

**PROPULSION SYSTEM GEARBOX SELECTION
: GEAR HAMMERING**

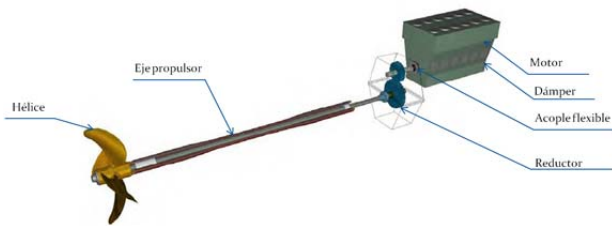


Fig 1. Typical propulsion system

The gearbox function is transmit power from propulsion engine to the propulsion shaft and propeller, decreasing the engine rotation speed (RPM) and increasing the torque.

The gearbox ratio should be selected according to propulsion engine and ship service, it should allow stresses from power transmission.

The adequate gearbox selection avoid gear hammering and axial, lateral and torsional resonances.

For gearbox selection should be considered:

- Ship propulsive calculation
- Axial vibration calculation
- Lateral vibration calculation
- Torsional vibration calculation
- Gear hammering

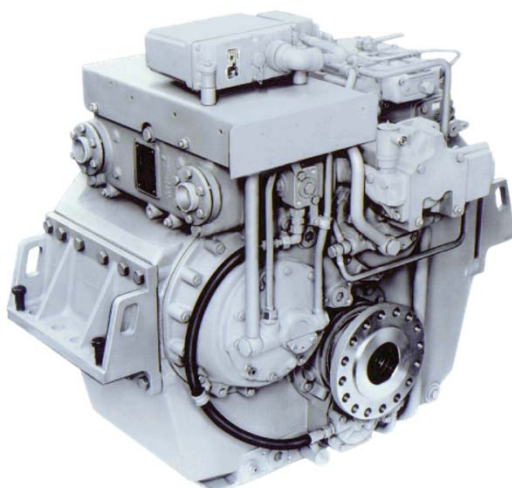


Fig 2. Gearbox

1. Ship propulsive calculation: This calculation consist in determining adequate components for the propulsion system to obtain the required ship speed with higher efficiency.

The propulsion engine, gearbox ratio, propulsion shaft diameter and material and propeller characteristics must be selected.

All ship service conditions should be evaluated, figure 3 show a results example of propeller required power and engine delivered power

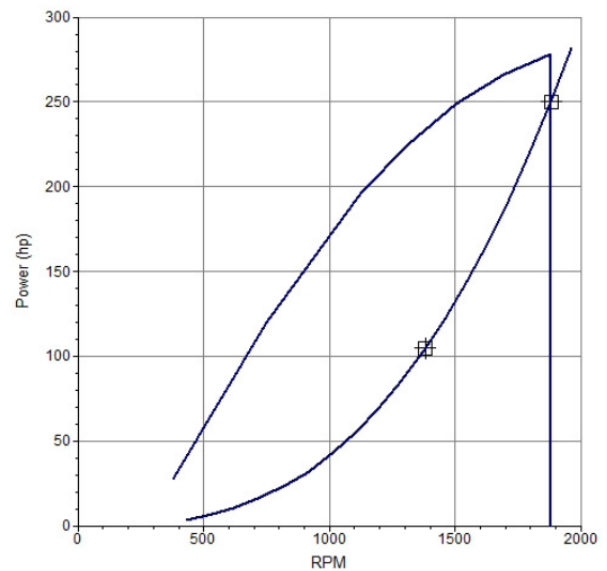


Fig 3. Power vs engine RPM curve

2. Axial vibration calculation: The axial vibration calculation determines axial resonances on propulsion system. In this calculation should be considered the propulsion system elements form thrust bearing to the propeller.

Generally the gearbox have a trust bearing, axial stiffness of this bearing must be known for axial vibration calculation.

Operation range should be restricted if a resonance exists in the system to avoid operating at this resonance speed, or gearbox ratio should be replaced.

Axial stiffness of trust bearing support should be considered in this calculation, this stiffness can vary to modify a resonance.

3. Lateral vibration calculation: Propulsion system Lateral natural frequencies are founded in this calculation, intervene gearbox, propulsion shaft with its supports and the propeller.

First vibration mode of a propulsion system is shown on figure 4, in the left is the propeller and in the right the gearbox bearings.

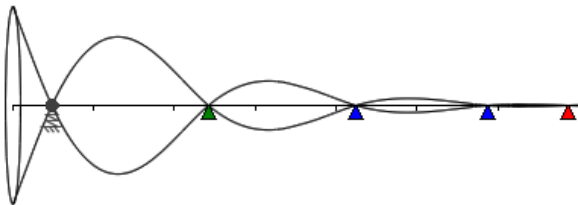


Fig 4. First vibration mode

Once natural frequencies are founded, a Campbell diagram can be done as show in Fig 5., in this diagram are represented natural frequencies and excitations from propeller and engine to analyze possible resonances that can be harmful for the propulsion system, especially in the critical operation range $\pm 15\%$ of max continuous rating (MCR)

Gearbox ratio, propeller characteristics, propulsion shaft bearings position or shaft diameter can be changed to avoid some resonances.

4. Torsional vibration calculation: For this calculation should be considered all propulsion system elements including propulsion engine, flexible coupling, gearbox, propulsion shaft, propeller and any other element.

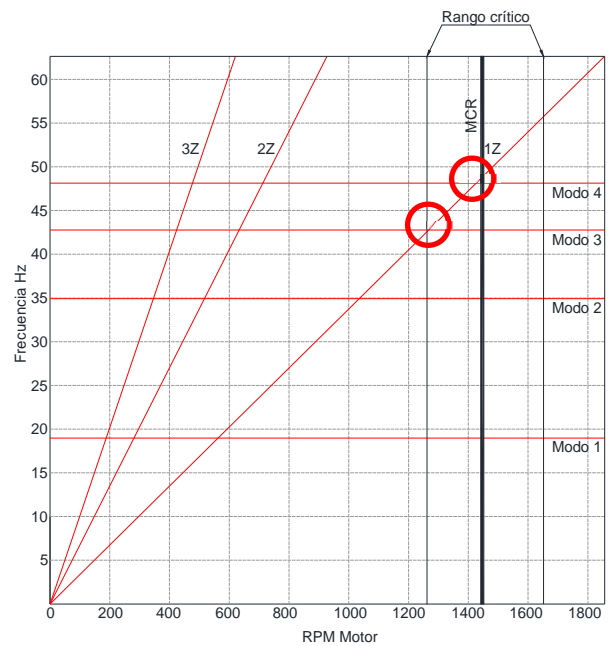


Fig 5. Campbell diagram

Natural and forced vibration calculation are performed, natural analysis determines the system natural frequencies and its possible resonances and the forced analysis calculate the effect of propulsion engine and propeller torsional excitations. Normal firing and misfiring of one engine cylinder should be considered according to Classification Societies recommendations.

Vibratory torque and stress of shafts and gears are founded in this calculation and compared to manufacturer limits or to Classification Societies recommendations.

5. Gear hammering: Due to excitations principally from propeller and gas explosion on internal combustion engines cylinders, dynamic forces cause the separation of gear teeth faces and restores contact as impacts known as gear hammering, generally it is produced when excitation torque (dynamic) is greater than nominal torque.

This hammering causes inefficiency in the system, noise problems, emissions increase and possible gear teeth fractures.

The figure 6 can be obtained from torsional vibrations calculations, this determines the possibility of gear hammering on gearbox.

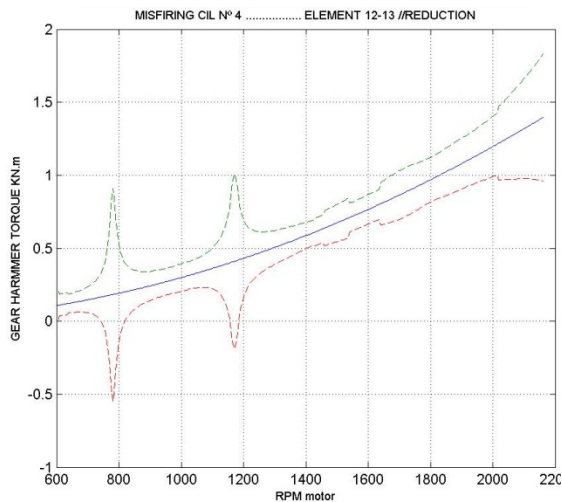


Fig. 6. Gear hammering diagram

To avoid gear hammering and other possible failure in the gearbox it is recommended to perform all the calculations mentioned on this paper and compare results with manufacturers and Classification Societies limits.

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