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Importance of Condition Assessment Programme by Ultrasonic Measurement

Abstract

Paper gathers information on Condition Assessment Programme (CAP), which is implemented by classification societies to thoroughly assess condition of tankers and bulk carriers by inspection of engine and hull. It is voluntary programme, mostly participated by tankers and bulk carriers which are fifteen and more years old and today less present on the market. Special focus will be on ultrasonic measurement of thickness of ship´s plates which is most significant indicator on condition of older vessels. After all measuring is done, data is compared with classification society rules and condition of hull and machinery will be assessed. This kind of inspection provides owners of older ships proof that despite age their ships are equally capable of conducting sea voyage. The authors analyse the number of ship arrivals in the port of Rijeka to gain a better insight into their age. Furthermore, the authors advocate ultrasonic thickness measurement for the purpose of reducing hazards.

Keywords: Condition Assessment Programme, tankers and bulk carriers, corrosion, classification society, hull and machinery condition, ultrasonic thickness measurement

1. Introduction

In today's shipping business average age of vessels has decreased compared to last century, ships older than fifteen years have become a rare sight. Older vessels represent risk considering fatigue of material which comes with age, and stresses and pounding they experience on rough seas. These factors contribute to additional deterioration of

steel which through corrosion loses thickness and additionally damages coating thus enabling oxidation process. Steel in a marine environment is, however, substantially different from steel on the receiving docks [11]. The unnoticed presence of corrosion may cause so many accidents leading to human and money loses [5]. The presences of corrosion underneath the paints of surface and between joints are not easy to detect [4]. All such ships must undergo a series of routine repair tasks while docking in a shipyard in order to maintain a smooth and foul free operation [8].

In order to assure charterers that the vessel is in a good condition, well maintained and with reliable planned maintenance system implemented despite the age of vessel, shipowners of older vessels are ordering Condition Assessment Programme (CAP). Primarily designed for tankers and bulk carriers more than fifteen years old but it is open for vessels of all types and ages. These two types of vessels are under highest restrictions and are facing increased demands from institutions and charterers. Statistics for ship hulls show that around 90% of ship failures are attributed to corrosion, including corrosion fatigue [12]. For oil tankers and bulk carriers there has been a number of sinkings, and environmental disasters attributed to poorly maintained and highly corroded hulls [3]. Inspection is conducted by classification societies, that is certified inspectors who issue certificate as a proof of condition.

Paper describes how is the programme conducted and which two basic inspections form it. Attention will be on hull inspection, mainly on inspection of material thickness, from hull to girders due to those parts being most exposed to rough conditions experienced at seas.

Furthermore, the paper analyses the role of port state control and flag state control in the condition assessment system. Article will also be focused on inspection of tankers considering their average age is older than bulk carriers, thus their inspections are more frequent, as well considering their potential threat to marine environment. The numbers of considered ships that arrived in the port of Rijeka in 2020 were obtained from the local pilot company.

2. What is CAP?

Condition Assessment Programme was implemented by classification societies to thoroughly assess condition of vessels by inspection of engine and hull. This is not usual inspection where they check condition visually and check that equipment is functional, but they check condition, thickness of materials, working temperatures, frequencies, vibrations of machinery.

Shipowners are required to apply for inspection at least two months in advance and prepare the ship for inspection. All external surfaces must be cleaned, otherwise it will be put as an observation in report. It cannot be unambiguously determined what time interval is preferable for cleaning and inspecting the state of a ship's hull; this depends significantly on many factors, in particular, on the type of paint covering the

underwater surface of the ship's hull, the ratio between the standing and movement times, the water temperature, etc [1].

Inspection is conducted by inspector from classification society, and if needed other specialised company, especially for ultrasonic thickness measurement. Inspection consists of two components which are independent:

- Hull Condition Assessment Programme – consists of inspecting structural elements, thickness measurement, strength calculation and condition evaluation.
- Machinery Condition Assessment Programme – inspection of all machinery including deck and cargo spaces equipment, pipelines, condition evaluation.

2.1. Hull inspection

Hull inspection is performed while the vessel is docked so that outer parts can be reached. Inspection starts with general visual inspection of deck, outer plating including sea chest, rudder, anchors and anchor chains. Next part is inspection of inner structures of cargo, ballast tanks, engine surfaces, forepeak tank, afterpeak tank, cofferdam, pumproom and all other spaces. After checking general condition, inspector starts with close up inspection, all frames in ballast tanks are checked, minimum 30% longitudinals in tanks, beams, all structural elements in cofferdams, all girders, individual deck points as well as hot points chosen in advance, which are places most affected by bending moments, shearing forces and stresses (Figure 1).

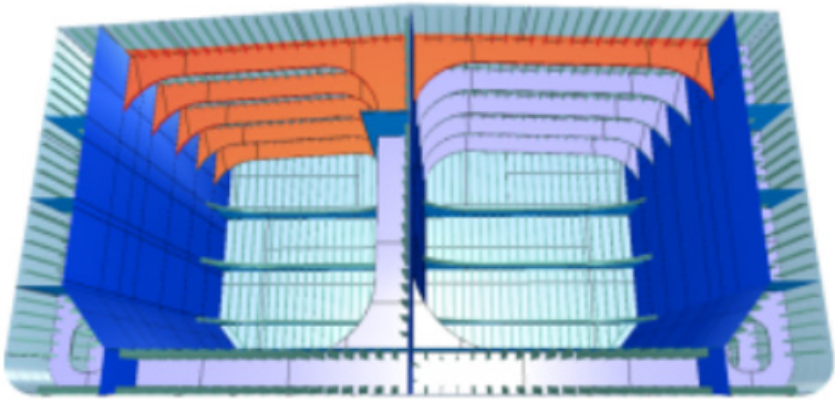

Figure 1: Example of hot points for inspection, deck transverse
Source: [6]

Afterwards ultrasonic thickness measurement is conducted and compared with original drawings and dimensions. This will be discussed in next chapter so it will be skipped for now. After measurement, strength calculation is conducted which consists of [7]:

- Longitudinal strength – calculation of bending moments for at least three sections, also calculation of vertical hull girder section modulus, buckling utilization factor (hull girder compressive stress compared to critical compressive buckling stress),

$$Z = (M_{SW} + M_{WV})/\sigma * 10^{-3} (m^3) \quad (1)$$

where:
Z – hull girder section modulus
M – bending moments, still water($_{SW}$) and waves($_{WV}$)

$$\sigma = 175/k \ (kN/m^2) \quad (2)$$

$$\eta = \sigma/\sigma_{crit} \quad (3)$$

where:
σ - hull girder compressive stress,
σ_{crit} - critical compressive buckling stress,
k - coefficient dependent on type of steel,
η - buckling utilization factor.

- Re - assessments of scantlings,
- Fatigue stress assessment – inspecting dimensions of stiffeners and hot spots with highest stresses with comparison to old dimensions with deduction of the corresponding corrosion allowance.

Based on this results, report is made.

2.2. Machinery inspection

Machinery inspection is conducted while the vessel is underway and while discharge operation is conducted so that cargo discharge equipment can be examined. Inspection starts with evaluation of Planned Maintenance System (PMS). Afterwards bunker and oil analyses are checked, samples are also taken. Remote and local sensors measure performances of main and auxiliary engines during different loads. Temperatures and vibrations are measured on all machinery, pumps and all alarms, limit switches are tested. Furthermore, propulsion system is checked, vibration and lubrication, and in case of controllable pitch propeller its hydraulic system is also checked. Steering equipment, vibrations as well as changeover from autopilot to hand steering is checked. Entire power system is checked, as well as operation of emergency power supply in case of blackout. All measured data is compared with nominal technical data and evaluated on base of that. Inspection of all pipes, deck equipment, cargo pumps, tank gauging units and operation of valves also falls under machinery inspection. They are checked for leaks, pressure limits, pump capacity and response time. Same as for hull inspection, after inspection certificate is given with report on condition of each part of equipment.

2.3. Results of measuring

After all measuring is taken, data is compared with classification society rules. Depending on age of vessel, allowances are made and depending on difference between allowed and measured data, condition of hull and machinery is assessed. If during inspection serious deficiency is observed, it must be dealt with as soon as possible.

Hull condition is assessed on base of condition of each individual space in which corrosion presence is observed, decrease in thickness, damage of coating, deformations. In case any section of hull has any of previous, it is marked and together with picture put into report, and it must be repaired while in dock.

Machinery condition assessment includes report on each part of equipment which is checked, with results of vibration, temperature measurements. Also quality reports of bunker, oil enter condition evaluation. In case of faulty equipment, it can be requested to be immediately repaired if necessary.

There are four condition assessments of hull, machinery [9]:

- Very good condition/CAP 1 – small differences from initial condition, no repairs needed,
- Good condition/CAP2 – small deficiencies observed, no repairs needed,
- Satisfactory condition/CAP 3- deficiencies observed, not required immediate repair,
- Poor condition/CAP 4 – results under class requirements, deficiencies need to be resolved before leaving dock.

3. Ultrasonic thickness measurement

Most significant indicator of ship's condition is thickness of plating and structural elements. Considering corrosion, striking reduces thickness of steel plates, which cannot be observed visually to which extent it happens, and layers of paint additionally disguise the problem. However, using Ultrasonic Thickness Measurement (UTD) we get real insight on condition of plating. With use of piezoelectric effect, piezoelectric transducer (PT) creates ultrasonic waves which emit through material using probe, wave reflects from inner surface of outer side and returns through probe on PT creating signal, which marks time interval for wave returning, and thickness is derived from that time.

$$L_{mat} = v*t/2 \tag{4}$$

where:
L_{mat} - Material thickness,
v - Sound velocity through material, instrument is calibrated depending on material,
t - Total time needed from sending of wave till wave reflection returns.

As mentioned wave is generated using piezoelectric effect. Piezoelectric element, crystal, placed between two metal plates which apply mechanical pressure releases

electric charge. When reflected electric charge reacts on crystal causing it to vibrate indicating end of time interval (Figure 2).

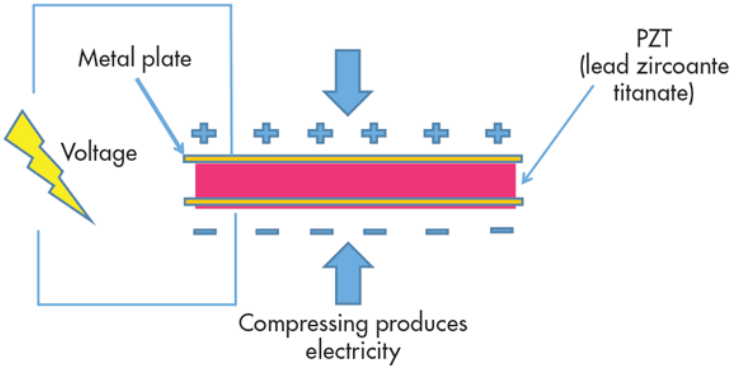

Figure 2. Piezoelectric effect
Source: [2]

Two types of crystal are being used [14]:

- Single crystal – such as quartz, lithium niobate and others. Exhibit less sensitivity than mixed ones,
- Double crystal – combinations such as lead-titanium, lead – zinc – nickel.

Instrument is easy to use, depending on surface type corresponding instrument is used. For clean surfaces without any coating, paint instrument creating single pulse is used, thus getting single time measurement, and to avoid losses between probe and surface liquid lubricant is used as conductor. However, when measuring thickness of coated tanks, instrument creating multiple pulses is used because it can isolate coating thickness, modern instrument can work on coatings up to 20 mm. DNV GL only allows later types of instruments. They measure three time intervals, with interval between second and third pulse corresponding to material thickness.

As mentioned before, shipowner has obligation to prepare surfaces to be measured, if corrosion is present it must be blasted. Surfaces measured are similar to those during close up inspection, most important being girders, frames, hull plating, keel, stiffeners, tank walls, forepeak and afterpeak tank, other locations exposed to stresses (with bulk carriers those would be hatch coamings, hatches). It is necessary to put scaffolds to access tank girders, it can be also arranged to use rafts in ballast tanks to check under deck structures by filling them. Inspector of classification society brings list of minimal thickness with him, which is then used to compare measurements and evaluate condition. For most ships surface degradation cannot be more than 10% of original, but some vessels have stricter demands. Thickness Measurement Report is shown in the Table 1.

Table 1. Thickness Measurement Report

THICKNESS MEASUREMENT REPORT

															Substantial corrosion
Ship's Name:		**Example Ship**			**Id.No.:**	**12345**	**Report No:**	**9876**					**Legend:**		Below Class minimum
Tank/ Space	Tank/Space Reverse side	Structural Element	Element/ Frame No.	Draw ref.	Orig. thk.	Class min thk.	Gauged		Diminution				Renewed		Comments Defects found
							Port	Stbd	Port		Starboard		Port	Stbd	
					mm	mm	mm	mm	mm	%	mm	%	mm	mm	
DTB4	N.A.	TRANSVERSE FLOOR	102	1	12,50	9,50	8,30	10,00	4,20	33,6 %	2,50	20,0 %	12,50		Crack port side
DTB4	N.A.	TRANSVERSE FLOOR	103	2	12,50	9,50	9,00	11,90	3,50	28,0 %	0,60	4,8 %	12,50		
DTB4	N.A.	TRANSVERSE FLOOR	104	3	12,50	9,50	10,00	12,00	2,50	20,0 %	0,50	4,0 %	12,50		
DTB4	N.A.	TRANSVERSE FLOOR	105	4	12,50	9,50	10,20	12,30	2,30	18,4 %	0,20	1,6 %	12,50		
DTB4	N.A.	LONGITUDINAL GIRDER	106	5	12,50	9,50	10,00	12,40	2,50	20,0 %	0,10	0,8 %	12,50		
DTB4	N.A.	LONGITUDINAL GIRDER	102, L3	6	12,00	9,00	10,00	11,50	2,00	16,7 %	0,50	4,2 %			
DTB4	N.A.	LONGITUDINAL GIRDER	102, L6	7	12,00	9,00	11,40	11,80	0,60	5,0 %	0,20	1,7 %			
DTB4	N.A.	LONGITUDINAL GIRDER	102, L9	8	12,00	9,00	11,70	10,00	0,30	2,5 %	2,00	16,7 %			
DTB4	N.A.	LONGITUDINAL GIRDER	102, L12	9	12,00	9,00	11,80	11,50	0,20	1,7 %	0,50	4,2 %			
DTB4	N.A.	LONGITUDINAL GIRDER	103, L2	10	12,00	9,00	12,00	12,00	0,00	0,0 %	0,00	0,0 %			
DTB4	N.A.	LONGITUDINAL GIRDER	103, L6	11	12,00	9,00	12,00	12,00	0,00	0,0 %	0,00	0,0 %			
DTB4	N.A.	LONGITUDINAL GIRDER	103, L9	12	12,00	9,00	12,00	12,60	0,00	0,0 %	0,00	0,0 %			
DTB4	N.A.	LONGITUDINAL GIRDER	103, L12	13	12,00	9,00	11,80	11,80	0,20	1,7 %	0,20	1,7 %			

Source: [6]

4. Role of port state control and flag state control in the condition assessment system

Croatian ports are recording a steady trend of increasing maritime traffic. In the Republic of Croatia six ports have major significance for the development of the economy and other industrial branches [13]. The Port of Rijeka is the most important and also the largest port in the Republic of Croatia handling a total of 13,6 million tons of cargo in 2020 [10]. The port consists of several basins: port basins Rijeka and Sušak, Bay of Bakar basin, Omišalj basin (a bay on the island of Krk) and Raša basin (in Istria). The article considers basins of Rijeka port in the Bay of Rijeka, excluding Raša basin.

An important advantage of the Port of Rijeka is its proximity to the neighbouring countries and today finally, due to accession to the EU on 1 July 2013. The mentioned port has equal market conditions as her major competitors (Koper and Trieste).

The ships' data were obtained from the pilot company providing pilotage in the Port of Rijeka for the year 2020. The number of ships that arrived in the port of Rijeka in 2020 is graphically shown on Figure 4.

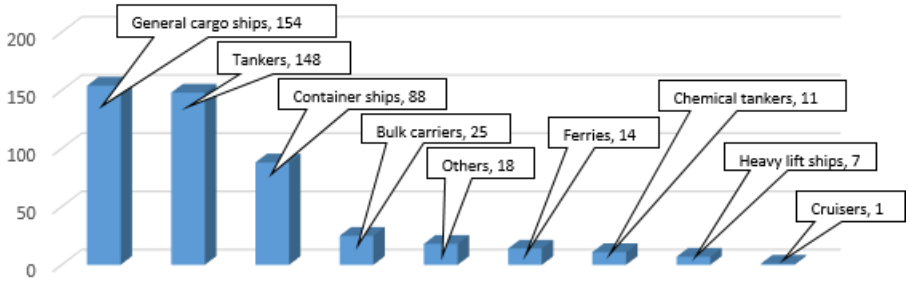

Figure 4. Number of ships in 2020
Source: Authors

During 2020., 466 ships were moored in the basins of the Port of Rijeka. Most of them were general cargo ships (154 ships). Condition Assessment Programme is established within the tanker industry, and also in the bulker sector. Tankers and bulk carriers are classified by age into the following categories by authors:

- < 5 years,
- 6 < 10 years,
- 11 < 15 years and
- > 15 years.

The division of tankers according to age categories is shown in the Figure 5. The largest share of takers that were moored in the port of Rijeka during 2020. are in the age group older than 15 years.

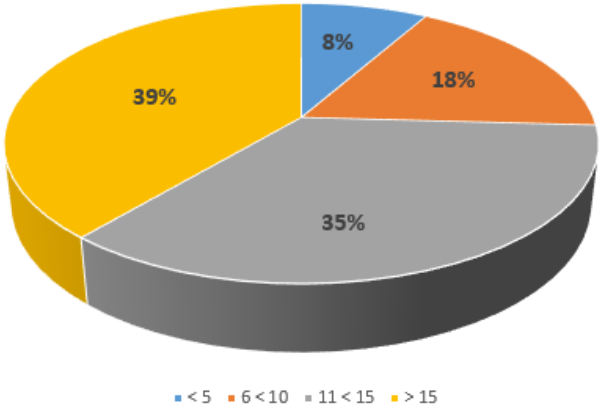

Figure 5. Division of tankers according to age categories
Source: Authors

Also, the division of bulk carriers according to age categories is shown in the Figure 6. The largest share of bulk carriers that were moored in the port of Rijeka during 2020 are in the age group between 11 and 15 years. However, the share of ships of the considered category older than 15 years is also large (28%).

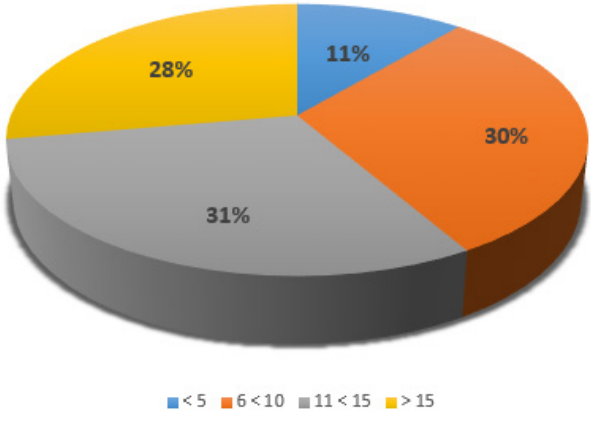

Figure 6: Division of bulk carriers according to age categories
Source: Authors

Condition Assessment Program is voluntary with the intention of verification of the condition of the vessel at the time of inspection. The main goal of this program is to verify the condition of aged vessels based on their current condition rather than their age. The port state control (PSC) conducts the inspection of foreign ships in national ports to verify that the condition of the ship complies with the international regulations. Also, the flag state control (FSC) conducts the supervising of the ship under national flag to ensure that considered ships reach require safety standards. Both of them contribute to maritime safety and environment protection, but also, they help to verify the condition of vessels. This is very important in case of aged vessels. Approximately one third of total tankers and bulk carrier berthed in Port of Rijeka were aged vessels. This category of ships is very often inspection target for PSC or FSC also in the Port of Rijeka. Among other things, such inspections include determining the condition of some segments of the hull and machinery. The authors suggest that such inspections should comply with CAP requirements. Thus, such inspections would contribute to a better assessment of the condition of older ships. Condition inspection flow by PSC or FSC is shown in Figure 7.

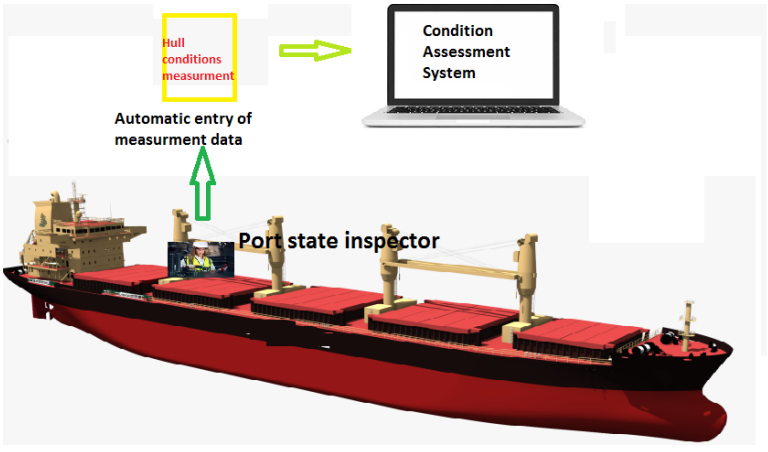

Figure 7. Condition inspection flow by PSC or FSC
Source: Authors

The specific challenge of the CAS has been to increase ship safety by providing a permanent easy and transparent access to ships conditions data regarding hull and machinery. This has been a way of protecting crews of tankers and bulk carriers from accident on aged vessel and also protecting the environment from oil spoilage and another kind of disasters, as well as. The PSC and FSC in the Port of Rijeka play an important role in preventing possible maritime accidents in this part of the Adriatic. According to the authors, the condition inspections of the hull and the machinery made by the PSC or FSC should be included in order to support the full condition assessment process. It is of the utmost importance for Classification societies and also for ship-owners, ship operators to reduce off-hire periods and to keep repair cost and other maintenance cost under control. Therefore, the history of all inspections on hull and machinery (by the classification society, PSC or FSC, the owner's people, and another inspections) should be recorded and updated in the tool, enabling at any time the drafting of ship′s conditions.

5. Conclusion

Considering exiting number of inspections, from class inspection to additional ones for tankers and bulk carriers question imposes why another one. Answer lies in fact that not one of them gives such detailed result as this one. It provides owners of older ships proof that despite age their ships are equally capable of conducting sea voyage.

The fact that it is voluntary is step ahead, it demonstrates that it is in shipowners interest to acquire certificate of condition from classification society. Most important is to prepare the vessel for inspection to save time and so that measurements are as

accurate as possible. As described, measurement is simple, important part is to the decide where to measure. The experience factor plays a major role in that, considering inspectors are already familiar which places have highest stresses. Additional help comes from specialised computer programmes which calculate hot points affected by strain forces (same as Loadingmaster calculating bending moments and shearing forces).

This assessment highlights the need for proper preventive maintenance, that is reliable PMS. System is also checked when inspecting machinery like mentioned before, with results providing evidence if maintenance was being done or if it was only written to have been done. All areas being inspected are also listed in PMS in regular intervals, some of them need to be only visually inspected when possible(tanks). Visual inspection can reveal if any structural damages exist, and it must be reported considering they can be repaired only in docks.

Considering past times, when vessels were being exploited to maximum extent, today older ships are being recycled much sooner although some still being capable of transport. The fact is that new buildings are built faster and it is easier to follow new requirements, however old vessels tend to be constructed of higher quality materials which this programme shows considering results from inspections.

The full condition assessment should include PSC or FSC condition inspections of hull and machinery in order to gain a better insight into the condition of the considered categories of older ships. It is very important for ship′s Classification societies and also for ship-owners, ship operators, to obtain better ship efficiency, especially in the case of aged ships considered category.

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