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THE CALCULATION OF HULL DEFORMATIONS BASED ON THE DECK INCLINATION ANGLES MEASURING

IZRAČUN DEFORMACIJA TRUPA MJERENJEM KUTOVA NAGIBA PALUBE

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Preliminary communication
Prethodno priopćenje

Summary

The possibility of ship hull deformation determination by measuring the angles of inclination at measuring points has been analyzed in the paper. The hull deformations have been reduced on relative and absolute shifts of measuring points in vertical longitudinal symmetric plane. The hull deformation values (of measuring points relative and absolute shifts) are determined by presuming the small deformations referred to the ship length/ measuring points distances, and the ship deck line, between measuring points, approximation by elements of circle. The measuring points are placed at the points of connection of shear strake, deck stringer and transversal bulkhead, i.e., at the points of maximal local stiffness. In that way the influence of local deformations on the accuracy of the inclination angles measuring has been declined.

Sažetak

U radu je analizirana mogućnost određenja deformacija trupa broda mjerenjem kuteva nagiba u mjernim točkama trupa. Deformacije trupa svedene su na relativne i apsolutne pomake mjernih točaka u vertikalnoj uzdužnoj simetralnoj ravnini. Veličine deformacija trupa (relativnih i apsolutnih pomaka mjernih točaka) određene su uz pretpostavku malih deformacija u odnosu na duljinu broda, udaljenost između mjernih točaka i aproksimaciju linije palube između mjernih točaka elementima kružnog luka. Mjerne točke smještene su u točkama spoja završnog voja, palubne proveze i poprečne pregrade tj. u točkama najveće lokalne krutosti čime je otklonjen utjecaj lokalnih deformacija na točnost mjerenja kuteva nagiba.

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1. Introduction
Uvod

The ship hull performances control in service conditions could be obtained using the system that consists of electronic inclinometers, digital/analog converter, personal computer and related software as described in [1] and [2]. To ensure the ship hull overall deformation measuring only and to avoid the local deformation influence, the measuring points are placed on the points where the highest local stiffness is obtained. For all types of ship hull structure those places are connections of shear strake, deck stringer and transversal bulkhead. At those points the local deformation influence on the measuring point inclination angles measuring accuracy could be neglected. For tankers equipped with central longitudinal bulkhead, the connection of deck, longitudinal and transversal bulkhead can also be considered as measuring point place. An example of measuring points possible placing is shown in the Fig. 1.

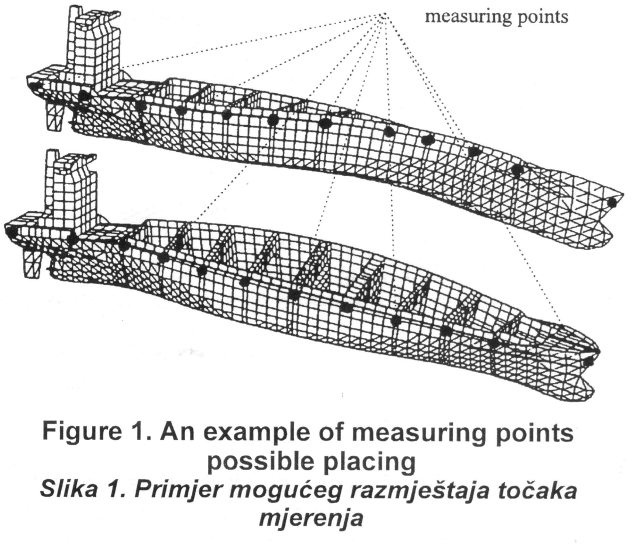


Figure 1. An example of measuring points possible placing
Slika 1. Primjer mogućeg razmještaja točaka mjerenja

The measuring point consists of two electronic digital inclinometers directed to x and y coordinates axes respectively, as it is shown in the Fig. 2.

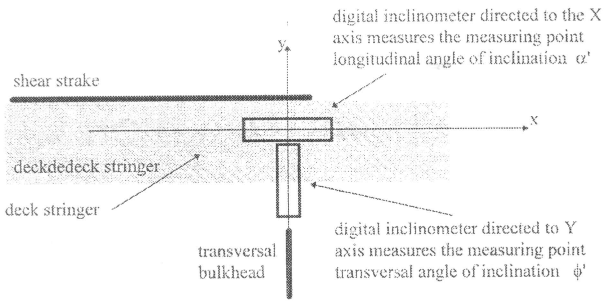


Figure 2. Inclinometers positioning
Slika 2. Postavljanje inklinometara

2. The measuring points scanning results
Rezultati očitanja s mjernih točaka

By scanning of digital inclinometers, in previously defined time intervals, the measuring values, as it is shown in the Table 1, could be obtained. The inclination angles obtained by scanning are not real but virtual angles of measuring points inclination. That appears due to mutual influence of inclination in x and y direction, where the inclination in transversal direction decreases the measured angle of inclination in longitudinal direction and contrariwise.

Table 1. Measuring values
Tablica 1. Mjerne vrijednosti

Measuring point	Longitudinal angle of inclination	Transversal angle of inclination
MP1	α_1'	ϕ_1'
MP2	α_2'	ϕ_2'
......	......	......
MPi	α_i'	ϕ_i'
......	......	......
MPn	α_n'	ϕ_n'

The correction of angles a' and f' due to mutual influence of longitudinal and transversal inclination will be done in the following manner. The first step is to make correction of the transversal inclination angle value as follows:

$$\phi_i = \frac{\phi_i'}{\cos\alpha_i} \qquad (1)$$

where ϕ_i is corrected transversal inclination angle. The longitudinal inclination angle correction should be done according (2).

$$\alpha_i = \frac{\alpha_i'}{\cos\phi_i} \qquad (2)$$

where α_i is the corrected longitudinal inclination angle of the measuring point. The corrected measured data are shown in Table 2.

Table 2. Corrected measured data
Tablica 2. Inspravljene izmjerene vrijednosti

Measuring point	Corrected longitudinal angle of inclination	Corrected transversal angle of inclination
MP1	α_1'	ϕ_1'
MP2	α_2'	ϕ_2'
......	......	......
MPi	α_i'	ϕ_i'
......	......	......
MPn	α_n'	ϕ_n'

3. The measuring points shift calculation
Izračun pomaka mjernih točaka

The relative and absolute measuring points shifts could be determined presuming the following:

1 distances between measuring points is small if it is compared to the ship hull length;

2 deformation of the deck line is small if compared to the distance between measuring points.

If presumptions 1 and 2 are correct, according to the Theory of Elasticity, the deck line between two measuring points could be approximated by the part of circle. The scheme of deck line with marked measuring points is shown in the Fig. 3.

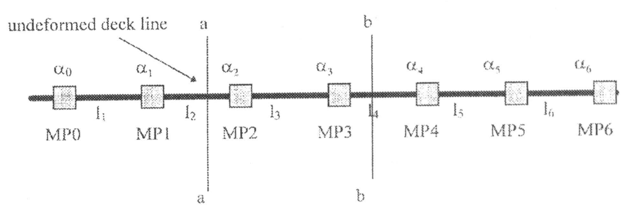
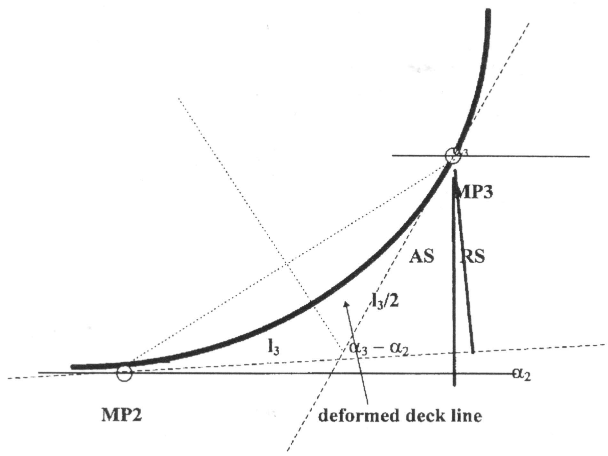


Figure 3. Deck Line with measuring points
Slika 3. Palubna crta s mjernim točkama

One can analyze the deck line segment between the lines a-a and b-b. The deformed deck segment a-a/b-b is shown in the Fig. 4.



AS - absolute shift of the MP3 in relation to the MP2
RS - relative shift of the MP3 in relation to the MP2

Figure 2. Inclinometers positioning
Slika 2. Postavljanje inklinometara

Relative and absolute shifts of the MP3 counted the presumptions 1 and 2 according to the Fig. 4 are:

$$RS_3 = \frac{l_3}{2} \cdot sin(\alpha_3 - \alpha_2) \quad (3)$$

and

$$AS_3 = l_3 \cdot sin\alpha_2 + \frac{l_3}{2} \cdot sin(\alpha_3 - \alpha_2) \quad (4)$$

The displacements of any measuring point on the ship, are:

$$RS_i = \frac{l_i}{2} \cdot sin(\alpha_i - \alpha_{i-1}) \quad (5)$$

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$$AS_i = l_i \cdot sin\alpha_{i-1} + RS_i \quad (6)$$

Total displacement of the measuring point MPj in relation to the measuring point MP0 is:

$$D_j = \sum_{i=1}^{j} \left[l_i \cdot sin\alpha_{i-1} + \frac{l_i}{2} \cdot sin(\alpha_i - \alpha_{i-1}) \right] \quad (7)$$

4. Conclusion
Zaključak

The performed analysis indicates that, along with the acceptable presumptions, it is possible to control the hull performances (the overall ship hull deformations) in very accurate and reliable manner. This analysis.obtains an essential improvement compared to the SAJ Instruments AB, TCL-2000 system (The Motor Ship, May 1996.). The possibility of hull deformation calculation has been proved. The paper is completely based on the basic idea of hull performances control presented in the papers [1], [2] and [4].The particular advantage of the analysed system is possibility of realization of the ship hull expert system for continous control in service conditions and a decision making support to the navigation.

References
Literatura

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