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DETERMINING WEIGHT OF CARGO ONBOARD SHIP BY MEANS OF OPTICAL FIBRE TECHNOLOGY DRAFT READING

ABSTRACT

The accuracy of measuring mass of loaded or discharged cargo by draft survey mass measuring method varies due to both systematic and accidental errors. The paper analyzes an error of draft readings on the calculated quarter mean draft, displacement based on the calculated quarter mean draft and the final displacement. By analyzing this problem, the authors have reached the conclusion that the influence of an error made in draft readings can be significant, especially on the draft marks amidships. Optical fibre technology has been suggested as a new option for draft readings. In this paper, the authors propose a liquid level optical sensor for measuring the sea level in the sounding pipe. Draft readings obtained by optical sensors will be entered into ships' navigational system and load master.

KEY WORDS

ship's draft, error of draft readings, optical fibre technology, liquid level optical sensors.

1. INTRODUCTION

The significant increase in the transport of bulk cargo at the end of the 20th and the beginning of the 21st century has caused higher accuracy in cargo mass calculation in the maritime transport process.

Loaded cargo mass onboard ship is calculated in loading (cargo admission) and discharging (cargo delivery) port. The mass of bulk cargo which is delivered for sea transport can be calculated before it is loaded onto a ship. Before loading and after discharging cargo from a ship, cargo mass is calculated by means of coastal scales, which differ by their performance. Cargo mass on a ship is usually calculated by means of a draft survey mass measuring method.

Draft survey mass measuring method is subject to certain systematic, as well as accidental errors. A vast number of errors is caused by draft readings, identification of type and size of ship's deflection (hogging and sagging), water density correction, identification of ship's deductibles (fuel and grease, ballast, drinking water, crew and their belongings, other ship supplies) and identification of dead weights [1].

Using this method, cargo mass is in most cases calculated as the difference between displacement before and after performance of ship transship operations. Errors in calculation of ship's deductibles, which do not change during transship operation, do not have any effect on the accuracy in cargo mass calculations.

It can be concluded that errors are possible with draft readings and measuring of masses of ship's deductibles which were exposed to changes during transship operations. Errors in measuring the mass of water (technical and drinking) and fuel of auxiliary engines during transship operations are negligible because, besides measuring, they can be controlled on the basis of average spending. In order to bring errors in measuring ballast water mass to a minimum, the ballast tanks are usually fully filled (control with pressure overflow via ballast air escape) or completely empty. With partial cargo transshipment, there is a possibility that the ballast water mass stays unchanged. In that case, even a possible error made during the identification of displacement before performing transship operations has no effect on calculating the transshipment cargo mass [2].

By calculating cargo mass with sub-variants of this method, which are not based on the displacement set before transship operations, the possibility of systematic and accidental errors effect is increased. Errors made in determining of ship's deductibles are reflected completely in the accuracy in cargo mass calculation.

According to experimental discoveries, an error in measuring cargo mass of a ship by means of draft is about 0.1%-1%. The accuracy is in most cases higher than with measuring mass by cargo weighing. Therefore, the cargo mass calculated by means of draft, especially with some types of cargo, is entered into the bill of loading.

The significance of this method can be seen in the possibility to include all the interested parties of maritime transport process directly in cargo mass calculation.

In this paper, among many influential factors of systematic and accidental errors in measuring cargo mass by means of draft, the draft reading influence will be analyzed. Draft readings are a significant factor which influences the accuracy of the implemented method because they represent the input parameters for estimating cargo mass of a ship. Besides parallax error, in practice there is a wide range of complicating states which reduce the accuracy in draft readings (waves, strong ocean currents, reduced visibility, rain, draft readings sea side of a ship, etc.), and thereby reduce also the accuracy of calculating weight of cargo onboard ship. Therefore, a special significance is given precisely to draft readings.

Because of its advantages in data transmission and simple installation over traditional information transmission technologies, in the past two decades the optical fibre technology has had a leading role in telecommunications and computer networks [3]. Apart from the communication systems, optical fibres have application for sensing and measurement of different nonelectrical and electrical values [4]. In both cases, their very small dimensions, easy installation, no sensitivity on external electromagnetic influences, enormous data transmission capacity and high reliability improve installation of optical communication networks and sensors in very demanding ship environment. This paper describes the application of optical sensors in draft survey.

2. DISPLACEMENT MEASURING BASED ON SHIP'S DRAFT

A ship's draft is the vertical distance between the lowest point of a hull (bottom keel edge or bottom rudder plate edge) and the existing waterline. On the basis of the intersection of waterline and draft marks, it is possible to measure the ship's draft. Draft marks are on the ship's hull, in the draft area, on the ship's bow, stern and, on longer ships (because of the deflection influence), also at the middle. The position of draft marks is shown in *Figure 1*.

Draft readings should be given proper attention. A ship's draft should not be read during ship's movement, strong tidal currents, rolling or extreme pitching of a ship. In case of slight seas it is recommendable to sequentially make draft readings at the intersection of wave's crest and draft marks, and wave's trough and

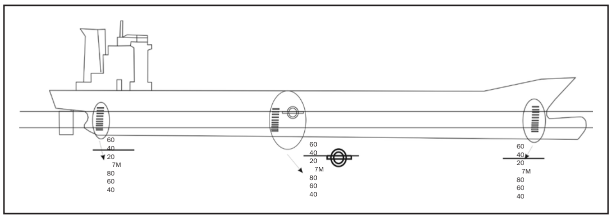

Figure 1 - Positions of draft marks on ship's hull

draft marks. On the basis of the measured values, it is possible to identify an approximate draft at a certain draft mark, by means of arithmetic mean expression. Draft at the draft marks on the side of a ship at the coastal edge is usually read from the coast, while at the outer side of a ship it is read in such a way that a person who is making readings gets as close as possible to the waterline by means of a pilot ladder, or it is done from a boat.

Draft midships, the precision of which is mostly reflected on the accuracy of determining of weight cargo onboard ship, is usually calculated in two different ways. Directly, by means of reading values from draft marks at midships; and indirectly, by means of measuring the existing freeboard. Then, draft is calculated as a difference between freeboard and the distance between upper edge of the main deck mark and the lowest point of the ship, the value of which was previously read from the general arrangement plan.

Based on the readings of drafts from draft marks on the left (port) and the right (starboard) sides of a ship ($Df(p)$ - draft forward on the left side, $Df(s)$ - draft forward on the right side, $Da(p)$ - draft aft on the left side, $Da(s)$ - draft aft on the right side, $Dm(p)$ - draft midship on the left side, $Dm(s)$ - draft midship on the right side), one can calculate draft forward (*Df*), draft aft (*Da*) and draft midships (*Dm*) with these expressions:

$$Df = \frac{Df(p) + Df(s)}{2}; \quad Da = \frac{Da(p) + Da(s)}{2};$$
$$Dm = \frac{Dm(p) + Dm(s)}{2} \tag{1}$$

In order to determine cargo mass via draft survey mass measuring method, in case a ship is not on a flat-plate keel, i.e. draft marks are not on perpendiculars, it is necessary to use certain corrections in order for drafts read from draft marks, or determined by other means, to be reduced into perpendicular draft. Corrections on bow (*x*), stern (*y*) and midships (*z*) are identified according to these expressions:

$$x = d_1 \cdot \left(\frac{Df - Da}{Lpp}\right); \quad y = d_2 \cdot \left(\frac{Df - Da}{Lpp}\right);$$
$$z = d_3 \cdot \left(\frac{Df - Da}{Lpp}\right) \tag{2}$$

The distances between draft forward mark and forward perpendicular (d_1), between draft aft mark and after perpendicular (d_2), and between midships draft mark and midships (d_3) are determined from ship's arrangement plans. *Lpp* mark represents the length of a ship between perpendiculars.

The drafts at forward perpendicular (*DF*), after perpendicular (*DA*) and midships (*DM*) are determined via these expressions:

$$DF = Df \pm x; \quad DA = Da \pm y; \quad DM = Dm \pm z \tag{3}$$

A ship on a flat-plate keel would have the same values of the mean draft and the draft at midships if there were no ship deflection. Due to uneven distribution of masses and buoyancy in longitudinal sense of a ship, the ship's hull becomes deformed, especially with longer ships. When the draft at midships is smaller than the mean draft (fore and aft), the deflection moment is positive - hogging condition. On the other hand, when the mean draft is smaller than the draft at midships, the deflection moment is negative – sagging condition. The deflection value (*DEF*) is determined according to the following expression:

$$DEF = DFA - DM \tag{4}$$

where:

$$DFA = \frac{DF - DA}{2}$$

In case there is a deflection of a ship, it is necessary to determine the quarter mean draft with correction. When determining corrections, one must start with the assumption that the ship is deflected in the shape of a small parabola. The quarter mean draft (*QMD*) is in most cases determined by this expression:

$$QMD = \frac{DF + DA + 6 \cdot DM}{8} \tag{5}$$

Starting from the quarter mean draft, the ship's displacement and all the necessary hydrostatic information for the continuation of calculations are identified. It should be noted that a ship's hull is usually deformed on an irregular curve, depending on the interrelation of mass and buoyancy distributions [5].

The displacement read from tables with hydrostatic information, or from curves, based on the quarter mean draft, represents the basis for further calculations progress. Errors made during the readings directly affect the size of error in the displacement identification and further calculation progress. Therefore, the following part of this paper emphasizes the need for the analysis of draft reading error effect.

3. ANALYSIS OF DRAFT READING ERROR EFFECT ON SHIP'S CARGO MASS MEASURING

A significant factor for accuracy in measuring ship's cargo mass are draft readings because they represent the basic input parameters. A ship in a harbour, or at an anchorage, can be exposed to different meteorological and oceanological effects (waves, strong ocean currents, rain, reduced visibility, etc.), and to other conditions (draft reading on the outer side of a ship, night conditions, etc.), which can result in major or minor discrepancies in draft readings.

In analyzing the effects of errors in draft readings we will use the information from the hydrostatic tables of a ship which, by all its characteristics, belongs to Handymax group of ships. The presumed error in draft readings on the bow, stern and at midships will be observed in the value range of -10cm to +10cm for change size of 1cm. The presumed error range is selected based on the authors' experimental discoveries and the research addressing the same issue has been conducted [5], starting from unfavourable conditions to which a ship can be exposed during draft readings. In the next part of the paper, we will present an analysis of the effect of the presumed error on the quarter mean draft, displacement read from hydrostatic

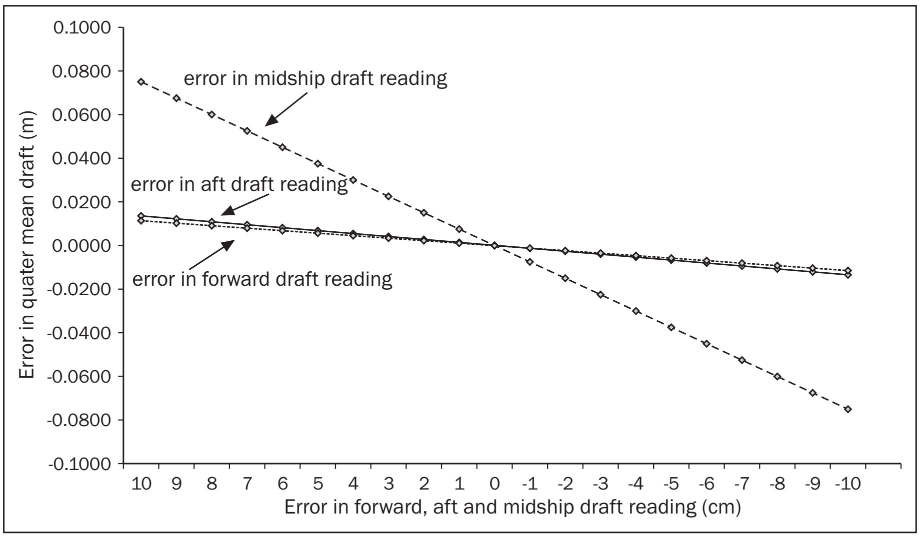

Figure 2 - Error in quarter mean draft for presumed error in draft reading on bow, stern and at midships with the value range of ±10 cm

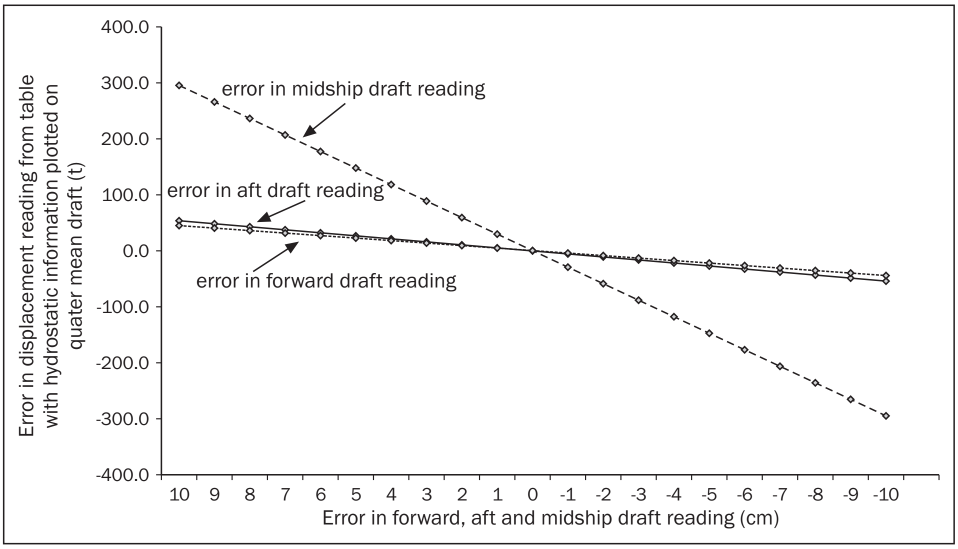

Figure 3 - Errors in displacement read from table with hydrostatic information plotted on quarter mean draft for presumed error in reading drafts from bow, stern and midships in value range of ±10 cm

tables, starting from the quarter mean draft and the final displacement. The positive or negative (+,-) sign of error in the draft reading does not have influence on the size of the absolute error of the quarter mean draft, displacement read from the table with hydrostatic information, which is derived from the quarter mean draft, and on the final displacement. Rather, it only determines the positive or negative value of the error. The results of the analysis are shown graphically in Figures 2, 3 and 4.

By analyzing the results from *Figure 2*, one can see a linear trend of increase in error of the quarter mean draft value caused by an increase of error in draft reading. The biggest trend of increase in the error of the quarter mean draft is caused by the error in draft reading amidships. The size of influence of midships draft on the quarter mean draft is derived from the used expression for calculating the value of the quarter mean draft. The differences between values of the quarter mean draft caused by the errors in draft reading on bow and stern are almost negligible. The different influence of the same error value appears with the same values of errors in draft reading on bow and stern due to different distances between draft marks and forward and after perpendicular because the expression for the quarter mean draft uses perpendicular draft[1] values.

By analyzing *Figure 3*, one can see that error which occurs in the displacement read from the table with hydrostatic information plotted on the quarter mean draft is the most expressed. The presumed error in draft reading influences the value of the quarter mean

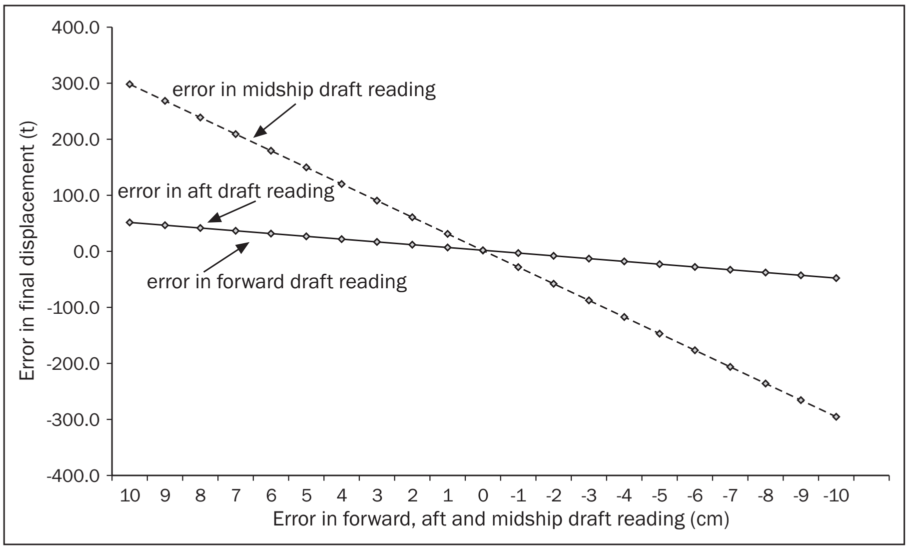

Figure 4 - Error in final displacement for presumed error in reading draft on bow, stern and midships in value range of ±10 cm

draft, which is the basis for displacement value identification. The influence of such presumed error is also transmitted to displacement. The changes of error in the considered displacement are linear because they follow the linearity of the change in the quarter mean draft.

By observing the data shown in *Figure 4*, it may be concluded that the influence of the presumed error in the draft read on bow, stern and midships is significantly larger for the displacement read from the table with hydrometric information based on the quarter mean draft than for the final displacement. The differences caused by error in draft reading which occur in corrections, by which displacement calculated from hydrometric tables based on the quarter mean draft is turned into the final displacement, are of low values. An error in reading can influence the relative trim change (difference in draft forward and draft aft). However, differences in mass which emerge from the limiting values of the relative trim change are small. Therefore, the change in final displacement is also almost negligible.

By analyzing the influence of error in visual draft reading, it can be concluded that the largest discrepancies caused by errors in draft reading appear with the displacement calculated on the basis of the quarter mean draft. Final displacement differs from the previously observed displacement in trim correction which is of relatively low values in the observed analysis. An error in midships draft reading leads to significant displacement discrepancy compared to discrepancies caused by error in forward and aft draft readings. The discrepancies in results of observed segments in the calculations of weight of cargo onboard ship have a linear trend in comparison with draft reading errors.

The observed errors in calculating the weight of cargo onboard ship directly financially damage one or more parties in the maritime transport process. The suggested analysis gives more accurate methods of draft measuring. In the following part of the paper the possibility of using optical fibre technology in draft reading will be considered.

4. DESIGNS OF OPTICAL FIBRE SENSOR FOR LIQUID LEVEL MONITORING

Fibre optic sensor technology offers significant advantages over other conventional sensors. Some of the attractive features of the fibre optic sensors include their small size, real-time monitoring, fast response, stability, large dynamic range, and remote access. Moreover, light consists of photons, which do not carry any charge and are immune to the electromagnetic fields. Therefore, fibre optic sensors are more reliable and safer when deployed in adverse environmental conditions [6].

Among the different devices proposed to measure the liquid level, fibre optic sensors have attractive properties. In fact, their non-electrical nature makes them suitable for chemical liquid explosives or flammable fuels control, as well as for dangerous environment [7]. Optical technologies with optical fibres are intrinsically safe in nature, with no risk of explosion even under malfunction operation. For this reason the device may be used in the all kinds of ships.

In its simplest form, a fibre optic sensor consists of a light source, an optical fibre, a sensing element, and a detector. The light source may be a broadband, a light-emitting diode, or a laser, depending upon the nature of the sensor. When the sensing element is an essential part of the fibre, the sensor is called an intrinsic sensor. When the fibre is only used to guide light to and from the sensing element, the arrangement is known as an extrinsic sensor [8]. The physical properties of light such as amplitude, frequency, phase, and polarization passing through the sensing element can be affected by the change in the environment surrounding the sensing part of the sensor [9]. In this concept of measuring the ship's draft, instead of visual draft reading we suggest the implementation of optical fibre technology draft reading.

For this purpose an intrinsic measuring device for precise continual monitoring of liquid levels may be used. A similar device was used for measuring liquid levels in tanks filled with various liquids [10].

Such device consists of a light source, sensor and optical detector. Light source is LED which was tested with power and temperature fluctuation, and also the external lighting conditions varied, subjecting the device to darkness and sunlight. Through all these alterations, the modulation guards against any effect in the final measurement [10]. The LED used in the device will be adjusted to have adequate output power so that the signal t reaches the detector after having flowed through the optical fibre, even with minimum ship's draft (minimum liquid level is in draft sounding pipe).

The optical detector is a PIN photodiode, made on flat silicon technology basis, with a theoretical working temperature in the range from -55° to 125°C, and other acceptable characteristic for precise measurement in ships operating conditions. The research was carried out indicating that the LED emission is constant and the obtained measurement results did not significantly differ over time or with temperature changes [10].

The plastic optical fibre (POF) is the sensor in such a measuring device. The diameter of the fibre used in our device may be from 2.2mm to 3mm. In the vertical pipe of draft monitoring system it will be placed within a plastic strip with free lower part to make the appropriate curvature radius (it will be bent 180°). The POF fibre curvature within the main pipeline does not influence the measurements and calibrations. From LED to end of the curvature POF is only used to guide light to the sensing element and it has the custom cladding layer (polyethylene jacket) around the outer region of the tip. The cladding layer around the outer region of the POF tip at the end of curvature to the end of the maximum ship's draft region is removed. This part of POF is used as a sensing element. The rest of POF is used to guide the signal to the optical detector and will be protected by primary coating.

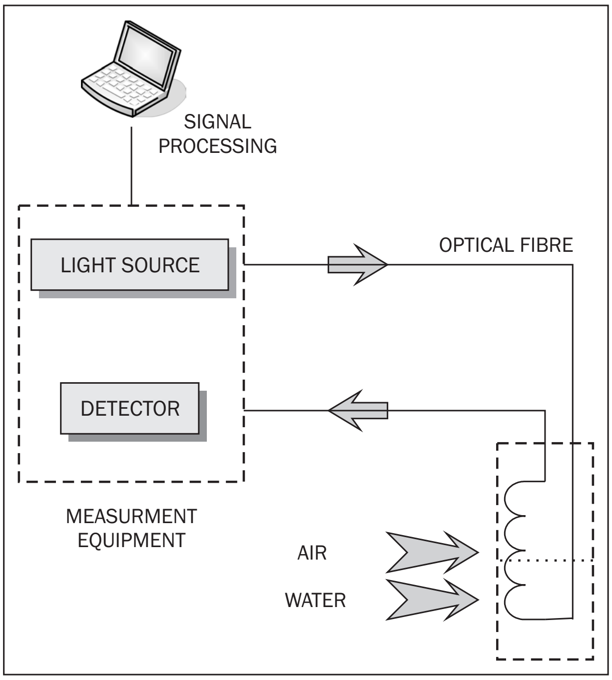

Figure 5 - General scheme of the gauge for measuring water levels

All of device characteristics exceed the requirements of our draft reading measurement design. The liquid level measurement can be accurately obtained in millimetre precision, using the aforementioned system. This represents a significant improvement compared to the existing systems that are used onboard ships for this purpose. The real measuring conditions due to the limited operations conditions of merchant ships will never reach or exceed the limits of the photodiode and LED characteristics.

5. IMPORTANCE OF OPTICAL FIBRE SENSOR IN SHIP'S DRAFT READING TO DETERMINE WEIGHT OF CARGO

The system design shows a new approach in draft reading and it demands certain constructive construction solutions, which would enable ship's draft readings from inside the ship's hull.

The pipeline of an appropriate diameter would be attached to the inflow of liquid in which the ship is floating by means of a bottom valve. The branching of the pipeline through the inside part of the hull would be conditioned by the positions of the draft marks on the outside part of the hull's plate. The concept design for the optical fibre technology draft reading is shown in *Figure 6*.

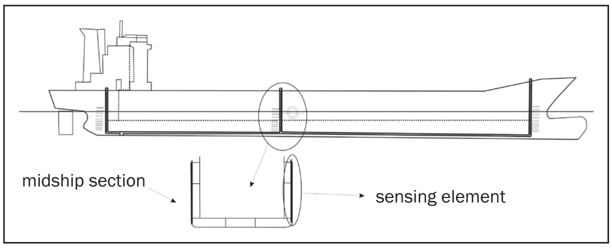

Figure 6 - System design for optical fibre technology draft

In this paper we proposed a liquid level optical sensor for measuring the sea level in the sounding pipe. By opening the bottom valve at the point where the sea enters the main pipe, the system would fill up with seawater in which the ship is emerged. In each branch, the level of liquid would correspond to the level of waterline to which the ship is emerged at the position of the pipe branch.

The principle of operation of the POF sensor used in this study is based on the loss of total internal reflection or absorption of evanescence wave when the probe is immersed into the water inside the branching pipeline. The schematic of the proposed liquid level optical sensor for draft reading is shown in *Figure 7*.

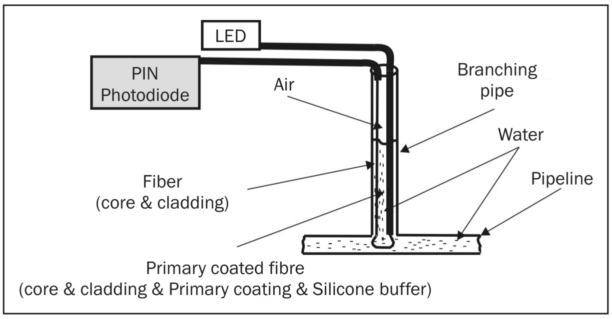

Figure 7 - Schematic of the liquid level optical sensor

The light from a LED is directed into an optical fibre appointed in the each vertical branching of pipeline conditioned by positions of draft marks. The light moves through the optical fibre. The part of the optical fibre submerged in the water to draft level behaves as fibre with double cladding (the water acts as the second cladding, with refractive index about 1.3). The light travels as cladding-mode rays because the total internal reflection occurs at the core–cladding interface. The rays of light arrive to the PIN photodiode as detector, almost without loss, except for absorption. On the part of optical fibre in the branch of the pipeline exposed to air (refractive index about 1), less total internal reflection occurs because the optical fibre has only the cladding and there are more leaky rays.

The intensity of the optical signal arriving at the output end of the fibre will be reduced correspondingly. It follows that when the optical fibre is not immersed in the water, more light will be lost from the optical fibre into the air.

The optical fibre will be calibrated for the different water heights (drafts) in the branch of the pipeline. The outgoing signal is processed by the detector and the water height in the branch of the pipeline can be determined. The higher draft means the larger value in the reading of the PIN photodiode. The calibrated curves in each branch of the pipeline will be the same. As they have a similar device used for measuring liquid levels in tanks the calibrated curve will be similar [8], and it will be shown in *Figure 8*.

Figure 8 gives a calibrated curve and indicates the response of the PIN photodiode according to the height of the liquid inside the container and for the water heights (drafts) in the branch of pipeline will be very similar. The results in the case of fresh water and seawater were so similar that these values are represented in a single row [8]. It can therefore be concluded that regardless of the density of water where the ship is sailing the calibration will be the same.

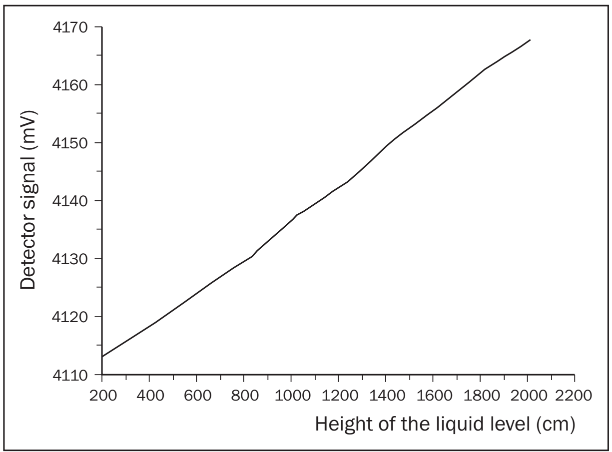

Figure 8 - Calibrated curve of fresh water and seawater

Source: F. Perez-Ocon, M. Rubino, J.M. Abril, P. Casanova, J.A. Martinez, Fibre-optic liquid-level continuous gauge, Elsevier, 2005

The results of the measuring sea levelling sounding pipes are connected to the ship systems which use the draft reading data. The observed draft value obtained via this method would be used as input data in the ship's cargo master and navigation system. The block-scheme of connecting the optical sensor measuring system with the systems which use information on a certain draft is shown in *Figure 9*.

The main advantage of using optical fibre technology in draft reading is in the elimination of possible errors which appear during the visual draft reading. The calculation of cargo weight onboard ship is more precise and it enables the ship-owner, as one of the participants in maritime transport process, higher accuracy in measuring the real cargo mass of a ship. Draft survey has been used most frequently on bulk carriers, although it can be used on other ships as well. The total deadweight of bulk carrier's fleet for 2010 was

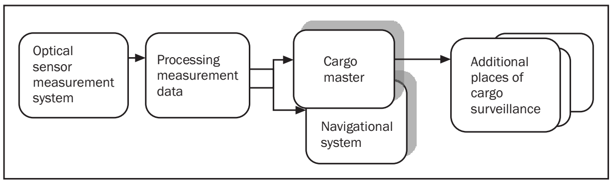

Figure 9 - Block-scheme of connecting optical sensor measuring system with systems which use information on certain draft

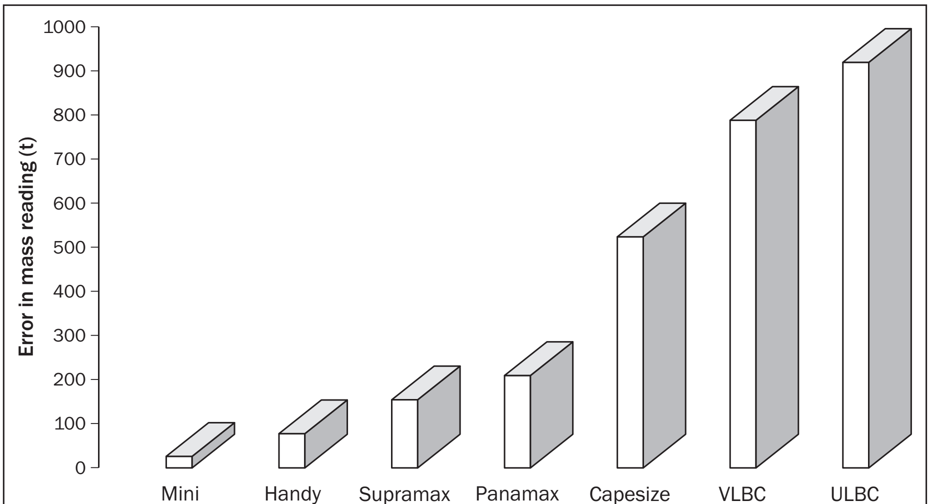

Figure 10 - Possible avoidance of error in determining mass for different bulk carriers categories using optical fibre sensor for draft reading

about 467 million tons. The direct possibility of errors that most affect the accuracy in determining weights onboard ship will be avoided by the application of optical sensors for measuring the sea level. For example, the assumed error in the draft readings of 2cm was taken, which is possible in most cases. By using fibre optic sensors for draft reading there is a possibility to avoid errors of the approximate weight for certain categories of ships for the transport of bulk cargo, as shown in *Figure 10*.

We should bear in mind the carrying capacity of ships for the transport of bulk cargo, as well as the fact that approximately 259 million tons of total deadweight of bulk carriers has been ordered in 2010. This indicates a search for new technologies in reading draft, and one of the options is draft reading by optic fibre technology.

It is possible to transmit draft reading data to additional places of cargo surveillance by means of optical fibre technology. This additionally reduces the possibility of the occurrence of error that happens in the standard data transmission technologies onboard ship.

Equipping of a ship with the considered systems, which enable draft measuring without the influence of objective, or in some cases, direct subjective erring possibility in draft reading, requires certain expenses for the ship-owner. The cost-benefit analysis study could determine an approximate cost effectiveness of the project, which, according to the authors' opinion, is long-term positive.

6. CONCLUSION

The method of determining weight of cargo onboard ship plotted by draft survey is susceptible to certain systematic, as well as accidental errors. The observed drafts are a significant factor which influences the precision of the implemented method because they represent input parameters for calculating the cargo mass on a ship.

This paper has presented the analyses of influence of draft reading error on the quarter mean draft, on the displacement read from hydrostatic tables based on the quarter mean draft and on the final displacement for a ship which, by all its characteristics, belongs to Handymax group of ships. The presumed error in draft readings on bow, stern and at midships was observed in the value range of -10cm to +10cm for change size of 1cm. By analyzing the influence of error in visual draft reading, a conclusion can be made that the largest discrepancies caused by errors in draft reading appear with the displacement calculated on the basis of the quarter mean draft. The final displacement differs from the previously observed displacement in trim correction which is of relatively low values in the observed analysis. An error in midships draft reading leads to significant displacement discrepancy compared to the discrepancies caused by error in forward and aft draft readings.

The observed errors in calculating the usable load-bearing capacity of a ship damage directly financially one or more parties in the maritime transport process. Therefore, the conducted analysis indicated the need for more precise methods of draft measuring and it considers the possibility of using optical fibre technology in draft reading.

In this concept of measuring ship's draft, instead of visual draft reading we suggested the implementation of optical fibre technology draft reading. The system design shows a new approach in draft reading and it demands certain constructive building solutions which would enable ship's draft readings from inside the ship's hull. A pipe of an appropriate diameter would be attached to the inflow of liquid in which the ship is floating by means of a bottom valve. The branching of the pipe through the inside part of the hull would be conditioned by positions of draft marks on the outside part of the hull's plate. Each pipe branch would be equipped with special subcategory of intrinsic sensors, so-called distributed sensors, in the area of ship's draft. The changes between the refractive indices of air and liquid generate signal power proportional to the position of the submerged connection, or the level of liquid in the pipe branch. The necessary measuring area would be limited by ship's draft zone.

In each branch the level of liquid would correspond to the level of waterline to which the ship is emerged at the position of pipe branch. A signal from the distributed sensor comes to the optical sensor and converts to electrical signal, which is further transmitted to the ship's systems which use draft readings. The observed draft value obtained by means of this method would be used as input data in the ship's cargo master and navigation system. The main advantage of using optical fibre technology in draft reading lies in the elimination of possible errors which appear during visual draft reading. The calculation of weight of cargo onboard ship is more precise and it enables all of the participants in maritime transport process higher accuracy in measuring the real cargo mass of a ship.

Equipping of a ship with the considered systems, which enable draft measuring without the influence of objective, or in some cases, direct subjective erring possibility in draft reading, requires certain expenses for the ship-owner. The project cost effectiveness can be determined using the cost-benefit analysis study. The authors expect that it will be positive in the long-term period.

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SAŽETAK

UTVRĐIVANJE KOLIČINE TERETA NA BRODU UZ POMOĆ GAZA PRIMJENOM SVJETLOVODNE TEHNOLOGIJE

Točnost u određivanju mase ukrcanog, ili iskrcanog tereta korištenjem metode određivanja mase temeljem očitanog gaza varira zbog sustavnih i slučajnih pogrešaka. U radu je izvedena analiza greške očitanja gaza na stvarni srednji gaz, deplasman na temelju stvarnog srednjeg gaza i završni deplasman. Autori su analizirajući problem došli do zaključka o značajnom utjecaju pogreške u očitavanju gaza, posebno na oznakama gaza na sredini broda. Sugerira se primjena svjetlovodne tehnologije kao nova metoda očitanja gaza. U radu autori predlažu korištenje optičkih senzora za mjerenje razine mora u sondi sustava Očitanja gaza s optičkih senzora će se uvoditi u brodski navigacijski sustav i računalni sustav nadzora tereta.

KLJUČNE RIJEČI

gaz broda, greška očitanja gaza, svjetlovodna tehnologija, optički senzori za mjerenje razine tekućine

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