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New Approaches to Through-life Asset Management in the Maritime Industry

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Abstract

European shipbuilders are facing a strong, worldwide competition. Consequently they have to reinvent their market approach and expand their business. In the past, European shipbuilders were focused on cost reduction in the production process to offer new build vessels at a competitive price for decades. Changing the focus from the selling price optimisation to the life cycle cost optimisation could lead to competitive advantages and enable new business opportunities. This new approach of through-life asset management is investigated in the EU-funded project ThroughLife. The minimisation of a vessel´s life cycle costs could be realised by applying new and innovative technologies. However, new technologies are characterised by higher investment costs and uncertainty regarding functionality, reliability and reparability. As a result, the situation can be characterised as a dilemma for the new building yard the ship owner and the repair yard. Therefore the ThroughLife project focuses besides the development of new technologies on the identification, elaboration and application of new business model concepts to overcome this dilemma. One business model concept is the offer of a comprehensive service package against a fixed, time based fee, which would lead to an overall cost reduction due to economies of scale, lower administration costs and a risk reduction for the customer, which would support the market penetration of new technologies. Combining this business model approach with the technology of monitoring sensors increases the potential of this approach. The service provider could use the gathered information to schedule maintenance according to the actual condition of the vessel and identify potential mistreatment by the client. The customer would benefit from reduced, calculable costs and a lower risk level when applying new technologies. Further research contains lifecycle cost model calculations as well as real-life tests of the monitoring hardware in order to proof the concept.

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Keywords: Through.-life asset management; repair; maintenance, sensors; maritime industry; business models;

1. Introduction and Problem Description

European shipbuilders are facing a strong, worldwide competition. In order to stay competitive they have to reinvent their market approach and expand their business. One way of reinventing their business could be the change of their perspective. European shipbuilders focused on cost reduction in the production process and as a result on the minimisation of the selling price for decades. Offering new buildings at a competitive price is becoming more and more difficult. Changing the focus from the selling price optimisation to the life cycle cost optimisation could lead to competitive advantages and enable new business opportunities. This new approach of through-life asset management is investigated in the EU-funded project ThroughLife.

The minimisation of a vessel´s life cycle costs could be realised by applying new and innovative technologies. However, new technologies are characterised by higher investment costs and uncertainty regarding functionality, reliability and reparability. As a result, the situation can be

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characterised as a dilemma for the new building yard the ship owner and the repair yard.

Besides the development of new technologies for the lifecycle optimisation of a vessel research is focused on the identification, elaboration and application of new business model concepts to overcome this dilemma and to expand the business opportunities of stakeholders.

One promising idea is to transfer the concept of comprehensive after sales services, like a "worry free" service package in the aeronautic industry to the maritime industry. Offering a comprehensive service package against a fixed, time based fee would lead to an overall cost reduction due to economies of scale and less administration costs and would also decrease the risk for the customer and thereby support the market penetration of new technologies.

Combining this business model approach with the use of sensors platform to monitor key parameters of interest would increase the potential of this approach. Indeed data gathered from sensors installed on vessels could be used to schedule maintenance according to the actual condition (e.g. condition based maintenance - CBM) of the vessel and help to identify potential mistreatment by the client. This definitely allows for a better management of the vessel across its lifetime [1]. Moreover, monitoring information can provide valuable operational feedback to the manufacturer of the new technologies. In fact the availability of historical data from a monitoring system can enhance the level of confidence and reduce the operational risk when introducing new materials, new designs or new repair concepts into the structure, by making use of data that provides performance on structures and components under real operative conditions.

Generally, the benefits of a monitoring system come out from the so-called 3Ms approach, whose aim is to make use of Monitoring data for optimizing Maintenance towards a better Management [2]. In this concept, new building yards, repair yards or dedicated companies could act as through-life service providers. The customer, in this case the ship owner or operator would benefit from reduced, calculable costs and a lower risk level by applying new technologies, while increasing knowledge, safety and confidence level.

This means that, at an upper level, monitoring information can be used to reduce lifecycle costs of ship operations. Indeed monitoring can minimize the requirements for maintenance given a better materials and structural system knowledge; it can minimize the requirements for unscheduled maintenance thanks diagnostic and prognosis of the monitored system/component; it can predict unscheduled events, thus optimizing the maintenance cycle time and improving up-grades and refurbishments.

2. Related Work

The German standard DIN 31051 defines maintenance as the combination of all technical, administrative and managerial measures carried out throughout the lifecycle of a unit towards preserving or restoring its functionality. Different maintenance policies can be adopted to fulfil this goal (see Figure 1). Literature differentiates between corrective and preventive strategies. [5] Corrective maintenance means repairing the unit after it has broken down. Preventive maintenance involves preventive actions such as inspection, repair, or replacement of the equipment.[5] Predetermined maintenance is carried out according to e.g. an established time schedule or number of units. It does not take into account the investigation of the units' condition. In condition-based maintenance, actions are performed "based on the information collected through condition monitoring techniques." [6]

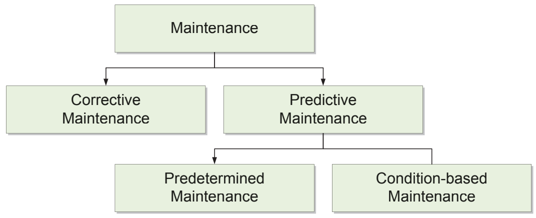

Fig. 1: Differentiation of Maintenance Policies following [5]

Condition-based maintenance (CBM) has a number of advantages compared to corrective and predetermined policies. [5] In comparison to corrective maintenance, unit downtimes, labour and maintenance costs connected to run-to-failure can be avoided. Whilst this is also true for predetermined maintenance, only condition-based maintenance can help avoid catastrophic failures. Moreover CBM can be used to trigger inspections autonomously, thus reducing maintenance costs and allowing for scheduling inspections based on the analysis of monitoring data available. This will reduce the uncertainty associated with performance of a given system between inspection intervals. Finally once CBM is based on monitoring data, this allows moving from inspection scheduling conducted based on off-time suggestions to inspection scheduling conducted based on performance assessment.

OSA-CBM (Open System Architecture for Condition-Based Maintenance), a reference implementation of ISO-13374, is a well-established concept for the implementation of condition-based maintenance (see Fig. 2). OSA-CBM defines the six system modules required for the implementation of a condition-based maintenance system. These are functional capabilities consisting of sensing and data acquisition, data manipulation, condition monitoring, health assessment and diagnostics, prognostics and decision reasoning. For interaction with the operators, a Human System Interface is also required. [7]

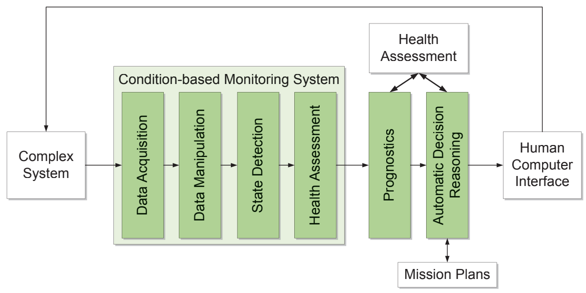

Fig. 2: Simplified Model of OSA-CBM following [7]

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Holistic service contracts are well known in other industries, like automotive or aeronautics, and include a number of customisable services in packages offered for a fixed, time based fee. An example for holistic service contracts in the aeronautics industry is the total support services" (TSS) offered by Lufthansa Technik. [8]

Table 1: Services offered witin the TSS by Lufthansa Technik

TSS includes:
• Customized maintenance planning • Troubleshooting • Engineering services • Repair and overhaul of aircraft • Engines and components • Spare parts pooling • Spare engine leasing • Painting • Cabin modifications • Airline support team

The customer benefits from calculable costs and a worry free use of the aircraft with one point of contact, which reduces administrative costs. Moreover, proper maintenance, repair and spare parts are assured.

In the maritime industry service contract are only offered for specific pieces of equipment. Based on the addressed advantages for the customer the transfer of holistic service contracts to the maritime industry is investigated within the ThroughLife project.

3. Methodology

In the development process of new business model approaches a close collaboration with experts of the maritime industry was essential. Therefore three different ways of collaboration were established:

1. Interviews
2. Online questionnaire
3. Public workshops

The interviews and the online questionnaire on the official project website were carried out to examine current business models and business relationships in order to identify obstacles and optimisation potential. Ideas for new business models were generated and discussed in public workshops with several experts of the maritime industry. Afterwards the most promising ideas were elaborated to business model concepts including model calculations and evaluated regarding their potential impact on cost reduction and reliability.

In the next step, a technical concept was developed on the basis of the business case. First, technical requirements towards a maritime condition-based maintenance system for the corrosion of ballast tanks supporting the business case were identified. Sensors suitable for the monitoring and prediction of corrosion processes were identified and selected. In the next step, a technical concept for the corrosion monitoring system was developed on the basis of OSA-CBM. It was first evaluated in a prototypical implementation under laboratory conditions. Currently, a pilot implementation is being installed in the ballast tanks of Mediterranean ferries for a twelve-month period of test and evaluation.

4. A Novel Concept for Through-Life Asset Management in the Maritime Industry

4.1. Service Concept

The service contract business model concept is based on the offer of a holistic service package, including maintenance, repair and spare parts in return of a fixed, time based fee. The benefits for the customer are summarised in the value proposition:

- Calculable costs for the purchased services for the contract duration including unlikely accidents. In this regard the service contract has an insurance character for the customer.
- One point of contact lowers the coordination effort and thereby lowers the administration costs use, since the coordination leads to a delay of the repair or maintenance process and causes besides the extended out-of-service days additional administrative costs. Furthermore, the service quality can´t be assured in all cases, since the service provider changes from case to case.
- The customer can concentrate on his core business.

The concept aims at the mass market for ships, which would generate benefits for the service provider and the customer: On the one hand, the provider of these services could offer a big amount of service contracts in order to diversify his risk and realise economies of scale effects, which could end up in a lower service fee for the customer. Moreover, these types of services could provide benefits for every type of vessel.

The marketing activities for the service contracts could be based on two different channels. Channel one is the offer right from the start of the lifecycle, which means that these services are offered in the negotiation phase of the new ship between the customer and the new building yard. The new building yard would take a key role in order to distribute the service contracts for new ships by distributing its own service contract or receiving a distribution provision from the service provider.

Channel two could be the offer for ships in service. In this regard, the repair yard could take over the role of the service contract agent. However, this market segment is riskier than the new build segment for these kinds of services because the failure probability is higher according to the age the vessel and the service provider has limited information about the ship. The service provider could compensate the higher risk by adjusting the service fee.

In order to generate the value proposition for the customer, the service provider has to carry out key activities, which are in terms of service contract concept the management of the offered services. This part is a very complex issue: The service provider has to collect all relevant data of the vessel.

The management of the offered services also includes the management of the resources, meaning the management of the relevant information and the business partners. In order to fulfil the service contract the service provider need facilities, equipment, suppliers of proper spare parts and the expertise of shipbuilding experts in order to provide high quality services.

In addition, the service provider has to rely on key partners to perform the service contract, like suppliers. The suppliers are key partners for several reasons: The service provider need proper spare parts to fulfil the service contract. Even more, for a successful business he needs the knowledge to maintain and repair the supplier parts as well as competitive acquisition costs of these parts.

The service contract business model is characterised by a continuous revenue stream for the service provider. The amount of the service fee is a critical success criterion for this business model concept: The fee needs to be high enough to cover the cost streams for the scheduled services and unscheduled services. Therefore the right failure and accident probabilities and the diversification of the financial risk by are the key factors for a successful business. On the other hand, the fee has to be low enough to be attractive for potential customers.

The profitability for the service provider depends on the reliability and customer´s treatment of the vessel. In this regard, the use of state of the art monitoring technology could help to reduce the risk of careless vessel treatment and moreover support the optimisation of maintenance schedule to increase the profitability. Therefore the combination of the described new business approach for the maritime industry in combination with a holistic monitoring approach is examined in the ThroughLife project.

Key partners:	Key activities:	Value proposition:	Customer relationship:	Customer segment:
❑ Shipbuilding experts ❑ Supplier ❑ Ship owner /operator for detailed information	❑ Managing the offered services	❑ Calculable costs for the contract duration ❑ One point of contact ❑ Lower administration costs ❑ Concentrate on the core business	❑ Long-term contract	❑ For every vessel segment
	Key resources:		**Marketing Channels:**	
	❑ Partners to fulfil the service contract ❑ Key information about the vessel		❑ Distributed by the new building yard in addition to the new vessel ❑ Distributed by the repair yard	
Cost structure:			**Revenue Streams:**	
❑ calculable costs for scheduled services ❑ Uncertain costs (in cases of repair)			❑ Regular revenues: time based fee	

Fig. 3: The business model concept in the business model canvas [9]

By means of such approach the monitoring system in ThroughLife is designed so that it consists of a range of sensors that are able to detect different measurements to capture different phenomena, ranging from ambient and environmental data to structural data. In such a way one can have initial notification of first impairments by means of corrosion sensors, then follows their propagation by means of structural sensors and finally make use of ambient sensors that aid in capturing the conditions that may have caused or are feeding the corrosion propagation.

4.2. Technical Implementation

The technical implementation of the condition-based maintenance system to support the service concept is designed according to the OSA-CBM architecture described above (see Fig. 2). The following sections outline the practical implementation of each of the OSA-CBM system modules.

4.2.1. Data Acquisition

The data acquisition module was implemented consisting of two distinct components. The first component comprises the actual sensor network. The second comprises the data collection unit. For the former, suitable sensors were selected for monitoring structural as well as ambient conditions to detect impairments first and to follow cracks propagations then that are caused by corrosion in the ballast tank.

The most important ambient factors which influence the rate of corrosion are diffusion, temperature, conductivity, type of ions, pH and electrochemical potential. The selected sensors comprise of pH, humidity, salinity, temperature and pressure sensors. These sensors are applied to relevant hotspots inside the ballast water tank.

These sensors are attached to the latter component, the data collection unit. In the current prototypical implementation, the data collection unit for ambient condition monitoring is realised using a low-cost, Linux-based single-board computer (BeagleBone).

The data collection unit is capable of transmitting logged ambient sensor data wired or wirelessly to the ship-board server. The unit comprises of a MySQL database and a Web Service interface, exposing a number of service with which data can be accessed from the other components in the condition-based maintenance system.

Fig. 4: Selected sensors for monitoring

4.2.2. Data Manipulation

Some data manipulation (pre-processing) is already carried out on the data collection unit. This includes filtering and pre-processing the raw sensor data to avoid false measurements and aggregation to reduce the data volume.

Filtered and aggregated data is then transferred from the data collection unit to a ship-board server where the main condition monitoring software provides state detection, health assessment and prognosis and automatic decision reasoning functionality.

4.2.3. State Detection

The sensors selected and consequently the data generated by them are by themselves not capable of detecting corrosion, but are intended to monitor the ambient conditions in the ballast tank which can influence corrosion propagation. That means that “state detection” in the presented approach refers to an assessment of the ambient condition with regards to the degree of its potential influence on corrosion propagation.
Since the presented technical solution can only provide data about the ambient conditions with relation to corrosion propagation, it is best used in combination with additional components capable of corrosion detection.

4.2.4. Health Assessment and Prognosis

Health assessment and prognosis is carried out on the ship-board server. A corrosion propagation model is used by the condition-based maintenance system to calculate predictions about the development of corrosion in the ballast tank. This model takes into account a number of different dimensions of data, including the type(s) of steel used in the ballast tank, the type(s) of coating used, the geometry of the tank in combination with sensor hotspots, and already detected instances of corrosion. This calculation depends on different environmental parameters: salinity, pH, temperature, humidity, pressure.

4.2.5. Automatic Decision Reasoning

On the basis of the corrosion propagation prognosis, the automatic decision reasoning component, which is realized as an expert system, can make recommendations regarding maintenance of the detected corrosion.

4.3. Exemplary business Case

The ThroughLife project examines the combination of the new business approach of holistic service contracts for the maritime industry and the monitoring technology is examined in the business case of a ballast water tank, where corrosion will be detected by the monitoring devices and the business model concept would assure a proper maintenance management. First results of this business case investigation are expected in 2014.

5. Model Calculation

The approach of holistic service concepts for the maritime industry is underlined with a model of life cycle costs calculations for the customer and the service provider. These model calculations were carried out with BAL.LCPA, a software tool for life cycle performance assessment. The model calculation is based on a 30 year life cycle of a passenger vessel. It is assumed, that every considered cash flow increases with 2% per annum. The investment costs are considered as well as the specialised operation profile. Moreover, the vessel gets refurbished every 10 years.

In order to compare the new business approach with the traditional business model, model calculations for both business models have been carried out. Revenues and operational costs are considered. For a first assessment of the business model concept the annual maintenance costs are the most interesting part, which amount to 250,000 € per year. In addition, one major accident is calculated with costs of 700,000 € for repair, a loss of revenue of 1,181,360, migration costs of 60,000 € and compensation costs of 105,000 €.

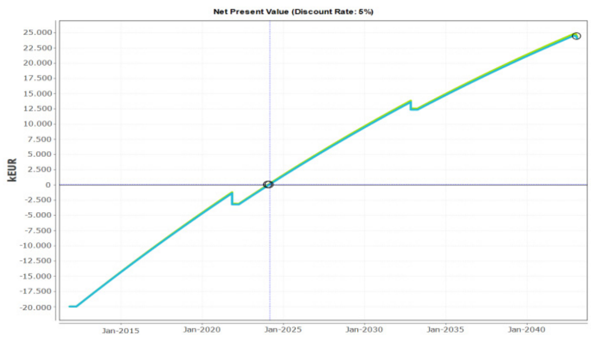

Fig. 5: Net present value comparison service contracts (customer view)

In the model calculation for the service package business model, repair and maintenance costs are not considered, since these costs are part of the holistic service package. Therefore it is assumed that the customer pays a yearly fee of 250,000 €, and reduces personnel costs of 20,000 € thanks to his lowered administrative efforts. Figure 5 presents the net present-value of the comparative model calculations from the customer´s point of view.

The service contract business model leads to higher net-present value of 290,000 € for the customer based on the overall reduced cost structure for maintenance and repair. Even without the assumed accident, the net–present value would be higher for the service contract business model.

The service provider would gain also financial benefit, even if one major accident occurs. The model calculation is based on the same assumptions. Thus, the revenue for the service provider is about 250.000 € per year and he defrays the maintenance, which has a selling price of 250.000 € and the repair costs.

The original price for the maintenance activities includes a profit margin, which is assumed to be 10% of the selling price. Moreover, it is expected to save additional 5% of the original maintenance and repair costs due to the realisation of economics of scale. On the other hand, offering a holistic service package means to have additional effort for coordination, which is assumed to be 10,000 € per year and contracted vessel. As a result, the service provider defrays costs of 222,500 € per year for offering the service contract for maintenance and repair. These costs and the gained revenues of 250,000 € are considered in the lifecycle cost calculation for the service provider. The same methodology is applied in cases of major accidents, which leads to costs of 598,500 € for the service provider. According to interviews with repair yards, a major accident happens every 15 years on average. Therefore the model calculations are carried out for the following three scenarios, which are presented in Figure 6:

1. No major accident happens
2. One major accident happens
3. Two major accidents

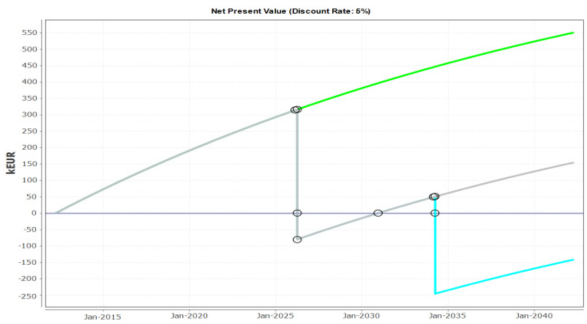

Fig. 6: Net present values service contracts (service provider view)

The results show, that even if the contracted vessel has one major accident in his lifecycle, the service provider would realise a net present value of 153.756 € over the lifecycle. If there is no accident in the lifecycle, the service provider could gain a net present value of 550.115€ out of one contract. If a second major accident happens, the contract won´t be beneficial for the service provider. In this case the net-present value in the model calculations would amount to minus 142,362 € and other service contracts could compensate this loss.

6. Outlook and Conclusions

It is evident that the service contract business model concept could provide benefits for the customer and the service provider and create a win-win situation. The model calculations underline the potential financial benefits for both stakeholders. In addition, the holistic service package also establishes the opportunity of applying new technologies with limit risk for the customer.

Using this technological concept, corrosion parameters can be collected and pre-processed in real time. Due to its generic development approach, the implemented system can be introduced into different environments. Future works are going to evaluate which weight factors asses additional influences on corrosion (e. g. microbiological aspects), the distribution of the sensor network in complex areas and long term robustness of the system.

The combination of the holistic service package approach with the opportunities of the monitoring devices would reduce the risk of careless vessel treatment and increase the cost efficiency due to optimised, condition based maintenance and repair and will be investigated in an on board test within the ThroughLife project.

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