Modelling the combustion process of marine diesel engines to reduce pollutant emissions and influence vibrations at the propeller shaft for a Bulk Carrier vessel

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1. INTRODUCTION

The vessel is designed for the transport of the following bulk cargo.
The modelling of the process in internal combustion engines has been a permanent concern of specialists in the field. The complexity of the phenomena and the strong interdependence between them make the approach particularly difficult. The application of the provisions of the Protocol required the signatory countries, from 2010, to put in place measures to reduce nitrogen oxide emissions, especially in coastal areas, the most affected being, in the first instance, port technical vessels. Satisfactory torsional vibration behaviour has been found both under normal conditions and when a cylinder is not operating properly. Maximum crankshaft vibration stresses never exceed the limits of the diesel crankshaft. Maximum vibration stresses in the countershaft and propeller are below the guide lines.
The indicated speed range (55~67 rpm) should be achieved against I-6.0 under normal conditions and with one cylinder running rough. In the case of improperly operating one cylinder, engine speed should not exceed 110 rpm (87% of MCR) to avoid resonance of the order of 3.0 and thermal overload of the working cylinders.

2. Propulsion system shaft line analysis

The second aim of the paper is to develop a simulation program to estimate the emissions of nitrogen oxides produced by compression ignition engines. The idea is based on an analysis of the methods of implementing the provisions of Annex 6 to the 1997 Protocol on the amendment of MARPOL 73/78, concerning the limitation of polluting emissions from ships, in this case, nitrogen oxides.

The combustion process is by far the most important and complex process that takes place in engines, its importance is derived from the supply of energy flow used in the engine, respectively is the source of all pollutant emissions, engine efficiency is directly influenced by it.

The mechanisms of combustion are particularly complex and are not fully known even today, the most difficult problem being the mechanisms of mixture formation and the chemistry of the combustion process.

FEM (Finite Element Method), starts from the idea that for the analysis of the deformation of a continuous structure (with some geometry and complex boundary conditions) the exact values of the parameters (displacements, forces) cannot be calculated or if they can be the calculation effort would be unjustified.

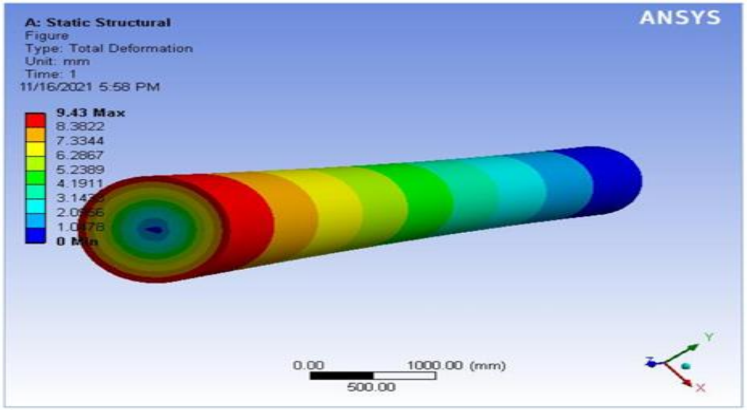
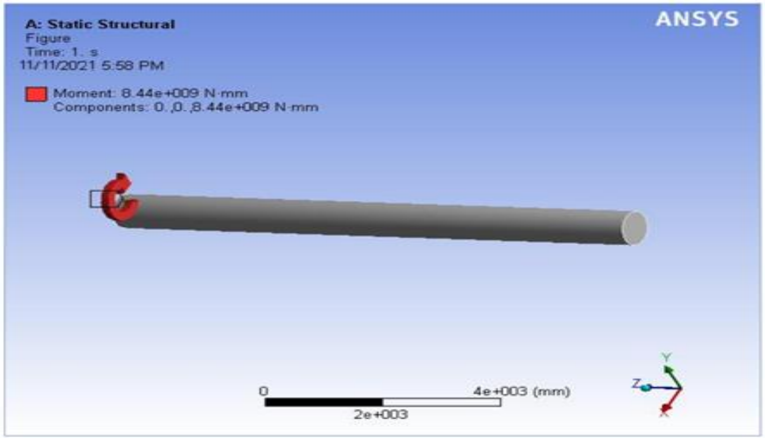


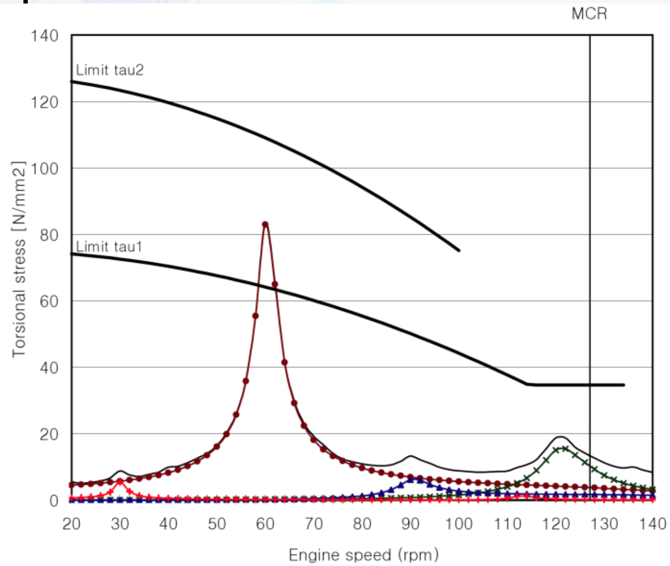
Diagram of total deformations expressed in [mm]



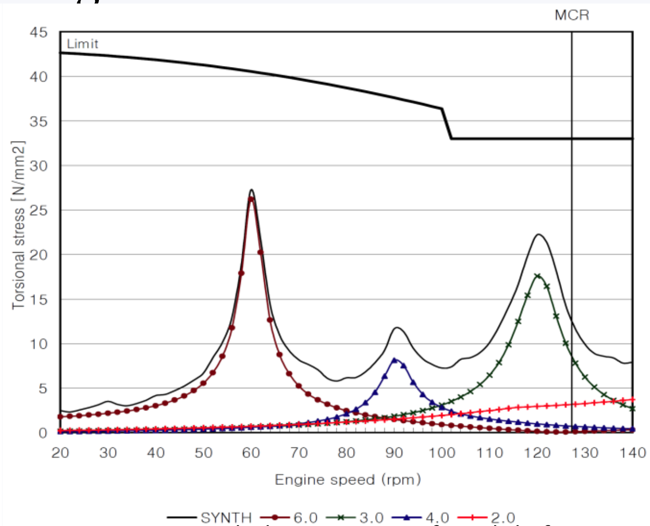
Applying loads related to the motor torque on the shaft

3. Natural frequencies and resonance modes

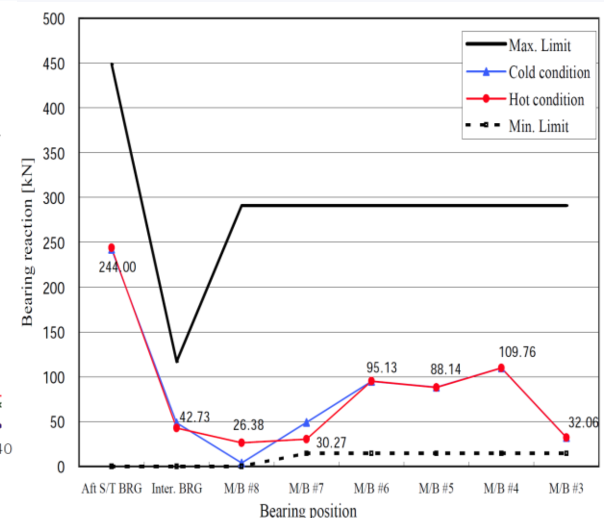
At the end of the analysis the program automatically generates a series of tables in which data are presented regarding the qualities of the material from which the shaft line is produced and how it behaves during the simulation.



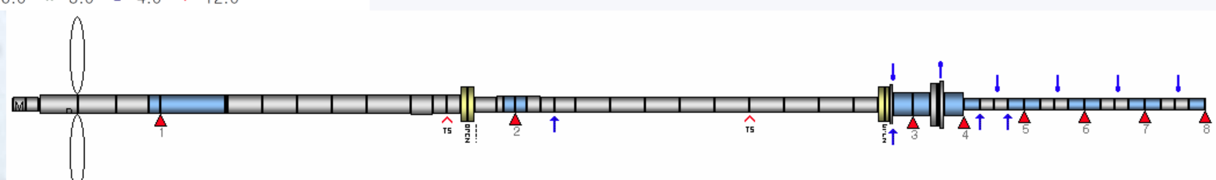
Torsional vibration stress of intermediate shaft



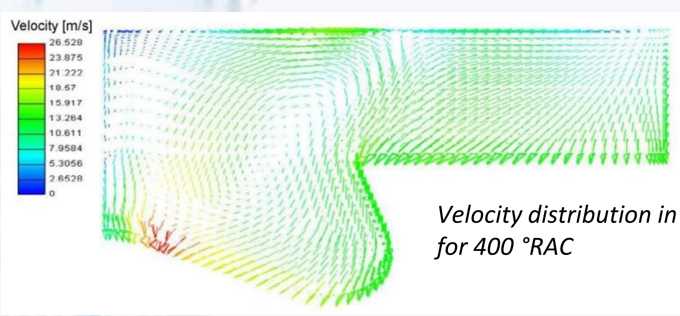
Torsional vibration stress of crankshaft



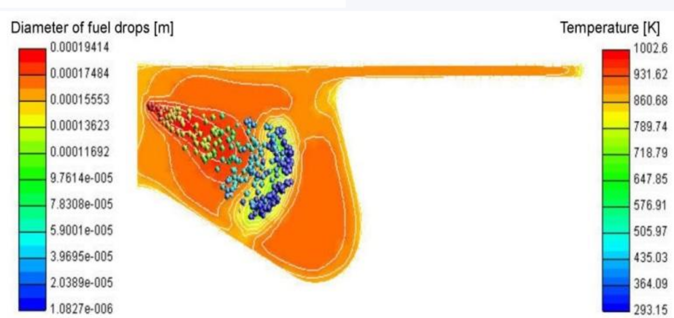
Graphical results of the loading of the pens



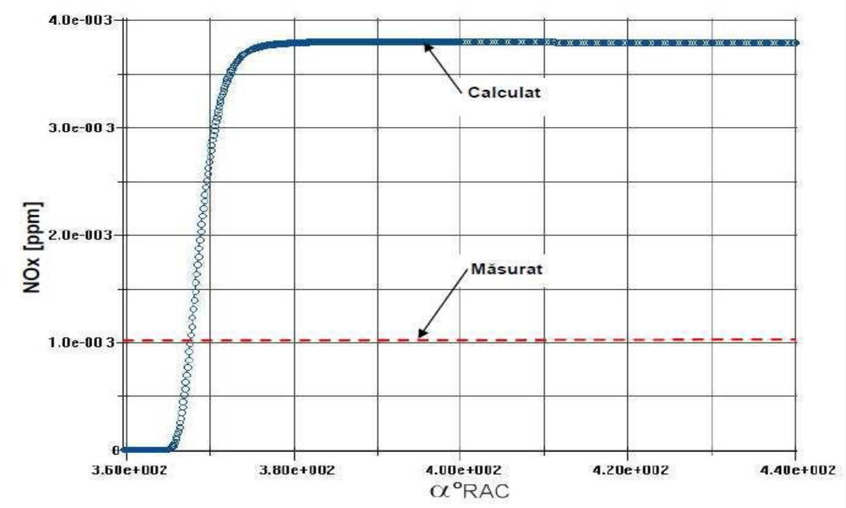
Shaft alignment



Velocity distribution in the cylinder for 400 °RAC



Fuel jet at 357 °RAC and 2 °RAC, after injection start



Evolution of NOx concentration in the cylinder, during one cycle

4. Conclusions

The results have only a qualitative character, the values not being in total agreement with the measured ones, but the evolution of the phenomena inside the cylinder is captured with sufficient accuracy: the vortices created by the fuel jet, the effect of the combustion chamber on the piston head, the presence of flame at the periphery of the fuel jet in the tire, NOx formation in areas with high temperatures and poor mixtures at the periphery of the jet, the presence of vortices at the outlet of the rich mixtures from the combustion chamber in the piston head; the presence of areas on the wall with low temperatures and areas without mixing where, depending on the flow regime, unused air can remain. After improving the performance of the model (by improving the discretization network, reducing the pressure gradient, reducing or eliminating errors caused by the numerical methods used and discrete representation of real numbers), it was found that increasing the fineness of the discretization network does not significantly reduce the pressure gradient and requires the application of more realistic initial conditions and material constants.

THANK YOU FOR YOUR TIME