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Modeling impact resistance of the ships hull

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Abstract

Ships' hull usually works in a hard environment caused by static forces and permanent dynamic loads. Modeling of dynamical reactions could bring information to the designer for recognizing the level of hazard for hull structure and propulsion system. A paper presents a proposal of identification of a degree of hazard the ships hull forced from underwater explosion. A theoretical analysis was made of influence of changes of hull structure in vicinity of shaft bearing foundations. The main problem of naval vessels is a lack of dynamical requirements of stiffness of the hull. Modelled signals and hull structure were recognized within sensitive symptoms of three sub models: model of hull structure, model of impact and model of propulsion system. All sub models allow testing forces and their responses in vibration spectrum using SIMULINK software.

Introduction

Minehunters are subjected to specific sea loads due to waving and dynamical impacts associated with underwater explosion. Sea waving can be sufficiently exactly modeled by means of statistical methods. Much more problems arise from modeling impacts due to underwater explosion. Knowledge of a character of impulse loading which affects ship shaft line can make it possible to identify potential failures by means of on-line vibration measuring systems.

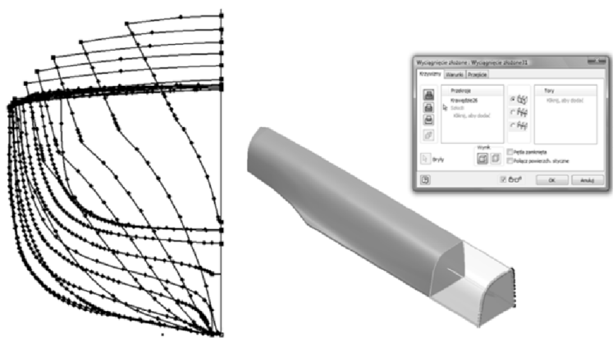
Spatial model of minehunter FM 206 type

The minehunters of FM 206 type a.o. belong to the Polish Navy ships which are subjected to researches tests figures 1–3. They are equipped with the propulsion systems fitted with two Sulzer AL 25/30 engines.

Underwater explosion

Knowledge of loads determined during simulative explosions is helpful in dimensioning ship's hull scantlings [1]. Another issue is possible quantification of explosion energy, as well as current potential hazard to whole ship and its moving system. From the point of view of shock wave impact on shaft line, underwater and over-water explosions should be considered in two situations:

- when shock wave (or its component) impacts screw propeller axially;
- when shock wave (or its component) impacts screw propeller perpendicularly to its rotation axis.



a) b)

Fig. 1. Creating a spatial model: a) fuselage sections; b) effect of using the loft function

The axial shock-wave component affects thrust bearing and due to its stepwise character it may completely damage sliding thrust bearing. Rolling thrust bearings are more resistant to stepwise loading hence they are commonly used on naval ships [1].

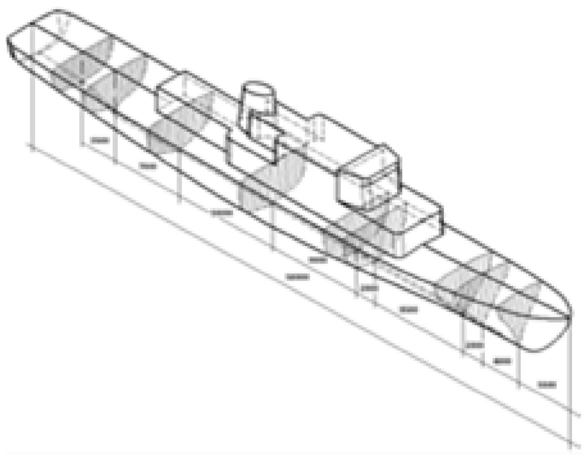


Fig. 2. Distances between watertight bulkheads

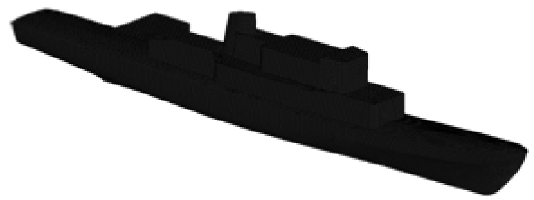


Fig. 3. Grid view model of the minehunter 206FM

The shock wave component perpendicular to shaft rotation axis is much more endangering. Shock wave can cause: damage of stern tube, brittle cracks in bearing covers and tracks, plastic displacement of shaft supporting elements including transmission gear and main engine, and even permanent deformation of propeller shaft. The problem of influence of sea mine explosion on hull structure is complex and belongs to more difficult issues of ship dynamics. Underwater explosion is meant as a violent upset of balance of a given system due to detonation of explosives in water environment. The process is accompanied with emission of large quantity of energy within a short time, fast running chemical and physical reactions, emission of heat and gas products. The influence of underwater explosion does not constitute a single impulse but a few (2 to 4) large energy pulsations of gas bubbles [2]. The pulsation process is repeated several times till the instant when the gas bubble surfaces.

Hence the number of pulsations depends on immersion depth of the explosive charge. The character of changes of pressure values in a motionless point of the considered area is shown in figure 2. In the subject-matter literature can be found many formulae for determining maximum pressure value, based on results of experiments; however data on a character of pulsation and its impact on ship structures are lacking. To identify underwater explosion parameters a pilotage test was performed with the use of the explosive charge having the mass $m = 37.5$ kg. The schematic diagram of the experiment is shown in figure 4.

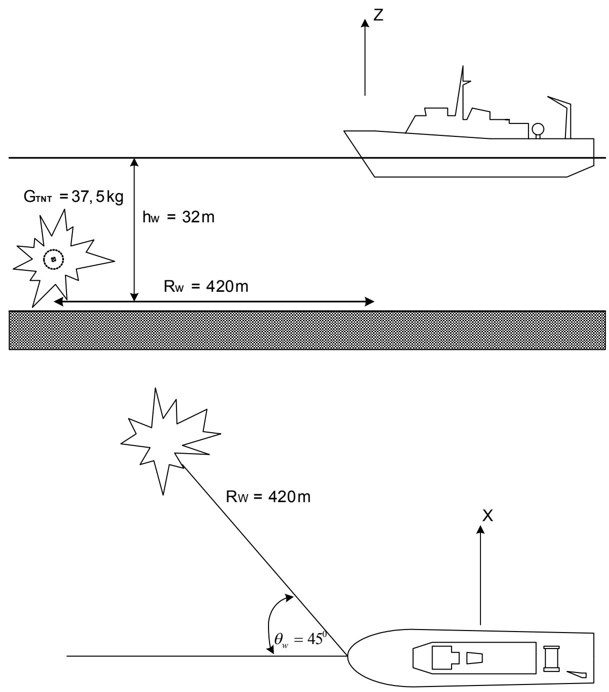


Fig. 4. Schematic diagram of the performed experimental test

During the sea-test were measured vibration accelerations of casings of intermediate and thrust bearings in the thrust direction and that perpendicular to shaft rotation axis. The ship course angle relative to the explosion epicentre was 450 and the shaft line rotated with the speed nLW = 500 rpm. Ship's distance from the mine and its immersion depth was determined by using a hydro-location station and ROV underwater vehicle (Fig. 5). The vibration gauges were fixed over the reduction gear bearing, as well as on the intermediate shaft bearing.

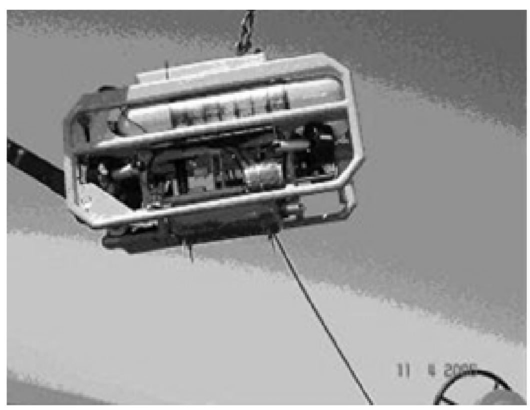


Fig. 5. ROV vehicle with TNT charge

The typical measurement record, in the vertical directions, is presented in figure 5. The time waveform of acceleration of the recorded signals was the same in all measurement points.

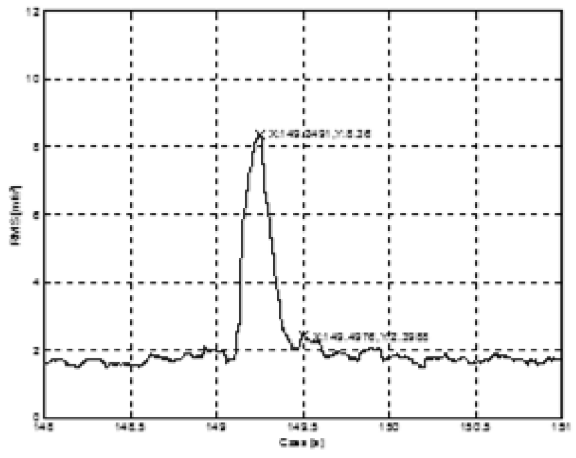


Fig. 6. Explosion, Port side (LB), Thrust bearing, V axis

The performed tests were aimed at achieving information dealing with:

- character of shock wave impact on shaft-line bearings , in the form of recorded vibration parameters;
- assessment of time-run of vibration accelerations with taking into account dynamic features of the signals in set measurement points;
- assessment of possible identification of influence of pulsation of successive gas bubbles during the time-run of vibration accelerations;
- identification of features of the signals by means of spectral analysis.

Since the mass of the explosive charge was small, to reliably identify the effect of only first and second pulsation was possible during the test.

Models of excitation due to underwater explosion

Analysis of dynamic impacts including impulse ones should take into account basic parameters which influence character of time-run of a given signal as well as its spectrum. The basic parameters which identify impulse impact resulting from explosion are the following:

- form of impulse which identifies kind of impulse;
- impulse duration time t_I at the ratio A/t_I maintained constant, which identifies explosive charge power time of propagation of gas bubble);
- influence of damping on spectrum form, which identifies distance from explosion and – simultaneously – epicentre depth
- number of excitation impulses, which informs on distance from explosion, combined with explosive charge mass;
- time between successive impulses, which characterizes explosive charge mass.

The possible recording of measured shock wave pressure and accelerations on intermediate and propeller shaft bearings enables to identify some explosion parameters hence also hazards to power transmission system. Analysing the run of underwater shock wave pressure one is able to assume its time-dependent function (Fig. 6 and Eq. 1):

$$A = at^{kb} \cdot e^{kct} \qquad (1)$$

For the assumed mathematical model of the first shock wave impulse the run of vibration accelerations recorded on ship hull – can be presented as shown in figures 7 and 8.

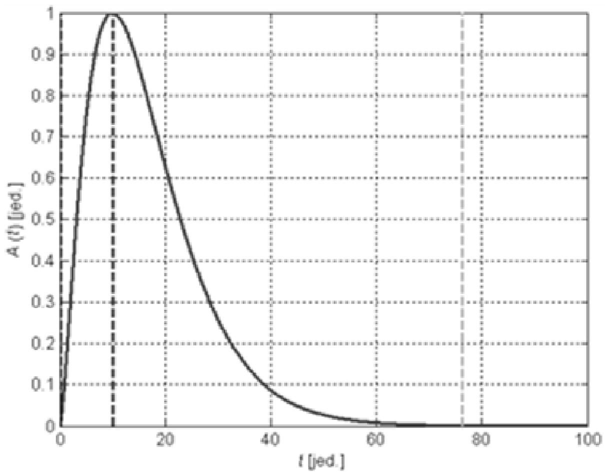


Fig. 7. Example of the function form for $b = 1.5$, $c = -0.15$ and $k = 1$

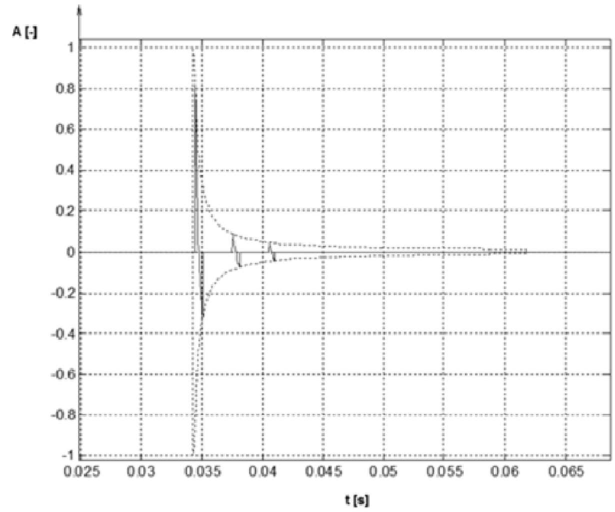


Fig. 8. Run of the assumed unit vibration acceleration model

For the assumed mathematical model of the first shock wave impulse the run of vibration accelerations recorded on ship hull – can be presented as shown in figure 9.

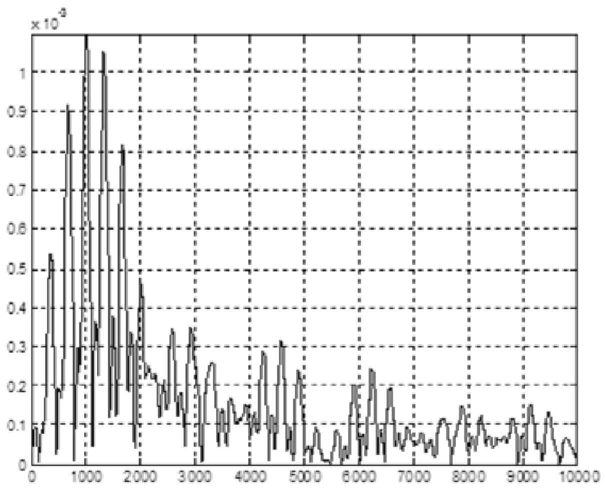


Fig. 9. Spectrum of the assumed vibration acceleration model

Conclusions

It's common knowledge that failure frequency is the most hazardous factor in marine industry, just after aeronautics. Dynamic reactions which occur on ships in service at sea are rarely able to produce wear sufficient to cause a failure. The possible application of an on-line monitoring system of vibration parameters of the propulsion system of minehunter makes it possible to perform the typical technical diagnostic tests of torque transmission system and to identify possible plastic deformations of hull plating as a result of underwater explosion.

The modelling of impulse impact form and next its identification makes it possible additionally: to identify explosion power by using an analysis of the first vibration impulse amplitude and its duration time, to identify distance from explosion epicentre (hence a degree of hazard) by analysing signal's damping, to identify a kind of explosion and even characteristic features of type of used mine, to select dynamic characteristics of a measuring system which has to comply with requirements for typical technical diagnostics and for a hazard identification system, to identify elastic or plastic deformation of shaft line by using spectral assessment of its characteristic features from before and after underwater explosion.

The presented results of modelling related to the performed experimental test do not make it possible – due to strongly non-linear character of interactions occurring in sea environment – to assign unambiguously the modelled signal features to those of the recorded ones during the real test.

Successive experimental tests will make it possible to verify features of the signals assumed for the analysis, to be able to build reliable models.

The wide range of stochastic dynamic loads acting on ships during its life-time makes that in the nearest future the application of on-line diagnostic techniques to ship propulsion systems, based on analysing vibration signals, will constitute an obvious tactical and technical necessity.

References

1. CUDNY, K., POWIERŻA Z.: Selected problems of shock resistance of ships (in Polish), Publ. Polish Naval University, Gdynia 1987.
2. COLE R.H.: Underwater Explosions, Princeton University Press, Princeton 1948.

Others

3. CEMPEL CZ., TOMASZEWSKI F. (ED.): Diagnostics of machines. General principles. Examples of applications, Publ. MCNEM, Radom 1992.
4. DĄBROWSKI Z.: Machine shafts (in Polish). State Scientific Publishing House (PWN), Warszawa 1999.
5. DIETRICH I., KOCAŃDA S., KOREWA W.: Essentials of machine building (in Polish). Scientific Technical Publishing House (WNT), Warszawa 1974.