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REDUCTION OF PROPELLER INDUCED HULL VIBRATION

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ABSTRACT

In the report the possible ways of reducing the ship's hull vibration caused by the operation of propeller are considered. The variable hydrodynamic forces accompanying the propeller operation cause the increase of the hull vibration at blade frequencies. These forces are partially transmitted through the water and their influence can be reduced by means of increasing the gap between the propeller and hull or by means of installing the special resilient structures in propeller area. The influence of the forces transmitted to the hull through the shaft line can be reduced by means of introducing the elastic elements into the bearing supports. The special attention should be paid to avoid the situation when the shaft line itself becomes the source of vibration due to its bad balancing or bad adjustment of the shaft and bearing inserts.

1 - REDUCTION OF PROPELLER INDUCED HULL VIBRATION

The reason of having the strict medical requirements to the noise and vibration levels on the ships lies in the fact that the crew and passengers are affected by these negative influences constantly.
The hull vibration being distributed in all ship's spaces in the form of structural noise is caused by the operation of the power plant and machinery, but as a rule the main source of vibration is the propeller.
The so called "vibration underway", that is the vibration related to the operation of propeller is developed in general by the frequency of rotations related to the number of blades, that is within the range of 20 - 25 Hz.
The vibration is transmitted from propeller to the hull in different ways. First of all these oscillations can be transferred by water or directly to the hull or through the rudder stock. Secondly, the vibration can be transmitted through the shaft line and the bearing (journal bearing and thrust bearing) to the hull. The oscillation distribution diagram is given on figure 1.
The influence of force transmission from the propeller through the water to the hull can be reduced by means of increasing the gap between the propeller and hull, for example by means of having the special recess in the hull above the propeller.
The additional advantage can be gained by means of providing the vibration insulation in propeller area locating the elastic coating on the hull (see fig. 2).
Certain experiments were made when the passive damper in the form of the weight on elastic supports was installed (see fig. 3) in order to reduce the vibration in the aft body of the hull.
The motor vessel "Maxim Gorky" built by "Kornoyburg", Austria was equipped by vibration insulators (dampers) located above propellers, with the weight of 1500 kg on the distance of 150 mm from the end of propeller blade thus permitting to reduce the hull vibration by 7 - 15 dB. The influence of vibration transfer from propeller through the water to the rudder blade and along the rudderstock to the ship's hull can be reduced by means of providing the vibration insulation of the rudderstock (see fig. 4).
The reduction of the forces being transmitted to the hull through the shaft line can be provided by means of making the shaft line supports flexible. For the compensation of forces acting in the longitudinal direction it is advisable to introduce the elastic component into the main thrust bearing (see fig. 5).

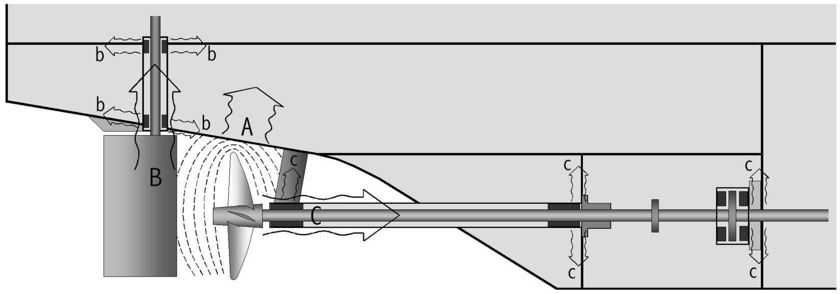

Figure 1: The diagram of vibration distribution in the ship's hull, the vibration being the result of propeller operation; A - from propeller through the water to the hull's plating; B - from propeller through the water to the rudder blade, rudder stock, bearings and hull; C - from propeller through the shaft line, bearings and hull.

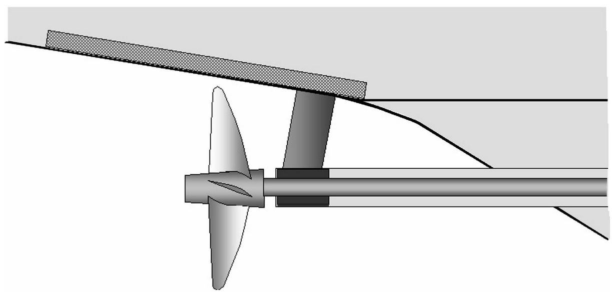

Figure 2: Elastic material coating.

The reduction of the "propeller-shaft-hull" dynamic system natural frequency in the longitudinal direction permits to reduce the hull vibration levels at full speed modes. In order to avoid the increased vibration in all modes, the connection of the elastic element must be carried out only when certain selected loading value is reached (see fig. 6). In this case the resonance vibration curve of the rigid system "a" is changed by curve "b" of the softened system. In this case the system vibration levels during the switching over of the thrust bearing will not pass the limits enveloped by the curve "c".
In order to reduce the influence of transversal forces transmitted from propeller, the vibration insulation of the shaft line bearings should be provided and first of all of the aft support bearings located on the smallest distance from propeller. The increase of the aft support flexibility makes the shaft line dynamic structure similar to the well-known structure of the shafts without struts used on river vessels [1]. The prevention of the strongest vibration through the aft support and propeller shaft strut permitted to reduce the air born noise level in the aft spaces of small passenger vessels by 6-8 dB in the frequency range lower than 1000 Hz.
For the reliable reduction of motion induced hull vibration resulting from propeller operation, all the above-mentioned technical solutions should be implemented combined in order to block all vibration distribution routes.
However the shaft line serves not only as the tool transmitting the excitation from propeller to the ship's hull, but can also excite the vibration of the hull itself.
For example the imbalance and play of the shaft excite the vibration on rotation frequency thus increasing the vibration on this frequency induced by mechanical and hydrodynamic imbalance of propeller. The vibration on the rotation frequency and its harmonics can be excited due to the deviation from the cylindrical shape of the shaft neck resting on the bearing, non-stability of the shaft's contact with the bearing with big radial gap and increased bearing length.
The occurrence of the set of discrete components in the vibration spectrum is the characteristic feature of the bearing with defective inserts. For example in propeller shaft bearings shaped as planks with longitudinal grooves for lubrication and water cooling fixed in the bracket the discrete components with the interval equal to the shaft rotation frequency occur and also the abrupt raising of the continuous part of the spectrum takes place in "plank" frequency area (shaft rotation frequency multiplied by the number of planks) (see fig. 7).
The vibration levels of the shaft bearings may not change with the change of rotation frequency - the

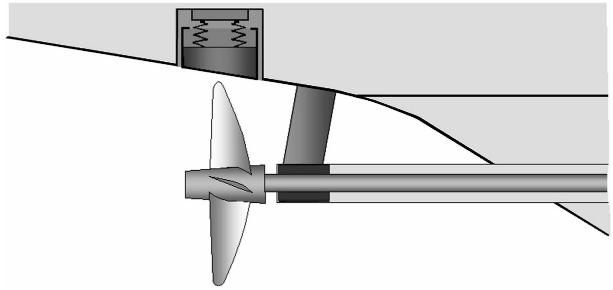

Figure 3: Load-piston hanging on elastic elements.

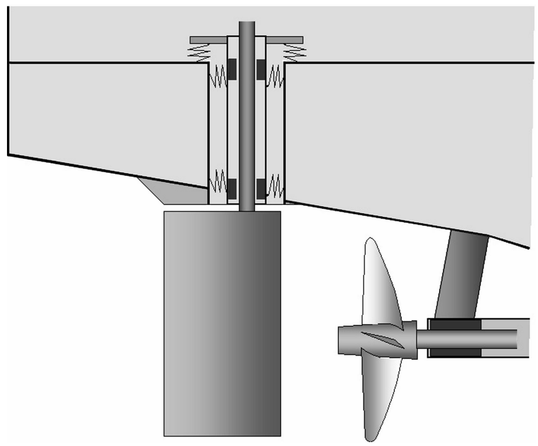

Figure 4: The scheme of the rudder stock elastic suspension.

discrete components in the spectrum just shift to the right.
In order to eliminate the defects of the shaft line as the vibration exciter, special attention should be made while designing the shaft and its bearings to the selection of the optimum bearing length providing, as much as possible, the uniform load on the insert surface.
The vibration insulation of the shaft line bearings from the ship's hull can be the efficient means of vibration reduction.

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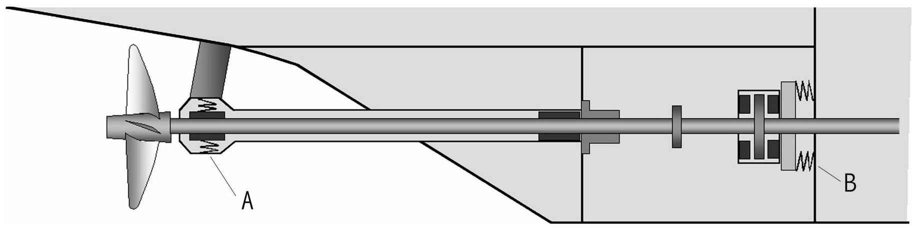

Figure 5: The reduction of vibration transmitted through the shaft line; A - the stern bearing elastic suspension; B - introduction of the elastic elements into the thrust bearing.

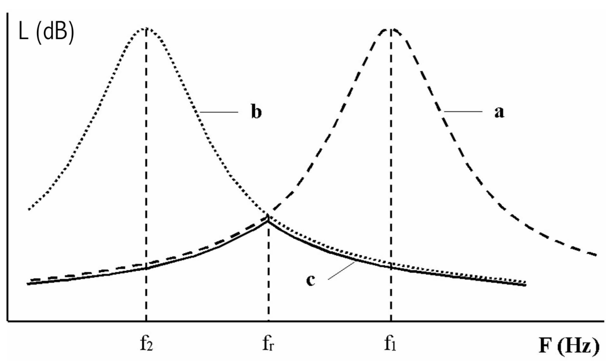

Figure 6: Changing of the shaft line longitudinal vibration with the change of the exciting forces frequency; a - with the rigid fastening of thrust bearing; b - with elastic fastening of thrust bearing; c - using the switched elastic element of thrust bearing; f- frequency of switching the thrust bearing elastic element.

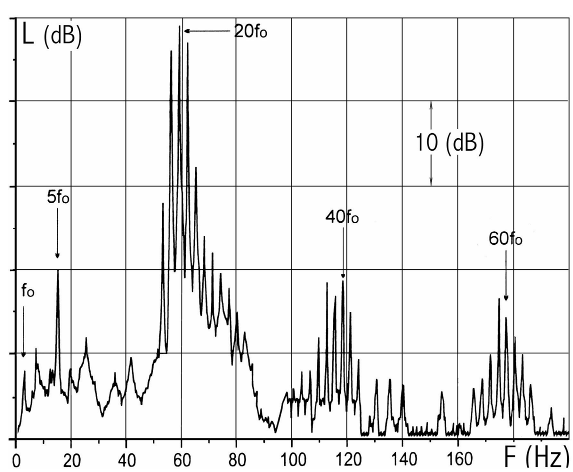

Figure 7: Stern bearing vibration spectrums at frequency rotations equal 3 Hz.