

Influence of Ship's Hull and Engines Monitoring on Maritime Safety Improvement

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Abstract- Today it is impossible to separate ship efficiency and ship safety. To join these aspects CBM (Condition Based Maintenance) was created. Different monitoring systems using different control principles such as ultrasonic, termografic, acoustic emission (AE), etc. are part of CBM, but there still is a need for simple and convenient monitoring system. Cracks in ship's hull and large size engine parts, such as a crankshaft, are quite a common occurrence. The sources of these cracks are different loads influencing the vessel. In order to prevent drastic consequences, detection of these cracks in the very early formation stage is extremely important. A lot of companies produce soft- and hardware to monitor hull and machinery condition.

Keywords- hull & machinery monitoring, Condition Based Maintenance, acoustic emission.

I. INTRODUCTION

It is well known that in the last decades the size of the ocean going vessels has significantly increased. The term "large container carrier", depending on the decade, was used to refer to different vessels. For instance, it was a 250m long vessel with 4,000TEU carrying capacity about 20 years ago and a 18,000TEU/400m vessel today.

Cracks in ship's hulls are not a new phenomenon and most known are the cracks in the "Liberty" type vessels of the Second World War period. The seriousness of the problem was recognized and "Ship Structure Committee" was established in 1943, which was following the issues in this matter [2]. Today we can find cracks on different vessel types, ranging from the merchant fleet (e.g. VLOC Vale Beijing, 400,000dwt, built in 2011[5]) to the navy, e.g. USS Freedom, built by Lockheed Martin in 2011[9]).



Fig.1. VLOC Vale Beijing

The 361 meter long, 404,389 dwt dry bulk carrier Vale Beijing suffered water ingress while loading iron ore at Ponta da Madeira, Brazil. The VLOC (Very Large Ore Carrier) suffered multiple cracks in its ballast tanks. The cracks allowed water to flood into No. 7 hold. The Vale Beijing was scheduled to load 384,000 tons of iron ore but loading stopped when 200,000 tons had been loaded. The vessel was to be pulled out of service for repairs. The Vale Beijing started service on September 27, 2011 as the largest ore carrier afloat. One report states that the cause of the hull cracks may be the result of poor quality in the construction of the vessel. Reports state if the vessel had sunk; it could have delayed further shipments of iron ore from the port [6].

Another example is 4,000TEU middle size containership[5], (main engine Sultzer 8RTA84Cu, 32400 kW at 102rpm) loaded up to about a half of her capacity with full containers, which suffered a sudden and unexpected crack in the crankshaft, resulting in heavy damage to the main bearing, and the breakdown of the engine. As in many similar cases, the problem was identified when the damage had already happened. Modern monitoring systems, including AE method, would have given an earlier warning, probably allowing to stop the engine and to prevent the breakdown.

The vessel herself was put out of service for a period for about half a year. The repairs and the new crankshaft cost over 3.5 million Euros. Taking into account the extra logistical costs for the transshipment and on-carriage operations, the vessel being out of service for an extensive period of time, etc. the overall costs involved can easily be estimated to reach an astonishing amount of 4.5 million Euros. [5] Fig.2 and 3 show the mentioned damage and the transportation of new crankshaft part to the engine room.

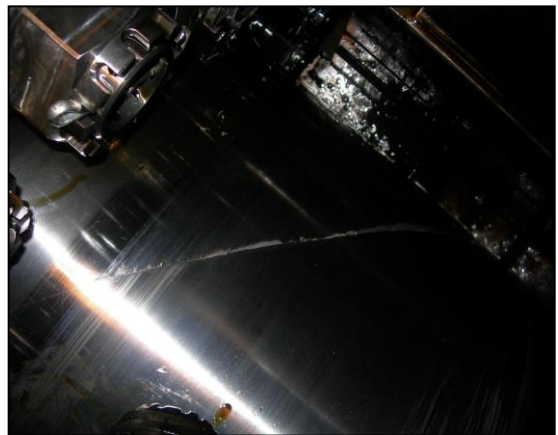


Fig.2. Crack in the main bearing journal;



Fig.3. Sultzer 8RTA84Cu crankshaft

Due to fierce competition and shipping market conditions, the owners decrease the costs of construction of their vessels as much as possible. The ship's hull and structure strength and resistance limits are calculated and built just to the minimal required amount. However, unfortunately, the forces, stresses and loads the vessel is exposed to, both internal and external, quite often exceed or are close to these resistance limits and that leads to cracks, accidents and all the corresponding unpleasant consequences. [1]

II. LOADS AND FORCES ON VESSEL

The main loads are:

Wave generated; cargo generated; during loading and discharge, as well as during carriage; generated by contact with floating objects, such as other vessels; generated by contact with fixed objects, such as piers, the seabed etc;

In general, we can group the stresses the ship's hull is exposed to into the following five categories:

Longitudinal stresses;

Torsional stresses;

Transverse stresses;

Local, mostly observed in the ship's bow;

Collapsing stresses, caused by either:

Cargo weight on ship's bottom when afloat, in which case the force tends to draw ship's sides together;

The vessel being in dry dock, in which case the force has an opposite effect [7].

It also has to be pointed out that the influence of the stress on the ship's structures is also dependant on the ship's type and her overall construction specifics. For example, bulk cargo carriers are ocean going vessels usually between 50,000 to 300,000 dwt, with large hatchways and machinery space located in the aft. Such design causes the vessel to suffer significant bending moments both during the cargo operation in port and while sailing in the open sea.

The IACS (International Association of Classification Societies) has issued a number of documents [8] to protect bulk carriers from overloading, but calculations show that a 10% overload of a hold could increase the bending moment up to

40%, and in modern port facilities a 10% overload can be reached quite swiftly in 5-7 minutes.

Vibration is another factor. There have been many cases where vibration has caused cracks to the hull and structure and also damage to machinery. Mostly vibration is generated by 2-stroke engines, auxiliary engines and propeller.

It is also vital to take into account high corrosion risk for bulk carriers, as some cargoes have aggressive effect on the metal constructions, thus thinning and weakening them and making it easier for cracks to appear.

Fatigue is also a factor with huge influence on the ship lifecycle. Monitoring this parameter is extremely important.

Hull monitoring is becoming one of the most important aspects of a vessel's operation. There have been a number of cases in the recent years, where ships suffered a major damage or even broke in half due to hull stresses caused by sea conditions, built quality, incorrect loading and vibration [3].

Tab.1 shows the most known sea disasters caused by hull breakdown in the last 30 years and amount of oil products spilled.

TABLE 1
MOST KNOWN SEA DISASTERS CAUSED BY HULL BREAKDOWN

Name	Year	Location	Amount (m ³)
Torrey Canyon	1967	Atlantic (France/Britain)	140,000
Amoco Cadiz	1978	Atlantic(France)	314,000
Exxon Valdez	1989	Alaska (USA)	50,000
Braer	1993	Scotland	100,000
Erika	1999	Atlantic(France)	20,000
Prestige	2002	Atlantic(France/Spain/Portugal)	35,000

III. NDT METHODS USED IN CBM

Vibration monitoring is one of the most effective techniques for determining the condition of rotating machinery. For simple items such as pumps it would be normal to record suction and discharge pressure and motor current at the same time when vibration readings are taken.

Thermographic imaging can be used to scan the infrared emissions from any surface and produce thermal maps of the scanned area. The complete thermal image is particularly useful in detecting local overheating in electrical equipment caused by dirt, loose connections, short circuiting or unbalance in 3-phase power supplies. Thermal imaging can be used to monitor mechanical machinery for detecting uneven heat distribution caused by faulty bearings.

Acoustic emission technology (AE) is relatively new technique based on frequencies much higher than the movement of vibrations. These frequencies are the result of shock, friction, cracking. Using AE techniques it is possible to detect failure before damage occurs and to monitor this process [3]. Principle of AE method is shown in fig.4.

It is supposed that using modern AE equipment it would be possible to detect cracks at the very early stage in such cases as the accident with the mentioned 8RTA84Cu engine crankshaft crack.

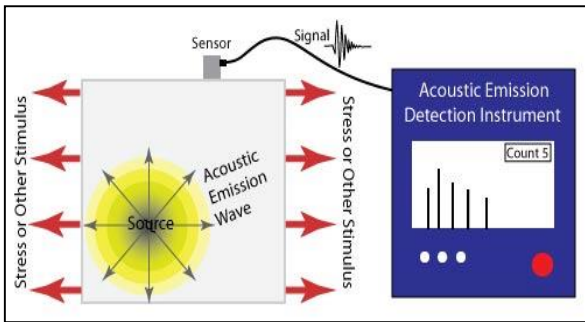


Fig.4.Principle of AE method

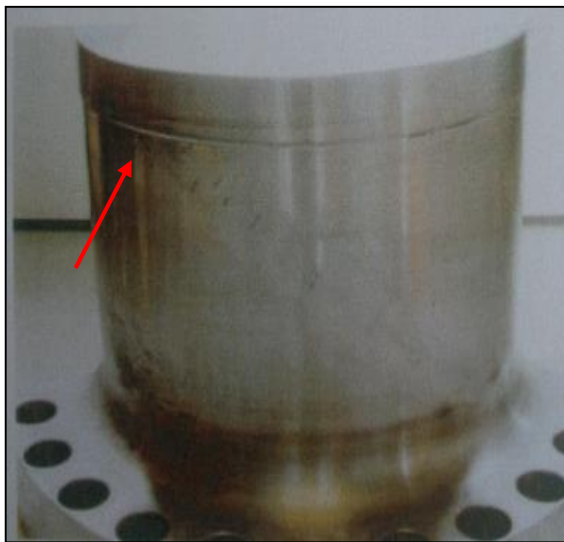


Fig.5. Crack starting point



Fig.6. Enlarged picture of the crack starting point

Furthermore, AE based technology can be used to forecast such important metal defects as crack propagation, fatigue, corrosion, stress corrosion [4].

Fig.5 and 6 show the crack starting point of the engine Sultzer 8RTA84Cu damaged crankshaft and the enlarged picture of this [5].

As already mentioned above, one of the biggest advantage of the AE system is the flexibility of the sensors allocation on the hull and machinery elements, which can be placed in convenient spots.

The use of AE will become more prevalent because it can provide unique insights into damage processes. However, the AE technology is not fully developed yet and still needs some improvements, such as noise reduction, reliability, and reducing the difficulty in solving the inverse problems of wave propagation in source-function and waveform analyses. These necessary improvements represent the areas of future endeavor in AE science and technology. There is also a great need for further research.



Fig.7.AE sensors on "Prince William"

Today many companies and major Classification Societies are involved in projects for monitoring systems implementation. The goal is to improve vessel's safety and extend dry-docking and repair intervals using these systems as part of CBM.

For example, joint development project between Alaska Tanker Company (ATC), American Bureau of Shipping and MISTRAS has resulted in the first commercial application of the latest acoustic emission technology in the marine industry.

Sensors placed on the deck near the midship of the ATC's 125,000 dwt, double hull tanker, Prince William Sound can electronically detect rapid stress-releasing events, such as the release of elastic energy in materials which then becomes an elastic wave [10].

Also Lloyds Register (LR) take part in the EU sponsored MINOAS project

Using acoustic emissions would allow for structural conditions to be monitored while the vessel is at sea. It is not intended that acoustic emissions replace current survey practices but, in the long term, this study and its subsequent findings could lead to more efficient and effective survey methods, and also shorten the downtime required of the vessel.

IV. CONCLUSION

It is clear that there is a need for further research. At the same time it is clear that it is quite hard to perform „field tests” as vessels have a tight schedule and sail worldwide.

RTU performed first “field test” of the AE implementation to the maritime industry in the spring of 2012. AE sensors were fixed on the tug “Sfinksa” belonging to Riga Port Authorities (commissioned on November, 2011); main engine: Caterpillar, Ne=2 x 1500 kW, n= 1600 n⁻¹. The goal was to measure the acoustic waves emitted from the main engine and follow up engine condition.



Fig.8. AE measurement on “Sfinksa”

On 13 May, 2013, the measurements were performed on Caterpillar marine engine G3520C, 2000kW at 1500 rpm, located on a shore power station.

AE equipment:

AE equipment includes a portable two-channel acoustic emission device PAC Pocket AE-2 with an internal range of 0, 14, 40 dB (manuf. by «Physical Acoustics Corporation»), which allows fixing the parameters of AE signals in the band frequencies from 1.0 kHz to 1.0 MHz. The device allows using the internal amplifiers with the range:

- 0 dB when using an external preamp with a range of 40dB,
- 14 dB when using an external preamp with a range of 26dB,
- 40 dB when not using external preamps.

Preparing for the AE monitoring:

To control the engine AE low-frequency transducer type R3α Company PAC is used. Sensors are positioned in three places (on the cylinder heads 5 and 6, on the crankshaft frame and the flywheel housing), AE sensor contact with the controlled object surface is provided by using the lubricant Silagel.

Setting up the AE equipment:

After connecting the equipment acoustic coupling and tuning range is checked with pulses automatic calibration of the sensors. Frequency bands of the instrument are 20 - 1000 kHz and 100 - 1000 kHz.

The coefficient of the main channels of amplification is set to 14 dB, as the sensors are used without built-in preamps, but with external preamplifiers with a range of 26 dB. For both channels the defined noise level given to the input of preamplifier is equal to 37 or 40 dB (for a cylinder heads).

Measurements and data processing:

Piezoceramic sensors detect elastic waves of the corresponding AE pulses and convert these mechanical vibrations into electrical signals, which are received over the cable lines for the AE signal and recorded. AE data recording during the engine monitoring was performed for a few minutes at engine speed at 1,500 rpm and load 1,630 kW. Fixed waveforms and parameters of AE form a portrait of the engine.

Results:

Engine AE portrait before overhaul, which will be used for comparison with AE portrait after overhaul.

Further AE measurements on different engines will allow finding common regularities and revealing causes of the engine malfunction at a very early stage using the AE method.

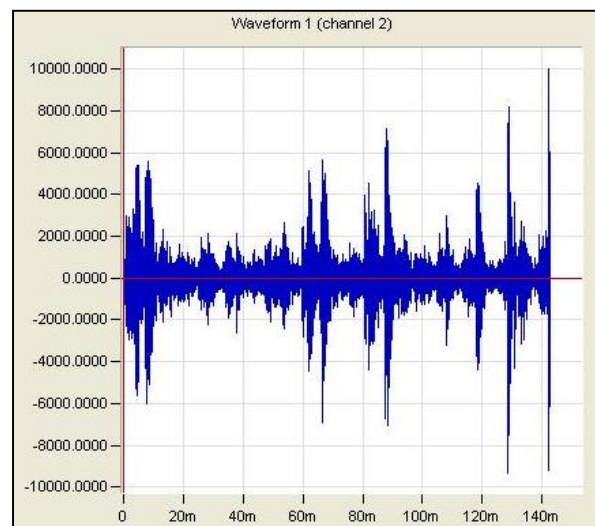


Fig. 9. AE waveform on the crankshaft frame

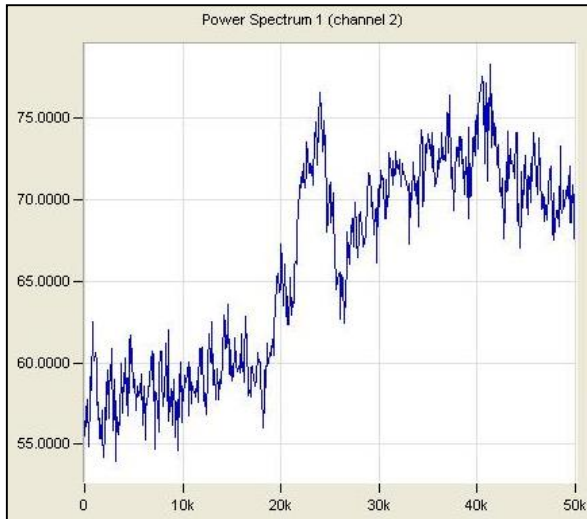


Fig. 10. AE wave spectrum on the crankshaft frame

Today non-destructive test methods become more and more popular, we believe the AE Method to be a very important and useful tool required in the modern shipping, as it would serve a very important purpose of preventing maritime accidents, minimizing their consequences and in general would help to keep the vessels properly maintained. It would also serve a very important purpose of preventing maritime pollution tragedies, such as oil spills. Needless to say, this would allow the industry in general and ship owners, as well as P&I clubs, in particular, to save a lot of funds spent on repairs and settlement of cargo liability claims. The benefit from these saving is incomparable with the relatively low costs of implementing the AE methodology.

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Gints Rijkuris (M.Sc.ing.) graduated from Latvian Maritime Academy as an engineer-ship’s navigator. In 2003-2008 he worked as a merchant vessel navigator. From 2008 onwards – the Captain on ASD tugboat in Riga Free Port. In 2010 he graduated from the Masters Course. Since 2011 he is a full time doctoral student at the Institute of Aeronautics. From August 2011 he is a researcher at the Institute of Aeronautics of Riga Technical University. His fields of scientific interests include: aeronautics, nanomaterials, nanocoatings, structural materials, unmanned vehicles, transport systems and logistics.

Muharbijs Banovs, Andris Unbedahts, Gints Rijkuris. Jūras kuģu korpasa un dzinēju uzraudzības ietekme uz kuģošanas drošības paaugstināšanu

Šodien ir neiespējami atdalīt kuģošanas efektivitāti no kuģošanas drošības. Šo jēdzienu apvienošanai kalpo arī pēdējos gados izstrādātā un arvien plašāk ieviestā kuģu mehānismu apkalpošana pēc to tehniskā stāvokļa - CBM (Condition Based Monitoring). Kā daļa no CBM ir dažādas monitoringa sistēmas, kas izmanto dažādus principus: ultraskaņu, termogrāfiju, vibrāciju kontroli, akustisko emisiju (AE) utt., bet aizvien ir vajadzība pēc vienkāršas un ērtas iekārtas. Plaisas kuģu dzinēju kloķvārpstās un korpusos ir diezgan izplatīta parādība un to sekas reizēm ir katastrofālas. Mūsdienās, kad jūrniecības nozare strādā ļoti saspringtos apstākļos, defektu identifikācija agrīnajā stadijā ir ļoti būtiska. AE izmantošana kā CBM sastāvdaļu defektu identificēšana varētu jūtami ietekmēt ne tikai kuģošanas drošību, bet arī uzlabot kuģošanas kompāniju ekonomiskos rādītājus. Pirmos pētījumus šajā nozarē RTU sāka 2012.gadā un tie tiek turpināti. Izmantojot mobilo AE reģistrēšanas iekārtu, tiek iegūts dzinēja akustiskais attēls pie dažādiem režīmiem, kā arī veikts monitorings, reģistrējot izmaiņas ekspluatācijas laikā.

Мухарбий Банов, Андрис Унбедахс, Гинте Рийкурис. Влияние мониторинга корпуса судна и двигателя на повышение безопасности плавания

В морской индустрии сегодня трудно отделить понятия экономичность и безопасность. Несколько лет назад при одобрении Классификационных обществ судоходные компании на своих судах начали вводить их обслуживание по техническому состоянию - CBM (Condition Based Maintenance). Как часть CBM, существует ряд устройств мониторинга механизмов, которые используют разные

принципы: ультразвук, вибродиагностику, термографию, акустическую эмиссию (АЭ), и т.д. Тем не менее, есть необходимость в простых и надежных приборах контроля. Трещины в корпусах судов и коленвалах двигателей – это довольно частое явление, вызванное разными причинами, и часто с катастрофическими последствиями. Сегодня, когда морская индустрия работает в напряженных условиях, раннее обнаружение дефектов имеет особо важное значение – оно не только улучшает безопасность мореплавания но и повышает экономические показатели компаний. Использование принципа АЭ в составе СВМ дает такую возможность. РТУ первые исследования в этой отрасли начал 2012 году и успешно продолжает их. Используя мобильную аппаратуру, регистрируются акустические волны на различных режимах двигателя, таким образом создается акустическая картина двигателя. Также ведется наблюдение за изменением АЭ по мере износа деталей движения, что позволяет определить техническое состояние двигателя.