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VIBRATION AND MOUNTING OF SHIPS MAIN ENGINES

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ABSTRACT

The main engine is an enormous structure that consists of several moving parts (both rotating and reciprocating) transmitting to the propeller all the engine mechanical power in order to move the ship. Because all these main engine components are subject to different forces, in order to avoid damages due to excessive vibrations, the engine must be secured firmly to the ship. This article deals with propulsion engine mounting on foundations and their relationship to ship framing.

Keywords: main engines, ships, forces and vibrations, mountings procedures

1. INTRODUCTION

On ship board, the main engine installed will influence the machinery layout. Three principal types of machinery installation are to be found at sea today: slow-speed diesel engines, medium-speed diesels and steam turbines.

It is necessary to investigate engine room layout from the very beginning stages of the design in order to obtain good working conditions.

A ship’s main engine is a massive structure with an average height of around 14 meters and weight of 2500 tonnes. A new engine installation in the engine room are done after a procedure which divides it into parts on the basis of different parts of the engine. In the shipyard during the ship building process, the engine is installed in parts.

The main engine is fitted on the ship hull with the help of holding down bolts and chocks. The bedplate which is the base of the engine is attached by means of holding down bolts and chocks arrangement and the floor where the engine is installed is excessively strengthened by heavy flooring and using additional bars and girders.

2. VIBRATIONS CAUSED BY A MOTOR AND MEANS OF REDUCING THEM

The forces acting on an engine cause mechanical stresses or stresses in its structure itself. These stresses are transmitted to the foundation surface of the engine and cause annoying vibrations for ship structures or adjacent auxiliary equipment in the engine room. These forces are caused by different phenomena.

Moreover, it is also the balancing of the components and the methods of reduction of the vibrations caused by an engine.

2.1. FORCES CAUSED BY THE MOVING PARTS INERTIA

Two types of forces caused by the inertia of moving parts exists:

- forces caused by the inertia of rotating parts (connecting rod head and crank)
- forces caused by the inertia of reciprocating parts (piston, piston rod, etc.)

2.2. FORCES BORN BY COMBUSTION

The forces of combustion produce an internal force on the engine body. Thus, the horizontal force of the reaction of the bearing and the force of the piston against the jacket form a torque. A torque, or "torque moment", is defined as the product of the intensity of a force by its distance or lever arm.

In practice, the forces of combustion impose additional transverse oscillations on the foundations of piston or sleeve piston engines.

Summarizing, it can be said that the forces and torques generated in a single-cylinder engine will be united in a multi-cylinder engine in order to subject the whole structure to cyclic stresses which first manifest themselves by shear forces between the cylinders. These forces can subject the structure to both horizontal and longitudinal flexions. In extreme cases, longitudinal bends may cause fracture of the adjustable bolts which connect the bulkhead sections of a sleeve piston engine.

Since the principles of internal equilibrium are explained, let's now discuss the notion of external balancing of a diesel engine. By definition, it is referred to as balancing as it is external when the balancing of the engine is considered as a whole with respect to the environment. We shall also see what devices are put in place to protect the engine and the structure of the ship from the inevitable vibrations of both.

2.3. EXTERNAL BALANCING OF AN ENGINE

Until now, there have been studied the forces undergone by the components of a single cylinder single engine. In fact, the presence of several cylinders facilitates the equilibration conditions since, on the one hand, the driving torque is more regular and, on the other hand, the composition of several vertical and horizontal forces can reduce the amplitude of the resultant. Thus, there is a certain composition of the effects of inertial forces in the case of the six-cylinder engines in line as well as in the case of a twelve-cylinder V-engine. Indeed, from the point of view of Equilibrium, a V-engine is nothing but a set of two in-line motors, offset with respect to each other, by an angle equal to that measured at the top of the V. For these Motors, the result of the vertical inertia forces is zero.

In general, engine balancing must meet the following requirements established by the manufacturers:

- in the great majority of cases, experience allows the engine to be considered very rigid, so that internal balancing and perfect external balancing are not required;

In general, the installation of counterweights on the crankshaft cheeks is sufficient to reduce the vertical and horizontal forces to acceptable values. Absorbed by the bearings of the crankshaft, these forces will be transmitted to the hull. What is most important is that these weights should be placed in such a way that, under the result of all efforts, the minimum value of the thickness of the oil film of each bearing is sufficient to prevent any contact between the two surfaces displaced under load relative to each other;

- for slow-moving engines with a reduced number of cylinders (four or five), torque irregularity and the weight of the moving parts of an alternating or rotating movement cause high external forces or moments.

In order to reduce the external moments produced by the vertical and horizontal forces, manufacturers opt for one of the two following solutions: placing counterweights on flywheels at each end of the crankshaft, or using Lanchester pendulums.

2.3.1. Installation of counterweights on flywheels located at each end of the crankshaft

The balancing technique depicted in Fig. 1 compensates for the first-order vibrations caused by the masses of inertia in rotation. Indeed, we already know that the use of counterweights on the crankshaft of this type of engines is insufficient. Furthermore, after a precise adjustment of their respective position, the counterweights on the flywheels will produce a minimum vertical force combined with a maximum horizontal force. These masses will therefore be arranged in such a way as to create an equal and opposite force to the horizontal force produced by the movement of the masses of inertia in rotation. We will then take into account the principles of balancing already stated.

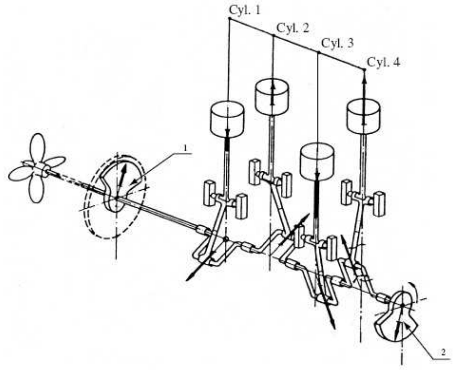

Fig.1. Balancing of first-order external moments for a slow propulsion engine, two-stroke (1-C-weight driven by the rear wheel, 2-C-weight driven by the front wheel)

2.3.2.Using Lanchester Balancers

The Lanchester balancers, whether driven by a chain or a gear, are formed of two counterweights or masses which rotate in opposite directions at a speed equal to twice that of the engine (Fig. 2).

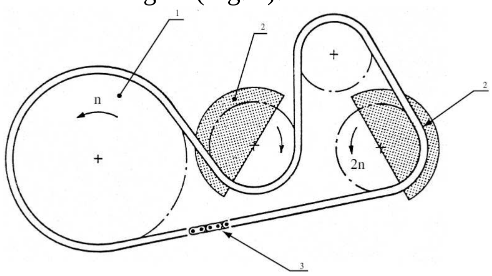

Fig.2. Lanchester Balancers (1- Camshaft; 2- C-weight; 3- Drive Chain; n) Crankshaft Rotation; 2n) Rotation of the counterweight, twice that of the crankshaft)

Each mass produces the same vertical reaction. This reaction is opposed to the displacement of the piston. The counterbalances of the Lanchester balances thus cancel out the vertical forces created by the inertial masses in reciprocating motion. Similarly, and since these counterweights are in opposite rotation, the horizontal reaction of each of the masses vanishes.

In fact, the use and arrangement of these pendulums in the building, as illustrated in Fig. 3, makes it possible to significantly improve the external equilibration. On the other hand, they generate considerable internal forces in the structure, in particular on the bearings in which the axes driving these balancing masses rotate. It is necessary that the released energy dissipates somewhere.

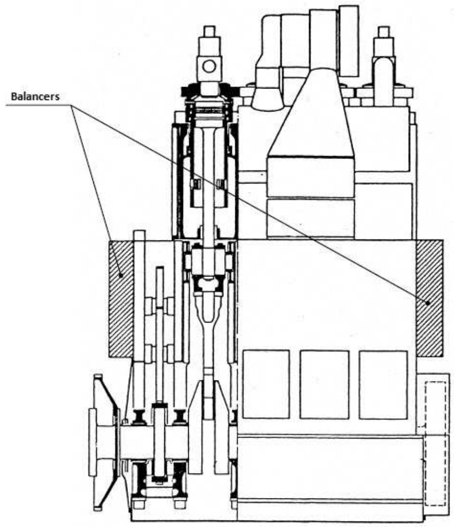

Fig.3. Positioning of Lanchester balancers for a slow motor

The hull of a ship which has interstitial disorders will be advantageous to crevice corrosion if it is docked at the wharf on the open sea. Indeed, once at sea, these interstices are no longer considered as of confined environments due to fluid renewal inside due to vessel speed.

2.3.3.Flywheel

The flywheel is a factory and balanced mass, cast iron or steel mould. It is attached to the crankshaft, on the coupling side, by means of adjustable bolts. Serious markings on the circumference of the steering wheel facilitate maintenance. Indeed, these benchmarks indicate the pistons positions, as well as the beginning of injection into the different cylinders of the engine. The flywheel reduces the coefficient of irregularity by storing a certain amount of energy during the driving stroke, in order to restore it during the other races.

This coefficient of irregularity is defined as follows :

CI = (maximum motor moment - minimum motor moment) / average motor moment

The coefficient of irregularity is about 0.02 for propulsion engines and varies between 0.010 and 0.004 for engines that drive the generators. For two-stroke slow engines with more than four cylinders or four-stroke engines with at least eight cylinders directly driving the propeller, the inertia of the propeller is considered to have been added to the inertia of the line of trees is sufficient to ensure the regularity of the engine without steering wheel.

3. METHODS OF FITTING THE SLOW ENGINE ON THE SHIP

The engine manufacturers always inform us about the operations to be carried out in order to properly mount and align the engine to the shaft line. However, it is the responsibility of the installation company to carry out all the execution of the assembly and adjustment of the alignment. Thus, only a close collaboration between the engine manufacturer and the shipbuilder makes it possible to make the most of the science and the experience of each other. In this section we will deal only with general notions and we will describe to the reader some assembly methods recommended by the manufacturers of slow motors.

3.1. FIXING THE FOUNDATION PLATE ON THE BOTTOM OF THE SHIP

A first method of mounting is to attach the foundation plate to the bottom of the vessel. In this case, the slow diesel engine rests directly on the upper side of the engine room double bottom tanks. Double bottom tanks include longitudinal and transverse beams and steel sheets. These beams are reinforced especially under the main engine, in order to support:

- the weight of the engine;
- the propeller thrust absorbed by the thrust bearing and transmitted to the motor foundation plate;
- the horizontal and vertical forces caused by the cyclic irregularity of the torque, as well as the inertia forces of the reciprocating and rotary masses (piston, connecting rod, crankshaft).

In Fig. 4, it is presented the cross-section of the double bottom of a ship. We can see the layout of the different steel beams and their thickness in millimetres, thickness recommended by the manufacturer Sulzer.

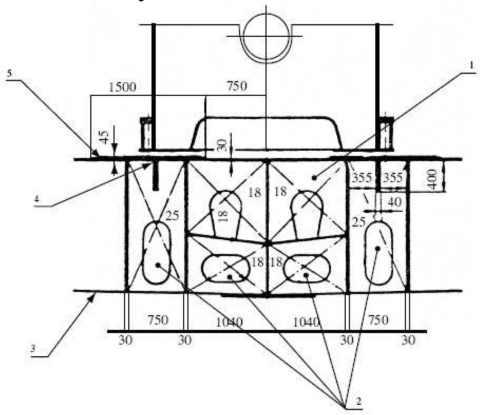

Fig.4. Cross-section of the double bottom of a ship (1- Lubricating oil tank, 2- Empty spaces, 3- Ship bottom, 4- Foundation bolts, 5- Top side of double bottom tanks)

The lubricating oil tank is usually located under the engine in the double bottom. Empty spaces allow access to foundation bolts. They prevent the contamination of the lubricating oil with seawater or the contents of the adjacent reservoirs. A series of rectangular blocks, the shims (not visible in the figure), support the foundation plate. These shims are positioned with respect to the transverse structures of the bearing bearings. The material used for their manufacture varies according to the thickness, the bearing surface of the foundation plate as well as the recommendations of the manufacturers.

In general, the support shims are made of steel and have a thickness of less than 30 mm; one can also find cast iron wedges whose thickness, this time, will be 30 mm and more. The bottom plate of the foundation plate, the support block and the bearing surface of the double bottom tanks are perforated to receive foundation bolts.

Usually, the engine is first assembled at the factory and the foundation plate supporting the crankshaft is aligned. So the manufacturer can test completely the engine. After testing, the engine must be completely dismantled for transportation to the shipyard. When the rear part of the vessel is completed, the foundation plate is deposited on the upper side of the double bottom tanks and temporarily supported by screw-type cylinders (Fig. 5). The gauges are adjusted so as to approximate the alignment measurements already obtained in the manufacturer workshop. Finally the engine is assembled inside the rear part of the vessel.

After the flange alignment of the coupling flange of the target shaft with the shaft line, the measurement of the space between the bottom flange of the foundation plate and the upper surface area of the double bottom tank is done. As it can be seen in Fig. 6, the support shims are then adjusted to the final position. This operation makes it possible to support the weight of the engine and to gradually replace the screw jacks.

Adjustable foundation bolts are used for the rear part, located under the thrust bearing. All other bolts are standard. The adjustable bolts transmit the propeller thrust to the hull, while the regular bolts allow for the forward movement or expansion of the foundation plate. It is the difference in temperature between the double bottom tank and the foundation plate, during the operation of the engine, which causes this displacement.

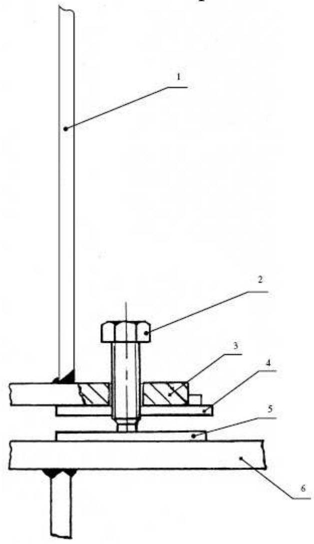

Fig.5. Details of use of a screw spindle when mounting an engine (1- Foundation plate, 2- Screw lock, 3- Base plate bottom plate, 4- Tole steel net, 5- Tole steel support; 6- Top side of the double bottom tank)

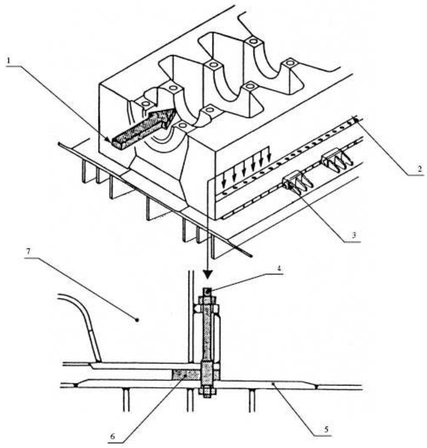

Fig.6. Foundation Plate Installation Schema (1- Helice Pulley, 2- Standard Foundation Bolts, 3- Transverse Bute, 4- Adjustable Foundation Bolts, 5- Superior Surface of Double-Bottom Tank, 6- Holders; 7- Foundation plate)

Fig. 7 describes a more recent technique according to which the support wedges are poured on the spot. An epoxy resin material is used, a technique that greatly reduces the cost of installing the engine. However, several manufacturers have reservations about the durability of this material, thus reducing their use.

Indeed, the problem is the following: the resin-based material can not withstand temperatures greater than 80^0 C nor with shear forces. Since the foundation plate of a slow-moving engine absorbs and transmits the propeller's thrust to the hull, it is necessary to add welded bearing supports to the bottom of the ship which replace the adjustable foundation bolts.

Finally, in addition to the support shims, transverse stops will be used to lock the motor in longitudinal and transverse position. These bumps prevent the foundation bolts, subjected to transverse forces, from working in shear during engine operation or collisions.

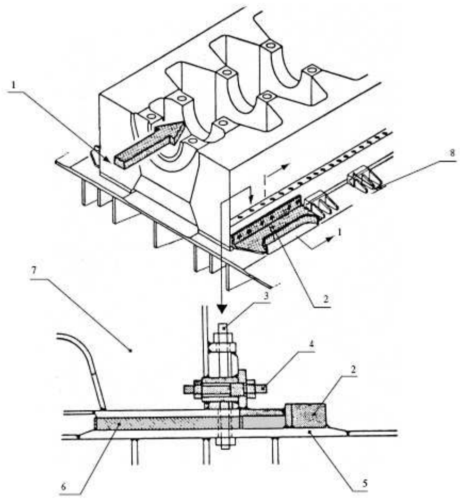

Fig.7. Use of epoxy resin base shims (1- Helix thrust, 2- Bottom bracket at the bottom of the ship, 3- Ordinary foundation bolts, 4. Adjustable bolt between the foundation plate and the sup-port 5- Upper surface of the reservoir with double bottom, 6- Epoxy resin support shims, 7- Foundation plate, 8- Transverse butee)

It should be borne in mind that the corrosion and wear of the support blocks deform the foundation plate. It is necessary to verify periodically the tightening of the foundation bolts. Indeed, loose bolts cause, in the long run, a misalignment of the crankshaft. In turn, the misalignment causes excessive effort, which will eventually risk breaking the crankshaft. Experience tells us that the foundation bolts on the coupling side and those on the front part of the engine are the most exposed to break and break. Similarly, we know that the oil and water in the bottom of the ship have particularly damaging effects when the foundation bolts are loosened. Also keep the underside of the engine very clean.

3.2. SUPERIOR FASTENING OF THE CYLINDER BLOCK AGAINST THE VESSEL FRAMEWORK

In another type of mounting, the cylinder block may be secured against the frame of the ship. The fixing of the cylinder block is then established based on the vibration data. Indeed, it is known that the forces of combustion, combined with the mass effects, create horizontal forces, which vary according to the position of the piston, on the sticks of slow motors. Compared to the point of attachment of the engine to its foundations, the action of these forces causes the appearance of lateral movements which are at the origin of the transverse vibrations of the engine (oscillations of the upper part of the engine). Moreover, since the base plate of the motors is more or less deformable, the effects of these lateral internal movements can be at the origin of the excitations of the shell (Fig. 8). These excitations cause high frequency vibrations, which will be transmitted both in the ship's framework and in the crew quarters.

Therefore, in order to obtain greater rigidity against transverse vibrations and to reduce the natural frequency of vibration of the hull, the upper part of the cylinder block is fastened to the frame of the ship. It is a hydraulic or friction damper that absorbs these vibrations. It allows slight movements of the framework, without increasing the pressures on the cylinder blocks. Structural displacements are often caused by variations in the ship draft or by the impact of waves and docks against the hull of the ship at the time of docking.

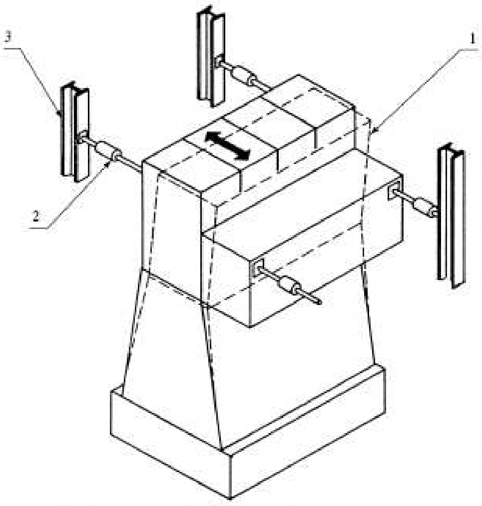

Fig.8. Top mounting of cylinder blocks (1- Cross vibration, 2- Hydraulic shock absorbers, 3- Ship structure)

Fig. 9 shows the assembly of the upper attachment of the cylinder block of an M.A.N.-B&W engine. The friction joint consists of two steel plates, attached to the engine's cylinder block. One of the steel plates is welded to the ship's framework. A nut, tightened by hydraulic pressure, provides the required coefficient of friction between the double plates of a material similar to that of the automobile brake bands.

In most cases, these soft coatings are special greases. If the preparation of the surface is simple and rapid, the disadvantages are numerous: frequent re-applications, flammable product, sensitivity to water and restrictive removal operation.

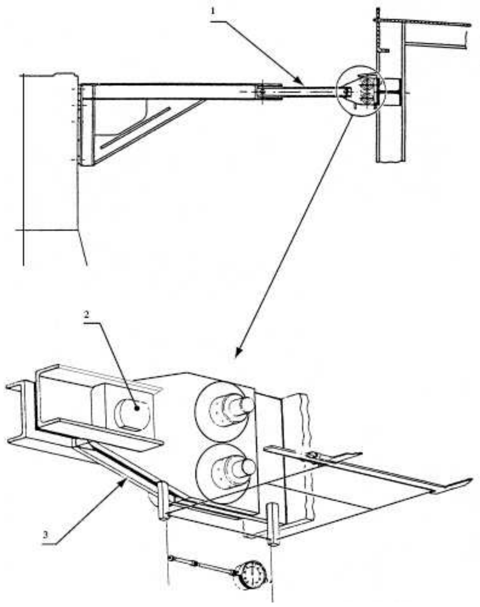

Fig.9. Top Mounting of Cylinder Blocks (1- Link, 2- Adjustable Bolt, 3- Brake Band)

3.3. ENGINE FITTING

In order to fix high speed semi-fast and large engines, the lower flange of the engine base plate is connected to the upper side of the double bottom tank according to the method already explained for slow engines (Fig. 10).

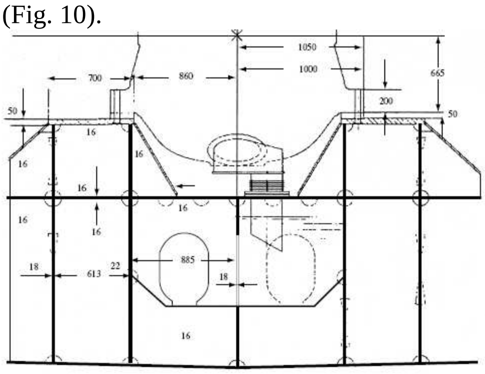

Fig.10. Fitting of a semi-fast engine M.A.N.-B&W

We can see in Fig. 10 the dimensions and spacing between the seat and support panels required for attaching a semi-fast engine M.A.N.-B&W.

Sometimes the fast and semi-fast engines used for propulsion or as a generating set are mounted on elastic elements, made of rubber.

4. CONCLUDING REMARKS

The main engine fixation on ships board is of extremely importance for the ships physical security on sea conditions and of crews life during the voyages.

It cannot be always used the exact analytical methods for engine foundations design. Several factors also influence this design such as experience, previous installations, engine basic dimensions etc.

These foundations must resist to deflections (horizontal, vertical and fore-and-aft) and must have sufficient rigidity in order to transfer the forces (static and dynamic) from the main engine to them. The support girder and the plate should increase bending inertia of the structure, to facilitate installation of chock, to allow installation of side blocks and of collision chocks and to ensure the safe space for maintenance aside the main engine.

The design of main engine foundation should be done in order to absorb the ship vibration, the loads from propeller, the loads from engine thrust and torque, the thermal, static and dynamic effects, loads from ship motion at sea, and the crash reversals. In order to avoid the natural frequency resonance between engine and the hull, we should make sure that the resonance between torque excitation and the natural transverse hull frequencies will not be present.

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