, with the use of the receiver.

1. Display unit 2. Fixturlaser M3 Transmitter/Sensor Unit 3. Fixturlaser S3 Transmitter/Sensor Unit 4. 2 pcs complete V-bracket 5. Ext. power cable 6. USB cable A-mini 7. Power supply 8. USB stick 9. 2 pcs Angled universal tool 10. 2 pcs Magnetic v-bracket 11. Magnetic base 12. Chain 8 mm 60 links L=970 mm 13. Rod kit 14. Extension fixture 15. Tape measure 5 m 16. T21 Transmitter 17. T21 Holder plate 18. XA RM Sensor Unit 19. BT2 Wireless Unit 20. Magnet base, detector holder

Figure 0-3: Fixturlaser NXA Ultimate (1)

Fixturlaser NXA Ultimate System	
Weight including all standard parts:	14,4 kg (31,75 lb)
Dimension:	510 mm x 417 mm x 214 mm (20 in x 16,4 in x 8,4 in)
Display Unit	
Weight:	1,2 kg (2,6 lbs) with battery
Dimensions:	124 mm x 158 mm x 49 mm (4,9 in x 6,2 in x 1,9 in)
Environmental protection:	IP 65 (Dust tight and protected against water jets)
Display size:	6,5" (165 mm) diagonal (133 x 100 mm)
Gyroscope:	6-Axis MEMS Inertial Motion Sensor with drift compensation and automatic field calibration.
Operating time	10 hours continuous use (with 50% LCD backlight)
Battery charging time (system off, room temperature):	5 hours (1 hour charge – 6 hours operating time)
S3/M3 Transmitter/Sensor Units	
Weight:	192 g (6,8 oz) with battery
Dimensions:	92 mm x 77 mm x 33 mm (3,6 in x 3,0 in x 1,3 in)
Environmental protection:	IP 65 (Dust tight and protected against water jets)
Measurement distance:	Up to 10 m
Detector:	Ultra HD CCD
Detector length:	30 mm (1,2 in)
Detector resolution:	1 µm
Measurement accuracy:	0,3% ± 7 µm
Gyroscope:	6-Axis MEMS Inertial Motion Sensor with drift compensation and automatic field calibration
Operating time:	17 hours continuous use (measuring)
Battery charging time (system off, room temperature):	8 hours
Shaft Brackets	
Shaft diameter:	Ø 20-450 mm (3/4"-18")
Rods:	4 pcs 85 mm and 4 pcs 160 mm (extendable to 245 mm)
XA RM Sensor Unit	
Weight:	116 g (4,1oz)
Dimensions:	57 x 50 x 40 mm (2.2 x 2.0 x 1.6 in)
Detector size:	20 mm x 20 mm (0.8 in x 0.8 in)
Measurement accuracy:	1% ± 3 µm

T21 Transmitter	
Housing Material:	Anodized aluminium
Operating Temp:	0 to 50°C (32 to 122°F)
Storage Temp:	-20 to 70°C (-4 to 158°F)
Weight:	1150 g
Laser class:	Class 2
Dimensions:	100 x 103 x 109 mm (3.9 x 4.1 x 4.3 in)
Measuring distance:	Up to 20 meters (66 feet)
Laser sweep flatness:	±0,02 mm/m
Angular prism accuracy:	±0,02 mm/m
Power supply:	2 batteries type LR6
Operating time:	15 hours continuously
BT2 Wireless Unit	
Weight:	190 g (6.7 oz) with batteries
Dimensions:	82 mm x 50 mm x 40 mm (3.2 in x 2.0 in x 1.6 in)
Wireless communication:	Class II Bluetooth transmitter
Communication range:	10 m (33 ft)
Power supply:	3 AA (LR6) batteries
Operating time:	10 hours continuously

ACOEM AB is a global player and leader in developing innovative, user-friendly equipment for shaft alignment. By helping industries worldwide to become perfectly aligned, and eliminating anything that might not be, we minimize unnecessary wear and production stoppages. This will ultimately make our customers more profitable and our environment more sustainable.

P-0253-GB Fixturlaser NXA Ultimate Rev A

Figure 0-4: Fixturlaser NXA Ultimate (2)

Prüftechnik

Three packages: Standard – Advanced – Expert

Standard

High resolution color backlit TFT screen – 145 mm/ 5.7 inch diagonal and backlit alphanumeric keyboard
USB interface for PC and printer
Heavy-duty Li-Ion rechargeable battery
Rigid pre-assembled universal brackets and additional support posts included in a pouch
UniBeam – patented single laser-sensor technology for quick laser adjustment
Integrated electronic inclinometer
Alignment of horizontal, vertical and flanged-mounted machines
Alignment of coupled / non-coupled and rotatable / non-rotatable machines
Alignment of cardan and spacer shafts (cardan requires a special bracket)
Machine train alignment up to 6 machines
Soft foot measurement and correction
User-defined tolerances
TolChek® – automatic evaluation of alignment condition with 'Smiley' and LEDs
Variety of measurement modes: SWEEP, Static, Multipoint and Dial gauge inputs
InfiniRange® extends detector measurement range to handle gross misalignment
Live monitoring of horizontal and vertical corrections – Live Move
Move simulator
Static feet selection to resolve base-bound and bolt-bound problems
Realistic machine graphics which can be designated
Save thousands of measurement files in the device
Save reports as PDFs directly to memory stick
Data protection - auto save and resume capability
In compliance with IP 65 classifications
PC display for presentations/training in customer premises
Platform prepared for other alignment applications like Straightness, Flatness and Bore concentricity measurement
RFID Machine Identification

ROTALIGN® Ultra iS is based on a three-level system. The basic Standard version is packed with powerful features that include the Move Simulator and user-defined tolerances. This version is easily upgradable to the Advanced version to include the intelligent features and the powerful analysis tools. The system can be extended to the Expert level by adding 'Live Trend' and/or the multiple coupling application.

Advanced

Intelligence features
Vibration acceptance check without extra accessories
Live simultaneous Move in both horizontal and vertical directions
Soft foot wizard
Machine train up to 14 machines
Measurement Pass mode
Standard Deviation
Editable ellipse
Thermal growth calculator
Under/over-constrained feet
File/Machine templates
Vector tolerances
History table

Optional: Shims and mounting brackets for different applications.

Expert

'Live Trend' with magnetic or permanent fixation brackets
Multiple coupling measurement

Technical data

sensALIGN® sensor

CPU and memory	ARM Cortex™ M3 and 2GB Flash memory
Environmental protection	IP 65 (dustproof and water jet resistant), shockproof
Relative humidity	10% to 90%
Ambient light protection	Optical and active electronic digital compensation
Operating temperature	-10°C to 50°C
Measurement range	Unlimited, dynamically extendible (U.S. Pat. 6,040,903)
Measurement resolution	1 µm
Measurement error	< 1.0%
Vibration measurement	mm/s, RMS, 10 Hz to 1 kHz, 0 mm/s – 5000/f • mm/s² (f in Hertz [1/s])
Inclinometer resolution	0.1°
Inclinometer error	± 0.25% full scale
External interface	Integrated Bluetooth® Class 1 wireless communication, RS232, RS485, I-Data
LED indicators	4 x LED for laser adjustment, 2 LEDs for Bluetooth® communication and battery status
Operating time	12 hours continuous use
Power supply	Lithium Polymer rechargeable battery 3.7 V / 1.6 Ah / 6 Wh
Dimensions	Approx. 103 x 84 x 60 mm
Weight	Approx. 310 g

sensALIGN® laser

Type	InGaAlP semiconductor laser
Beam divergence	0.3 mrad
Environmental protection	IP 65 (dustproof and water jet resistant), shockproof
Relative humidity	10% to 90%
Beam power	< 1mW
Wavelength (typical)	635 nm (red, highly visible)
Safety class and precautions	Class 2, IEC/EN 60825-1:2007 Do not stare into laser beam
Operating temperature	-10°C to 50°C
Inclinometer resolution	0.1°
Inclinometer error	± 0.25% full scale
LED indicator	2 LEDs for battery status and laser transmission
Operating time	70 hours continuous use
Power supply	Lithium Polymer rechargeable battery 3.7 V / 1.6 Ah / 6 Wh
Dimensions	Approx. 103 x 84 x 60 mm
Weight	Approx. 330 g

ROTALIGN® Ultra iS technical data

CPU	Marvell XScale Processor running at 520 MHz
Memory	64 MB RAM, 64 MB Internal Flash, 1024 MB Compact Flash Memory
Display	Type: Transmissive (sunlight-readable) backlit TFT color graphic display
	Resolution: Full VGA, 640 x 480 pixels; Dimensions: 145 mm / 5.7 inch diagonal
	Keyboard elements: navigation cursor cross with up, clear and menu keys; Alphanumeric keyboard with dimensions, measure and results hard keys
LED indicators	4 LEDs for laser status and alignment condition
	2 LEDs for wireless communication and battery status
Power supply	Operating time: 25 hours (using Li-Ion rechargeable battery) 12 hours (using disposable batteries) typical use (based upon an operating cycle of 25% measurement, 25% computation and 50% 'sleep' mode)
	Lithium-Ion rechargeable battery: 7.2 V / 6.0 Ah
	Disposable batteries: 6 x 1.5 V IEC LR14 (°C°) [optional]
External interface	2 x USB host for printer, keyboard or PC communication
	1 x USB slave for printer, keyboard or PC communication
	RS232 (serial) for receiver
	I-Data socket for receiver
	Integrated Bluetooth® wireless communication, Class 1, transmitting power 100mW
	AC adapter/charger socket
Environmental protection	IP 65 (dustproof and water spray resistant), shockproof
	Relative humidity 10% to 90%
Temperature range	Operation: 0°C to 45°C [32°F to 113°F]
	Storage: -20°C to 60°C [-4°F to 140°F]
Dimensions	Approx. 243 x 172 x 61 mm [9 9/16" x 6 3/4" x 2 3/8"]
Weight	1 kg (without battery)
CE conformity	EC guidelines for electric devices (2004/108 EEC) are fulfilled

ROTALIGN® Ultra iS case

Contents may vary depending upon package ordered

Figure 0-5: Pruftechnik rotalign

SKF

Technical data

Complete System

- Measure distance*: Up to 10 m *(33.0 ft.)*
- Relative humidity: 10 to 90%
- Temperature range: –10 to +50 °C *(+14 to +122 °F)*
- Weight (with case): 7.64 kg *(16.84 lb.)*

* Range can be compromised when operating in bright sunlight.

Display unit

- Display: Seven inch backlit color LCD, daylight viewable with touch screen and keypad
- Power: Rechargeable Li-ion battery and external power supply
- Operating time on battery: Typical ten hours continuous operation
- Storage memory: 64 MB
- Housing: PC / ABS plastic with integrated lockable stand
- Dimensions (height × width × depth): 276 × 160 × 53 mm *(10.9 × 6.3 × 2.1 in.)*
- Weight: 1 060 g *(37.4 oz.)*
- Environment protection: IP 65
- Connectivity: Low-power, industrial wireless network, 802.15.4 compliant
  - USB: Host v1.1, device v1.1
- Drop test: 1,2 m *(3.9 ft.)* to MIL-STD-810F

Measuring units (A, B)

- Type of laser: Red diode laser
- Laser wavelength: 635 nm
- Laser safety class: Class II
- Laser output power: <1 mW
- Displacement measurement accuracy: ±5 µm, ±0,5%
- Detector: Linear CCD with length 36 mm *(1.4 in.)*
- Relative accelerometer accuracy*: ±0,1° (at 24 °C / 75 °F)
- Accelerometer resolution: 0,1°

* Relative accelerometer accuracy is the difference between the angles reported by the two measurement units when held at the same absolute angle.

- Thermal sensors: ±2 °C *(±3.5 °F)*
- Housing material: Chassis, aluminum sides, glass filled PBT
- Dimensions (height × width × depth): 96 × 93 × 36 mm *(3.8 × 3.7 × 1.4 in.)*
- Weight: 326 g *(11.5 oz.)*
- Environment protection: IP 65
- Ambient light protection: Optical filtering and ambient light signal rejection
- Power supply: Two (2) AA alkaline batteries or rechargeable battery

Rod / fixing bar

- Length: 4 off 90 mm, 4 off 150 mm, can be screwed together to increase length

Standard shaft diameter

- Up to 300 mm *(11.8 in.)*

Ordering information

The TKSA 80 Shaft Alignment System consists of:

- Display unit TKSA 80-DISPLAYUNIT, one (1) each
- Measuring unit TKSA 60/80 V2-HA and TKSA 60/80 V2-HB, one (1) each
- Mechanical shaft fixtures, two (2) each
- Adjustable chains with tightening pin, two (2) each
- Rods, four (4) each
  - 90 mm
  - 150 mm
- Measuring tape, one (1) each
- Screw driver, one (1) each
- Tommy bar, two (2) each
- USB cable, one (1) each
- Charger for display unit, one (1) each
- Quick start guide, one (1) each
- CD with instructions for use, one (1) each
- Extension Chain, two (2) each

For a tailored solution for available applications, please contact your local SKF sales office.

Figure 0-6: SKF TKSA system

Appendix G: On-site machining tools

Climax portable

BB5000 BORING MACHINE

06 2015 BB5

A powerful boring machine that can be customized to suit your needs

The most powerful boring machine in its class, you'll be amazed at the power and flexibility of the BB5000 Portable Boring Machine.
Exclusive, Climax-patented mounting components provide the flexibility to handle tough boring jobs, even when used in cramped, tight workspaces.

Quick and Easy Setup

- Modular components make setup quick and easy.
- Fast and easy setup using high quality cast-iron set-up cones and spherical bearing mounts.
- Patented spherical bearing mounting system allows quick setup, with up to 5° of bearing misalignment.
- Typical set-up time for an experienced operator is 30 minutes or less.

Powerful

- Up to 650 ft-lbs (881 N·m) of torque at the bar – more than any other portable boring machine in its boring range.
- Specially-designed rotational drive unit provides 4:1 or optional 12:1 or worm gear reduction for increased torque at all speeds

Flexible, High Quality Design

- Through-bar design allows the rotational drive and feed unit to be mounted anywhere along the bar, even separately.

- Patented heavy-duty spherical bearing mounts ensure rigid attachment to the work piece, for more effective machining.

Versatile

- Highly customizable to meet a variety of needs.
- Available in electric, servo, hydraulic, or pneumatic motor configurations.
- Reversible electric motor.
- Fast, easy two-bolt change-out process to switch motors.
- Available in a variety of bar lengths, from 4 - 24 feet (1219.2 – 7315.2 mm).
- Bars are straightened, and have ½ inch or 12 mm square-broached tooling holes.
- Accessories allow the BB5000 to be used for blind boring, line boring, drilling, facing, and valve repair.
- An interface kit allows attachment and quick alignment of the Climax AutoBoreWelders for efficient bore welding.

Compact

- Extremely compact for ease of use in cramped, tight work spaces.
- Drive & Feed can be mounted between bearings for use in even more confined spaces.

SPECIFICATIONS

	US	Metric
Operating Ranges:		
Boring Bar Diameter		
Standard	2.25 inches	57.2 mm
Optional	1.75 inches	44.5 mm
Optional	1.25 inches	31.8 mm
Boring Diameter		
Standard	2.5 - 12 inches	63.5 - 304.8 mm
Optional	1.375 - 24 inches	34.9 - 609.6 mm
Boring Stroke	12, 24, or 36 inches	304.8, 609.6, or 914.4 mm
Power Options		
Electric: 8 to 160 free speed bar RPM	3.35 Hp	2.5 kW
Servo: up to 230 free speed bar RPM	4.7 Hp	3.5 kW
Hydraulic:		
5 Hp HPU: up to 148 free speed bar RPM	3.9 Hp	2.9 kW
10 Hp HPU: up to 250 free speed bar RPM	6.5 Hp	4.8 kW
Pneumatic: up to 120 bar free speed RPM	3.0 Hp	2.2 kW
Mounting Options	Single Arm, Double Arm, Universal, ID	
Rotational Drive Unit	4:1 gear ratio reduction Option 12:1 gear ratio reduction	
Set-Up Cones		
Standard	2.75 - 12 inches	70.0 – 304.8 mm
Optional	1.375 - 5 inches	34.9 – 127.0 mm
Feed	Mechanical	Mechanical
Feed Rate per revolution (Infinitely variable and reversible)	0 – 0.018 inches/rev.	0 – 0.46 mm/rev.
Measures		
Typical Machine Ship Weight (Typical machine with single arm mounts, set-up cones & hydraulic motor)	444 lbs	201 kg
Approximate Boring Bar Ship Weight (Includes metal shipping container)	1.48 lbs/inch	0.264 kg/cm
Shipping Dimensions (Shipped in 2 containers, 3 containers for hydraulic power unit option.)		
Machine W, D, H	52.5 x 27 x 16.5 inches	1334 x 686 x 419 mm
Bar 72 inch (1828.8 mm) W, D, H	74.5 x 6.5 x 7 inches	1892 x 165 x 178 mm
HPU [5 or 10 Hp] W, D, H	49.5 x 30.5 x 41 inches	1257 x 775 x 1041 mm

BB6100 LINE BORING MACHINE

12 | 2014 BB61

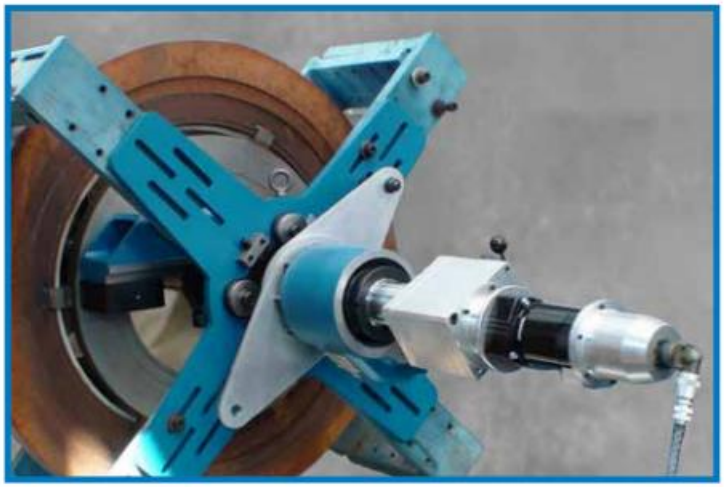
Packing big boring capability into a compact, modular machine, maximizing efficiency and minimizing downtime.

Powerful Yet Compact

- Take the power of a stationary machine to the job site to solve tough machining challenges in record time.
- Using the 11.3 in^3 (185.3 cm^3) Hydraulic motor, it produces 1435 ft•lb (1945.6 N•m) of torque at the bar, at 33 rpm.
- Compact, modular components allow fast, easy setup, maximizing efficiencies, and minimizing downtime.

Versatile and Flexible

- Huge machining range bores from 8.8 - 40.8 inches (223.5 - 1036.3 mm) in diameter, and faces from 7.5 - 42.1 inches (190.5 - 1069.3 mm) with various facing attachments.
- ID and End Mount Bearings feature spherical taper-lock roller bearings for easy setup and removal of the bar, and allow for up to 1.5 degrees of misalignment when setting up bearings.
- End mount bearings can be fine adjusted by +/- 0.625 inches (15.9 mm) to center the bar.
- Optional dual action boring/facing arms increase facing range, and allow for both boring and facing without switching equipment. Full-length square ways on boring/facing arms allow for quick positioning anywhere along the arm. Attaches to the net fit tool carrier by compression-clamping, to provide maximum tool stability.
- Net fit tool carrier can be clamped to bar for facing operations. For boring operations, carrier can be adjusted to remove clearance between carrier and the bar. This flexibility also ensures maximum rigidity for either operation.
- For even greater facing range and longer continuous stroke, the new boring/facing arms



are available. Setup is quick & easy for both boring and facing operations.

- Net fit tool carrier is designed with a split frame to simplify installation on the boring bar. It can be configured to use either the boring head set for boring, the mechanical facing head for facing, or the new boring/facing arm assembly for both boring and facing operations.
- With leading & trailing boring head configuration, 2 boring heads can be used simultaneously.
- Highly versatile tool holder block accepts industry standard tooling with a nominal ¾ inch (19.1 mm) square shank.
- Tool post on the boring/facing arm can be rotated to provide maximum flexibility in machining setup (including some cantilevered configurations).

High Quality Design

- Features a uniquely-designed modular tool carrier which provides a new level of strength and rigidity by channeling machining forces directly to the boring bar through strategically-located adjustable guide shoes.
- Durable chromed bars, straight to within 0.001 inch per foot (0.0254 per 304.8 mm) ensure accurate machining.
- Adjustable, removable half nut increases net fit tool carrier flexibility. Easy removal of tool carrier allows for machining of multiple bores.
- Backlash adjustment nut allows in-the-field adjustment to eliminate backlash in the tool carrier, and extend the life of the machine.

SPECIFICATIONS

	US	Metric
Boring and Facing Ranges:		
Boring diameter range, standard stack block assembly:	8.8 - 40.8 inches	223.5 - 1036.3 mm
Boring diameter range, boring/facing arm assembly:		
with 18 inch (457.2 mm) boring/facing arm	19.9 - 32.1 inches	505.5 - 815.3 mm
with 23 inch (584.2 mm) boring/facing arm	24.8 - 42.1 inches	629.9 - 1069.3 mm
Recommended facing diameter range, using mechanical facing head assy:	10.6 - 38.0 inches	269.2 - 965.2 mm
Facing diameter range, boring/facing arm assembly:		
with 18 inch (457.2 mm) boring/facing arm	17.5 - 32.1 inches	444.5 - 815.3 mm
with 23 inch (584.2 mm) boring/facing arm	17.5 - 42.1 inches	444.5 - 1069.3 mm
Facing diameter range, boring/facing arm assembly, tool post reversed: ("tool post reversed" refers to rotating the tool post so that the tool is on the bar side of the tool post.)		
with 18 inch (457.2 mm) boring/facing arm	7.5 - 20.1 inches	190.5 - 510.5 mm
with 23 inch (584.2 mm) boring/facing arm	7.5 - 30.1 inches	190.5 - 765.5 mm
Performance Data		
Rotational Drive Unit (RDU) gear ratio:	6:1 gear reduction	6:1 gear reduction
Hydraulic motor size affects torque and speed. Theoretical values calculated using a 10 Hp hydraulic power unit producing 2000 psi (13790 kPa) continuous, [normal operation is 1200 psi (8270 kPa)] and pumping 10 gpm (37.9 l/min).		
Hydraulic motor size range:	3.6 - 17.9 in^3	59.9 - 293.3 cm^3
Boring Bar Torque:	470 - 1820 ft•lb	637.2 - 2467.6 N•m
Max boring rpm:	107 - 21 rpm	107 - 21 rpm
For example, with 11.3 in^3 (185.3 cm^3) hydraulic motor (43457):		
Boring Bar Torque:	1435 ft•lb	1945.6 N•m
Max boring rpm:	33 rpm	33 rpm
Feed Rate of mechanical Axial Feed Unit (AFU):	0.003 - 0.020 inches/rev	0.076 - 0.508 mm/rev
Feed Rate of electric Axial Feed Unit (AFU):	0 - 0.3 inches/min	0 - 7.62 mm/min
Measures		
Shipping Weights (estimated): Machine includes Rotational Drive Unit (RDU), Axial Feed Unit (AFU), boring head set, tool carrier, tool kit, and hydraulic motor.		
for machine (wood crate)	640 lbs	290.3 kg
for machine (metal crate)	740 lbs	335.7 kg
for one 4 arm bearing assembly	160 lbs	72.6 kg
for one 3 arm bearing assembly	80 lbs	36.3 kg
for boring bar	2.5 lbs/inch	0.04 kg/mm
for 10 Hp Hydraulic Power Unit	500 lbs	226.8 kg
Shipping dimensions:		
Machine, in wood crate, W, D, H	18.5 x 34 x 24 inches	469.9 x 863.6 x 609.6 mm
Machine, in steel crate, W, D, H	43.3 x 29.5 x 22.5 inches	1099.8 x 749.3 x 571.5 mm
Bearing (each bearing shipped separately) W, D, H	32 x 32 x 11 inches	812.8 x 812.8 x 279.4 mm
12 foot (3657.6 mm) bar W, D, H	11 x 13 x 154 inches	279.4 x 330.2 x 3911.6 mm
10 Hp Hydraulic Power Unit W, D, H	27 x 33 x 48 inches	685.8 x 838.2 x 1219.2 mm

FF5000 FLANGE FACER

3 | 2015 FF5

Light, Portable, and Powerful - Designed to get the job done FAST!

The FF5000 is a versatile flange facing machine that allows you to face, bevel, and turn pipe, valve, and pump flanges with ease. The two-piece mounting system makes setup and alignment of this machine quick and easy. It allows one operator to easily set up the machine and begin machining in just a few minutes.

Quick and Easy Setup & Removal

- Separate mounting chuck.
- All centering and leveling is done on the chuck.
- Loosen one bolt and machine can be removed from the chuck without disturbing alignment or calibration.

Lightweight

- Body of machine weighs only 60 lbs (27.2 kg).
- Smallest mounting chuck weighs about 5 lbs (2.2 kg).

Low Profile

- Right angle motor mount.
- Machine extends only 7.6 inches (193.0 mm) above flange.

Safe and Quiet Operation

- Stationary feed rate selector.
- Machine is controlled without touching any moving parts.
- Exhaust air is routed through body of machine for increased muffling.

Simplified Operation

- Single selector switch for bidirectional radial feed or vertical downfeed.
- One wrench size for clamping jaws and body draw bolt.

Cuts Chamfers and Grooves

- Compound tool head and downfeed for cutting angles and grooves.

SPECIFICATIONS

		US	Metric
Machine Performance Ranges			
ID: Mounting range		11.8 - 57.5 inches	299.7 - 1460.5 mm
Facing diameter range		11.8 - 60 inches	299.7 - 1524.0 mm
Swing diameter @ minimum w/ feedbox on arm		39.4 inches	1000.8 mm
Radial tool slide travel (full length of turning arm)		21.2 inches max	538.5 mm max
Axial tool head travel		4 inches	101.6 mm
Depth required inside bore for ID chuck			
Single plane		3.5 ± 0.25 inches	88.9 ± 6.4 mm
Surface mount		0 inches	0 mm
Travel of leveling foot		± 0.25 inches	± 6.4 mm
Radial adjustment stroke of chuck foot		2.5 inches	63.5 mm
OD: Mounting range (with optional clamp kit)		38.1 - 63.8 inches	967.7 - 1620.5 mm
Facing diameter range		8.5 - 60 inches	215.9 - 1524.0 mm
Refer to ID for specifications not listed			
Rotational Drive System			
Drive type		Pneumatic or hydraulic drive with cone drive	
Worm gear reduction		10:1	10:1
Turning arm speed range:	Pneumatic	7 - 40 RPM	7 - 40 RPM
	Hydraulic	3.5 - 37 RPM (6.2 cu.in motor @ 10gpm)	3.5 - 37 RPM 101.6 cm³ motor at 23.5 L/min
Power input requirements	Pneumatic (2.0 Hp, 1.5kW)	90 psi @ 65ft^3/min	620kPa @ 1.84m^3/min
	Hydraulic	1200 psi @ 10 gpm	8273 kPa @ 37.9 L/min
Air Feed System			
Drive type		Air actuated feed box engaged by machine rotation and infinitely adjustable from pneumatic conditioning unit	
Feed power requirements		90 psi @ 1ft^3/min	620kPa @ 0.028m^3/min
Feed rate		0.02 - 0.035 inches/rev	0.08 - 0.89 mm/rev
Measures			
For machine dimensions, please refer to dimensional drawings			
ID machine height with fittings (± for leveling)		16 ± 0.25 inches	406.4 ± 6.4 mm
ID machine weight, max approximate		473 lbs	214.5 kg
OD Machine height with fittings (± for leveling)		27.5 ± 1.25 inches	698.5 ± 31.75 mm
OD machine weight, approximate		925 lbs	419.6 kg
ID crate dimensions (WxDxH)			
Wood, approx.		26 x 63.5 x 25.75 inches	660.4 x 1612.9 x 654.1 mm
Metal, approx.		60 x 24 x 28 inches	1524 x 609.6 x 711.2 mm
OD crate dimensions (WxDxH)			
Wood, approx.		47.25 x 42.25 x 19.75 inches	1200.2 x 1073.2 x 501.7 mm

Testing Data

Internal Testing Performance Results	Test 1 (Material Removal)	Test 2 (Surface Finish)
Depth of Cut	.05 in (1.25mm)	.05 in (1.25mm)
RPM	28rpm Hydraulic	28rpm Hydraulic
Feed	.035 in/rev (0.9mm)	.007 in/rev (0.18mm)
Diameter of Cut	38 in 965mm)	36 in 914mm)
Type of Tool	Carbide	Carbide
Finish	Phonograph	112
MRR	5.85 in^3/min (95.8cc)	1.11 in^3/min (18.2cc)

Flatness at 50 inch (1270 mm) diameter. 0.0018 inches (0.046 mm).

Tested on a dedicated fixture made of A-36 steel in a controlled environment with single point machine, after warm-up.

FF6300 FLANGE FACER

6 | 2015 FF63

Performance. Versatility. Safety.

The rigid and versatile FF6300 delivers high-torque performance to quickly re-face flanges and repair sealing and bearing surfaces efficiently and cost-effectively.

IMPROVED EFFICIENCY AND OPERATIONAL FLEXIBILITY

Extended machining range, from 12 - 60 inches (304 - 1524 mm) provides more flexibility - one machine for many applications.

Remote feed-control system helps operators safely adjust feed rate and RPM at the pneumatic conditioning unit while the machine is moving.

ID, OD, or surface-mount configurations are available for a variety of machining applications, with a quick and easy change over.

Chain-clamp assembly securely clamps OD-mount configurations to eliminate the need to weld for mounting.

Tool head and tool bit rotate 360°, which allows for machining and positioning at an angle. This provides flexibility to create a variety of cuts including chamfers, O-Ring grooves, lens rings and other angular surfaces.

Back-facing attachment option provides even more flexibility in machining operations for heat exchanger tube sheets and other applications.

Modular components and overall lighter weight make setup, transport and storage quick and easy.

Hydraulic or pneumatic drive options allow flexibility for a variety of working conditions.

RUGGED DESIGN FOR POWERFUL, PRECISE MACHINING PERFORMANCE

Heavy-duty bearings provide rigid performance and reliable results, even over bolt-hole patterns.

Chucking system with leveling feet allows for quick and easy setup.

Modular chuck can be mounted separate from the machine body, makes accurate setup quick & easy.

The worm gear drive system runs smoothly and provides low backlash even with interrupted cuts. High-torque power allows higher metal removal rates.

REDUCING OPERATOR RISK

Adjust feed rate from pneumatic conditioning unit keeps operators hands safe from moving parts and keeps the job running smoothing.

Multiple lifting points for lifting in all orientations simplify balancing and rigging challenges for easy machine positioning.

SPECIFICATIONS

	US	Metric
Facing Diameter:		
Min Facing Diameter	5.0 inches	127.0 mm
Max Facing Diameter	24.0 inches	609.6 mm
ID Mounting Diameter		
Min I.D. Mount	3.5 inches	88.9 mm
Max I.D. Mount (optional chuck)	18.0 inches	457.2 mm
Stroke:		
Radial Tool Feed Stroke	8.5 inches	215.9 mm
Vertical Tool Stroke	2.0 inches	50.8 mm
Counterbore Machining Dia. and Depth	5.0 - 24.0 inches dia. and depth 1.97 inch in one setup	127.0 - 609.6 mm dia and depth 50.0 mm in one setup
Feed:		
Power Radial & Vertical Feed	Automatic, adjustable and reversible	
Automatic Radial Tool Feed	0 - 0.03 inch/rev. in eight increments	0 - 0.76 mm/rev, in eight increments
Automatic Vertical Tool Feed	0 - 0.02 inch in eight increments	0 - 0.51 mm in eight increments
Swing Radius at 24 inches (609.6 mm)	Min 9.5 inches, Max 15.2 inches	Min 241.3 mm Max 386mm
Height Above Flange	7.6 inch	193 mm
Tool Head Adjustment	+/- 60° from vertical	
Torque at Cutter	150 ft-lbs	204 N•m
Motor Hp (pneumatic)	1.2 Hp	0.89 kW
Gear Reduction	28.2:1	28.2:1
Rotational Speed	0 - 40 rpm (29 rpm maximum power)	
Air Requirements	90 psi	620 kPa
	30 ft^3 per min. (max power)	0.85 m^3 per min (max power)
Approx. Operational Wt	60 lbs	27 kg
Approx. Shipping Wt	175 lbs	80 kg
Approx. Shipping Dimensions (1 container)	25 x 25 x 18 inches	635 x 635 x 457 mm

PM4200 MILLING MACHINE

Variable bed lengths and milling head options offer enhanced versatility.

Quality Machine Design with Power-Packed Performance

- Precision machined dovetail ways and adjustable gibs provide smooth accurate travel.
- All gears and drives are permanently lubricated and sealed to allow operation in any position.

Powerful

- Hydraulic, pneumatic, and electric motors are available to provide power for milling spindle.
- Feed options include manual, electric, and pneumatic.
- Optional HSK spindle.

Versatile

- Two different milling head options are available; the ¾-inch Weldon shank spindle, and the flexible HSK 40A spindle.
- 120V and 230V electric feed options are available in addition to manual feed for fine adjustment.
- The electric feed option provides infinitely variable rates from 0 to 20 IPM, with push-button rapid traverse.
- Forward, neutral and reverse modes are controlled by a simple shift lever.

Rigid and Durable

- Compact yet rigid design for hard to reach and limited clearance applications.

Flexible

- Cross slide allows mounting of milling spindle on either side of the bed.
- An extended ram may be used in conjunction with the more powerful and versatile HSK spindle.
- The optional HSK milling head swivel plate accessory allows 360° range of spindle angles
- Optional sub-plates are available for extra bed rigidity and installation versatility.

Quick and Easy Setup

- The PM4200 3-axis portable milling machine provides precise and versatile on the job milling capabilities. It is designed to be attached either to the work piece or to a support structure beside it.
- Beds are available in 20, 49 and 78 inch (508, 1244.6 and 1981.2 mm) travel.

Applications Include:

- The PM4200 is commonly used for milling large cumbersome parts.
- Many customers use the PM4200 machines when welding up and re-machining worn parts on production machinery like stamping presses.
- Long motor mount slots are easily machined, often without dismantling since the mill can be mounted right on the workpiece.
- Motor mounts and pump bases are easily machined, especially in tight locations.

SPECIFICATIONS

	US	Metric
Bed Length	29, 58 or 87 inches	736.6, 1473.2 or 2209.8 mm
Bed Travel (X Travel)	20, 49 or 78 inches	508.0, 1244.6 or 1981.2 mm
Cross Slide Travel (Y-Axis)	8 inches (Weldon) 12 inches (HSK)	203.2 mm 304.8 mm
Spindle Reach from edge of bed	8.85 inches (Weldon) 12 inches (HSK)	224.8 mm 304.8 mm
Tool Head Vertical Travel	3 inches (Weldon) 4 inches (HSK)	76.2 mm 101.6 mm
No Load Spindle Speed		
Weldon Electric	230-525 RPM	
Weldon Hydraulic	282-696 RPM	
Weldon Pneumatic	Up to 510 RPM	
HSK Electric	Up to 800 RPM	
HSK Hydraulic	369-1006 RPM	
HSK Pneumatic	Up to 1100 RPM	
Spindle Size	0.75 inch (Weldon) 40A (HSK)	19.1 mm
Milling Head Gearbox Ratio	2.15:1 (Weldon Spindle) 6.25:1 (HSK Spindle) Electric 1:1 (HSK Spindle) Hydraulic 1:1 (HSK Spindle) Pneumatic	
Spindle Power		
3/4" Weldon Shank		
120V or 230V Electric	1 HP	0.75 kW
Hydraulic Motor Assemblies	J Series with 24 inch (609.6 mm) hose and QD Min Motor RPM @1 gpm (3.8 L/min) Max Motor RPM @5.5 gpm (20.8 L/m)	
65263 0.79 in^3 (13 cm^3) J SERIES	116	696
65094 1.21 in^3 (19.8 cm^3) J SERIES	81	469
65095 1.93 in^3 (31.6 cm^3) J SERIES	46	283
Pneumatic *	1.55 HP	1.15 kW
HSK Spindle		
120V or 230V Electric	1.85 HP	1.38 kW
Hydraulic	J Series with 24 inch (609.6 mm) hose and QD Max Motor RPM @1 gpm (3.8 L/min) Min Motor RPM @5.5 gpm (20.8 L/m)	
65094 (1.21 in^3 (19.8 cm^3) J SERIES)	175	1009
65095 (1.93 in^3 (31.6 cm^3) J SERIES)	99	606
68455 Pneumatic Right Angle *	1.55 HP	1.15 kW
68584 Pneumatic Direct Drive *	1.35 HP	1.01 kW
* Air motor requires 32 FT^3/min (0.9m^3/min) at	90 PSI	550 kPa

Hydratight

The 8200 Boring Bar System is the largest of the Hydratight portable line boring machines. Its advanced technology, rigid design and operator friendly controls make it ideal for precision machining steam turbines, hydro turbines, boiler feed pumps, wicket gate rudder posts, large mining equipment and many other in-situ boring applications.

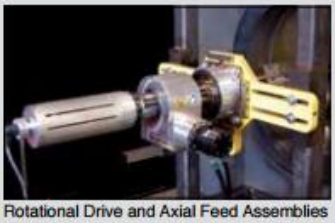
Three standard models are available to finish bores from 152mm–1625.6mm (6"–64") in diameter. Boring bars are available in lengths up to 7.3m (24'). A unique coupling arrangement is available for easy extension to meet special length requirements.

The 8200 Boring Bar System line boring range is available with manual or two-axis programmable position controls. These user friendly controls enable the boring bars to accurately machine straight, tapered and spherical bores as well as face in a single set-up. Programs are menu-driven, requiring only simple keypad entry of machining parameters without requiring any programming experience.

The boring bar components are engineered for durability and operator safety. Each component contributes its unique advantages to enhance the smooth operation of the complete boring system.

Features & Benefits

- Electric or hydraulic drives provide variable speed and constant cutting torque throughout the entire speed range
- Self-aligning bearings secure to the boring bar with split tapered sleeves for vibration free cutting
- Modular boring head provides flexibility and rapid setup
- Electronic axial feed improves quality and productivity by providing rapid tool positioning and on-the-fly feed rate adjustments

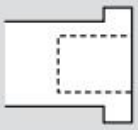


Rotational Drive and Axial Feed Assemblies

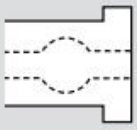
Dual Arm Bearing Support

Intermediate Bearing Support

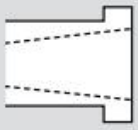
Two-Axis Position Control



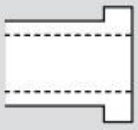
Blind Boring



Spherical Boring



Taper Boring



Straight Boring

Model	Unit	Bar Dia.	Max Bar Length	Electric Drive	Boring Range		RPM		Cutting Torque	Axial Feed Rate IPM	
					Min.	Max.	Min.	Max.		Feed	Rapid
8204	Std	4"	20'	7.5 HP	6"	40"	7	70	563 ft-lb	0–1.5"	20"
	Metric	101.6mm	6.1m	5.59 Kw	152.4mm	1016mm	7	70	763.3 Nm	0–38.1 mm	508mm
8206	Std	6"	24'	10 HP	9"	48"	10	58	900 ft-lb	0–1.5"	20"
	Metric	152.4mm	7.32m	7.46 Kw	228.6mm	1219.2mm	10	58	1220.2 Nm	0–38.1 mm	508mm
8208	Std	8"	24'	15 HP	12"	64"	3	30	2100 ft-lb	0–1.5"	12"
	Metric	203.2mm	7.32m	11.19 Kw	304.8mm	1625.6mm	3	30	2847.2 Nm	0–38.1 mm	304.8mm

hydratight

Flange Facer MM1500i, 12"-60"

An internally mounted machine for flange facing, seal groove machining, weld preparation and counter boring. Tool also features a patented power tool post.

Features:

- Quick set adjustable clamping jaws
- Swivel toolpost for grooves and bevels
- Continuous groove geared facing and boring feeds
- Includes a toolkit which contains tools and inserts, air filter lubricator and hose connection, all required mounting bases and extensions, and manual, inside a convenient storage/shipping box

Benefits:

- High torque drive with low noise level
- Latest linear technology for durability and repeatable accuracy
- Storage/shipping box
- CE certificate

Specification

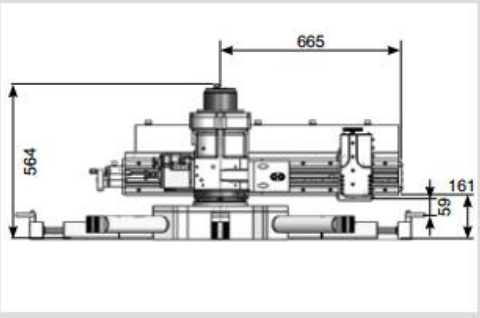
Min. Facing Diameter	12"	305 mm
Max. Facing Diameter	60"	1500 mm
Min. Clamping Diameter	11.4"	290 mm
Max. Clamping Diameter	55"	1400 mm
Min. Swing Diameter	40"	1000 mm
R.P.M – Air 1.2 hp or 2.2 hp Hydraulic	Max: 22	Min: 5
Tool Post Travel	4"	102 mm
Drive – Pneumatic @ 90 p.s.i (6 bar)	4.0 hp	3.0 kw
Drive – Hydraulic @ 1050 p.s.i (70 bar)	5.0 hp	3.73 kw
Air Supply Required	98 scfm	2.7 m^3/m
Hydraulic Supply Required	10 Gpm	50 Lpm

Feed Rates

Facing Feeds (3 off in / out)	0.008 – 0.012 – 0.032"	0.20 – 0.32 – 0.80 mm
Boring Feeds (3 off up / down)	0.001 – 0.003 – 0.006"	0.04 – 0.08 – 0.15 mm

Weight and Dimensions

Machine Weight	906 lbs	412 kgs	
Shipping Weight	1096 lbs	498 kgs	
Shipping Dimensions	L – 48" (123 cm)	W – 32" (82 cm)	H – 33" (83 cm)



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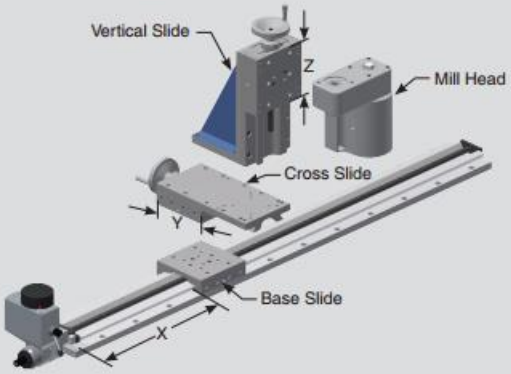
Portable Milling Machine



Hydratight's '3 Axis' Portable Milling Machine is our most versatile and accurate milling tool, capable of travelling and machining in all axis (XYZ).

This tool is designed for rugged onsite machining e.g. milling, drilling and boring applications on jobs previously thought to be impossible without extensive disassembly. The precision ground dovetails with adjustable gibs, to provide smooth, accurate travel in all axis.

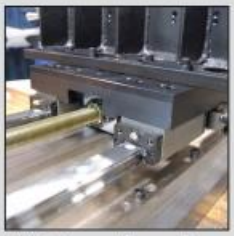
When used as a facing mill, this milling machine tool will quickly face off pitted or misaligned surfaces, restoring the original condition of the part being machined. Servo power feeds are available for all axis', allowing the application of smooth and consistent power feed throughout the speed range, forward and in reverse.

We offer three different tapered mill heads. The new 40 taper mill head works with our 152.4mm (6") and 203.2mm (8") mills. A 50 taper for larger milling is also available with our 203.2mm (8") mill head:

- The angular contact bearings allow for better accuracy in cutting.
- The speed of change allows greater utilisation of existing tooling, allowing more industry standardisation plus more versatility in applications.
- The 40 taper spindle also allows the machine to take more per cut.
- It also offers a new sealed oil gear head for leak proof seals.
- More tooling-friendly spindles give our mills more precision with a more rigid tool performance.

Max Dimensions

	X		Y		Z		Z Travel	
	m	In	mm	In	mm	In	mm	In
4T Mill	1.22	48	254	10	254	10	101.6	4
6T Mill	1.22	48	330.2	13	609.6	24	457.2	18
4T Mill	1.83	72	406.4	16	660.4	26	431.8	17
4T Mill	2.44	96	812.8	32	508	20	245	10



High tolerance linear rail construction

Multiple drive and spindle options

http://climaxportable.com/assets/CLIMAX-BB6100-Line-Boring-Machine.pdf

http://climaxportable.com/assets/BB5-BB5000-E1.pdf

http://climaxportable.com/assets/FF5000-Flange-Facer-E1.pdf

http://climaxportable.com/assets/FF63-FF6300.pdf

http://climaxportable.com/assets/PM4200-E5.pdf

http://www.hydratight.com/sites/default/files/downloads/media/htbr0150315ukboringbarbrochurelres_0.pdf

http://www.hydratight.com/sites/default/files/downloads/media/ht-td-mm1500i-us-08-12-flange-facing-mm1500i-data-sheet-copy.pdf

http://www.hydratight.com/sites/default/files/downloads/media/httl0590115ukportablemillingmachinedatasheethres_1.pdf

Appendix H: Vibration analysers

SKF Microlog

SKF Microlog Analyzer GX series

CMXA 75

Portable data collector / FFT analyzer

The SKF Microlog GX series are high performance, one to four channel, route-based portable data collector / FFT analyzers that provide unmatched versatility and functionality in a rugged, industrial design. Developed for use in a wide range of industries, the SKF Microlog GX series is approved for use in hazardous environments requiring ATEX, IECEx and Class I Division 2 certifications.

Key features

- Marvell 806 MHz PXA320 processor for exceptionally fast operation
- Bright 1/4 VGA color display that enhances visibility in all environments – dark or bright
- Rugged design
  - Two meter multiple drop
  - IP 65 rated
- Outstanding data storage capacity with 128 MB flash memory for internal storage and Secure Digital (SD) memory expansion slot
- Multi-language support – 15 language options
- Choose between instruments that have single channel input, or four channels plus simultaneous triaxial input
- Multi-plane balancing application
- Intuitive graphical user interface
- Long-life battery for up to eight hours of operation
- Wide range of accessories to expand functionality even further
- Field upgradeable from an entry level instrument to an advanced analyzer

State-of-the-art technology

With a robust, high-speed data processor, the SKF Microlog GX series captures full feature route and non-route dynamic (vibration) and static (process) measurements from many sources. Fixed mode autoranging automatically selects an input range based on the sensor type and sensitivity. Three channel simultaneous triaxial input with the separate tachometer input enables faster, more comprehensive data collection without adding to collection time. The SKF Microlog GX series also includes a triggering functionality that enables the unit to examine the trigger signal first, and then automatically set the trigger level. For even faster data collection, users can configure up to 12 measurements for automatic, one button data collection at a measurement location.

Modular approach offers seamless expansion

The modular design of the SKF Microlog GX series offers customers the option to upgrade and expand functionality without having to buy another instrument. Accessories are inter-changeable between models. The SKF Microlog GX is shipped with the full SKF Microlog suite of modules installed. To add additional functionality, units can be upgraded to more advanced models, simply purchase the module and enter the supplied license key.

For companies who are interested in an entry-level route-based data collector, the SKF Microlog GX-R model offers ease of use and implementation with multi-route, single channel data collection. This model features a measurement range of 80 kHz F_{max} and up to 25 600 FFT lines of resolution.

The SKF Microlog GX-M includes multiple routes, and non-route data collection, four channel FFT analysis, three channel simultaneous triax and the Balancing module.

Additional features are added to create the SKF Microlog GX-F model, which includes all modules. The SKF Microlog GX-M can also be upgraded to any of the other modules including Run up Coast down module that is used to record and analyze data from machines where noise or vibration levels are changing with speed or time, and the Frequency Response Function (FRF) module, which uses a modal hammer to establish the properties of mechanical structures.

Specifications

Performance characteristics

Acceleration, velocity, and displacement from hand-held or installed vibration sensors or monitoring systems:	• AC / DC sensors • Pressure sensors • Temperature sensors • Keyboard entry: Measurements read from indicators or installed instruments entered in engineering units • Universal tachometer • Visual inspections: Added to measurement as coded notes
Enveloper (demodulator):	With four selectable input filters for enhanced bearing and gear mesh fault detection
gE filter selections:	• 5 Hz to 100 Hz • 50 Hz to 1 kHz • 500 Hz to 10 kHz • 5 kHz to 40 kHz
Input parameters:	• Tachometer: TTL / analogue programmable to ±25 V • RPM range 1 to 99 999 • Tachometer power supply output +5 V at 100 mA
Input over-voltage protection:	• AC ±50 V peak • DC ±50 V sustained
Dynamic range:	>90 dB (24 bit ADC sigma-delta)
Input connectors:	• CH1: Six pin Fischer, CH1, CH2, CH3, CH4 • CH2: Six pin Fischer, CH2, CH3, CH4 • USB host / CHR / headphone: USB keyboard, CHR, headphones • USB Device / power / trigger: Seven pin Fischer trigger in, trigger tachometer power supply, USB COMMS, charger
Input signal range:	±25 V maximum
Signal:	RMS/Peak/Peak-Peak/True Peak/True Peak-Peak
Transducer check:	Bias Voltage Integrity (O/C and S/C detection)
Auto range:	Yes
Frequency range:	DC to 80 kHz
Bearing condition:	gE
FFT resolution:	100 to 25 600 lines
Time block length:	256 to 65 536 samples
Alarms:	Overall, Spectrum and Exponential (Peak and RMS level)

Measurement

Range:	• Route measurements: DC to 80 kHz (GX-R: 80 kHz) • Non-route measurements: DC to 80 kHz (not available in GX-R)
Averaging:	1 to 255 time averages, 1 to 4 096 spectral averages
Averaging type:	RMS, Time, Peak Hold, Exponential
Cursor:	Fixed and cursor lock. Single, harmonic and peak pick.
Trigger modes:	Free run or external trigger (trigger slope and amplitude)

Measurement

Resolution:	Programmable 100, 200, 400, 800, 1 600, 3 200, 6 400, 12 800 and 25 600 lines
Measurement windows:	Hanning, flat top, hamming and rectangular
Measurement parameters:	Acceleration, velocity, displacement, gE, temperature, phase, voltage, user specified
Measurement types:	Overall, spectrum, time waveform, cross phase, orbits, shaft centerline
Multi-point automation:	Up to 12 measurements can be listed for one button push automated data collection at each measurement location
Accuracy:	±2.5% of full scale range
Data display:	• Single and dual channel spectrum, single and dual channel time, phase table, process, orbit, cross channel phase (GX-R: single-channel spectrum, time, phase table, and process) • Simultaneous spectrum, time waveform, peak hold averaging • Up to 12 bands (fixed or order base) downloadable from host software

Power

Battery:	• Li-ion smart battery pack • Eight hours continuous operation minimum

Physical data

Dedicated keys:	Up, down, right, and left two enter keys for right and left hand operation, four function keys
Hot keys:	Peak find, harmonic, expand
LCD screen:	1/4 VGA color TFT screen, 320 × 240 pixels resolution
Case:	High impact ABS with IP 65 dust and splash rating
Weight:	715 g *(1.6 lb.)*
Size (height × width):	• Narrowest point: 186 × 93 mm *(7.4 × 3.7 in.)* • Widest point: 186 × 134 mm *(7.4 × 5.4 in.)*
Drop test:	2 m *(6.6 ft.)*, to MIL STD 810F specifications

Environmental

Certifications:	• **Special conditions per certifications** • ATEX: II 3 G Ex ic IIC T4 Gc (Ta = –10 °C to +50 °C) • IECEx: Ex ic IIC T4 Gc (Ta = –10 °C to +50 °C) • CE rated • CSA, Class I, Division 2, Groups A, B, C, D, temperature code T4@Ta = 50 °C
IP Rating:	IP 65
Temperature ratings:	• Operating temperature: –10 to +50 °C *(14 to +122 °F)* • Storage temperature: –20 to +60 °C *(–4 to +140 °F)*
Humidity:	95% non-condensing
Vibration:	MIL STD 810 transportation

Prüftechnik

VIBXPERT® II at a glance

Don't miss out on these great features

Versatile

- Route-based data collection
- Vibration diagnosis
- One- or two-plane field balancing
- Acceptance measurement with machine templates
- Troubleshooting
- Multimeter
- Data logging
- Visual inspection
- Print reports on USB stick
- EX version (optional)

Analysis in detail

- Characteristic overall values & process parameters
- Time waveform
- Amplitude/envelope spectrum
- Cepstrum
- Phase, cross-channel phase
- Orbit
- Static shaft position
- Runout analysis (shaft vibration)
- Bump test
- Coast-down/run-up test
- Order analysis
- Modal analysis
- Operating Deflection Shape Analysis (ODS)
- Transient capture
- Long-term recording
- Characteristic frequency markers
- Signal post-processing
- ISO standards for evaluation

Valuable additional features

- Handles multiple measurement points automatically (Multiplexer switch box)
- Printing of measurement reports
- Rugged hard case
- Extensive accessories
- Optional measuring functions enabled by a password

http://www.skf.com/binary/21-144316/CM-P1-14285-3-EN-SKF-Microlog-Product-Catalog.pdf

http://www.pruftechnik.com/products/condition-monitoring-systems/portable-systems-for-condition-monitoring/vibxpert-ii.html