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APPLICATION OF ACOUSTIC SIMULATION FOR ENGINE NOISE EMISSION ANALYSIS

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ABSTRACT: In this paper we present a case study of noise propagation in a IC engine casing. Noise reduction is a main issue for car manufacturers and also for environment protection specialists. The analysis of noise sources and propagation can help in better understanding of the phenomena and in designing casings and engine parts that better reduce the noise emissions of cars.

1. INTRODUCTION

Acoustics is the physics of *sound*. Sound is the sensation, as detected by the ear, of very small rapid changes in the air pressure above and below a static value. This static value is atmospheric pressure. Associated with a sound pressure wave is a flow of energy. Physically, sound in air is a longitudinal wave where the wave motion is in the direction of the movement of energy. The wave crests are the pressure maxima, while the troughs represent the pressure minima.

Sound results when the air is disturbed by some source. An example is a vibrating object, which in case of engine casing can be the transmission gear, the piston head or the exhaust pipes. It is possible to see the movement of some engine parts when it generates sound at a very low frequency. As the vibrating surface moves forward, it compresses the air in front of it, causing an increase in air pressure. Then it moves back past its resting position and causes a reduction in air pressure. This process continues, radiating a wave of alternating high and low pressure at the speed of sound. Acoustic analysis were made mostly, until now, with the boundary element method due to low system requirements [1],[2]. In the last years, the development of computing power and information technology allowed the use of finite element methods in this field.

An acoustics analysis can often be categorized as one of the following standard problems or scenarios [3]:

- *The radiation problem*—A vibrating structure (a speaker, for example) radiates sound into the surrounding space. A far-field boundary condition or a PML (perfectly matched layer) is necessary to model the unbounded domain.
- *The scattering problem*—An incident wave impinges on a body and creates a scattered wave. A far-field radiation boundary condition or a PML is necessary.
- *The sound field in an interior space* (such as a room)—The acoustic waves stay in a finite volume so no radiation condition is necessary.
- *Coupled fluid-elastic structure interaction* (structural acoustics)—If the radiating or scattering structure consists of an elastic material, you must consider the interaction between the body and the surrounding fluid. In the multiphysics coupling, the acoustic analysis provides a load (the sound pressure) to the structural analysis, and the structural analysis provides accelerations to the acoustic analysis.
- *The transmission problem*—An incident sound wave propagates into a body, which can have different acoustic properties. Pressure and acceleration are continuous on the boundary.
- *Aeroacoustic problems*—Sound (noise) is generated by turbulent fluid motion or by the interaction between a fluid and a surface.

The Acoustics Module provides application modes with accompanying boundary conditions and example models for all these types of acoustics analyses.

Depending on the basic dependent variable used to model the acoustic field, the acoustical application modes can be divided in two main categories:

- *Pressure Acoustics* — The dependent variable is the acoustic pressure, *p*.
- A*eroacoustics* — The dependent variable is the potential,Φ, for the acoustic particle-velocity field, v=vΦ.

2. MODEL DEVELOPMENT

In order to model the noise propagation in the engine casing, the space between the engine surface and the interior of the engine casing had been modeled. The finite element model was simulated with COMSOL Multiphysics program which has unique capabilities to model acoustic phenomena and a user friendly graphical interface. The 3D model of the propagation space is given in figure 1. The mesh of the analyzed domain is given in figure 2. The number of tetrahedral elements used is 27726 elements.

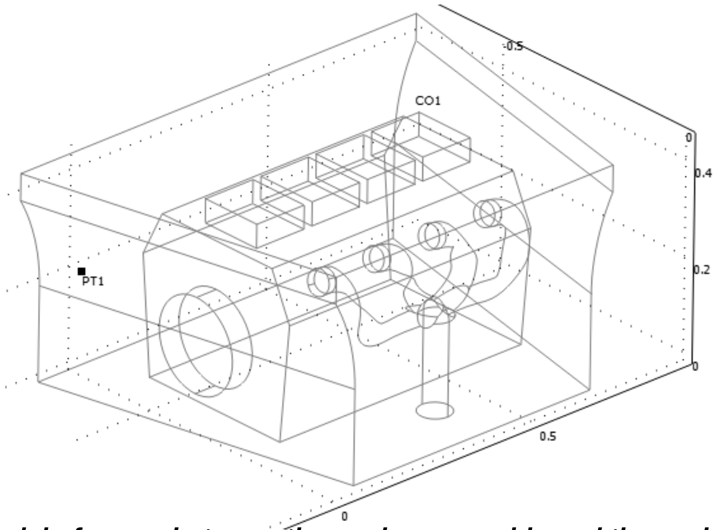

Fig. 1. 3D model of space between the engine assembly and the casing walls.

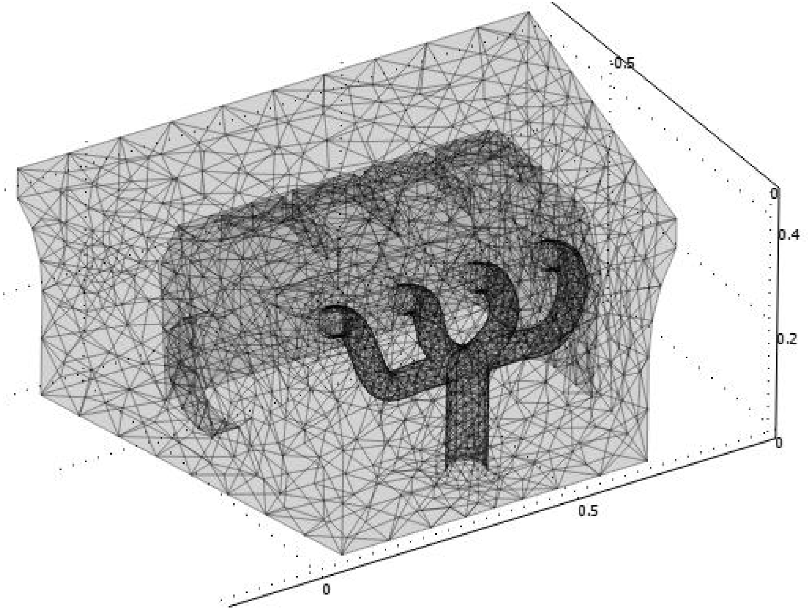

Fig. 2. Meshing of the model.

Boundary conditions and constants for different items in the model are as follows:

- boundary condition for vibration source: $n(1/\rho_0(\nabla p - q)) = a$; a = 10 m/s^2;
- boundary condition for surfaces : $n(1/\rho_0(\nabla p - q)) = 0$;
- density of air : ρ_0 = 1,2 [kg/m^3];
- speed of sound in air : c_s = 343,8 [m/s].

3. SIMULATION RESULTS

The goal of the analysis was to find the sound pressure levels of the inner volume defined by the engine surfaces and the outer casing interior surfaces.

The radiation condition of the source was set for the cylindric surface on the side of the engine to be a source of vibration of a = 10 m/s^2.

Studies were conducted to cover a frequency range from the basic engine rotation speed of 800 RPM (33.333 Hz) to the maximum rotation speed for this type of engine which is 5000 RPM (83.333 Hz).

For some relevant results the sound pressure isosurface diagrams are ploted in figures 3 to 7.

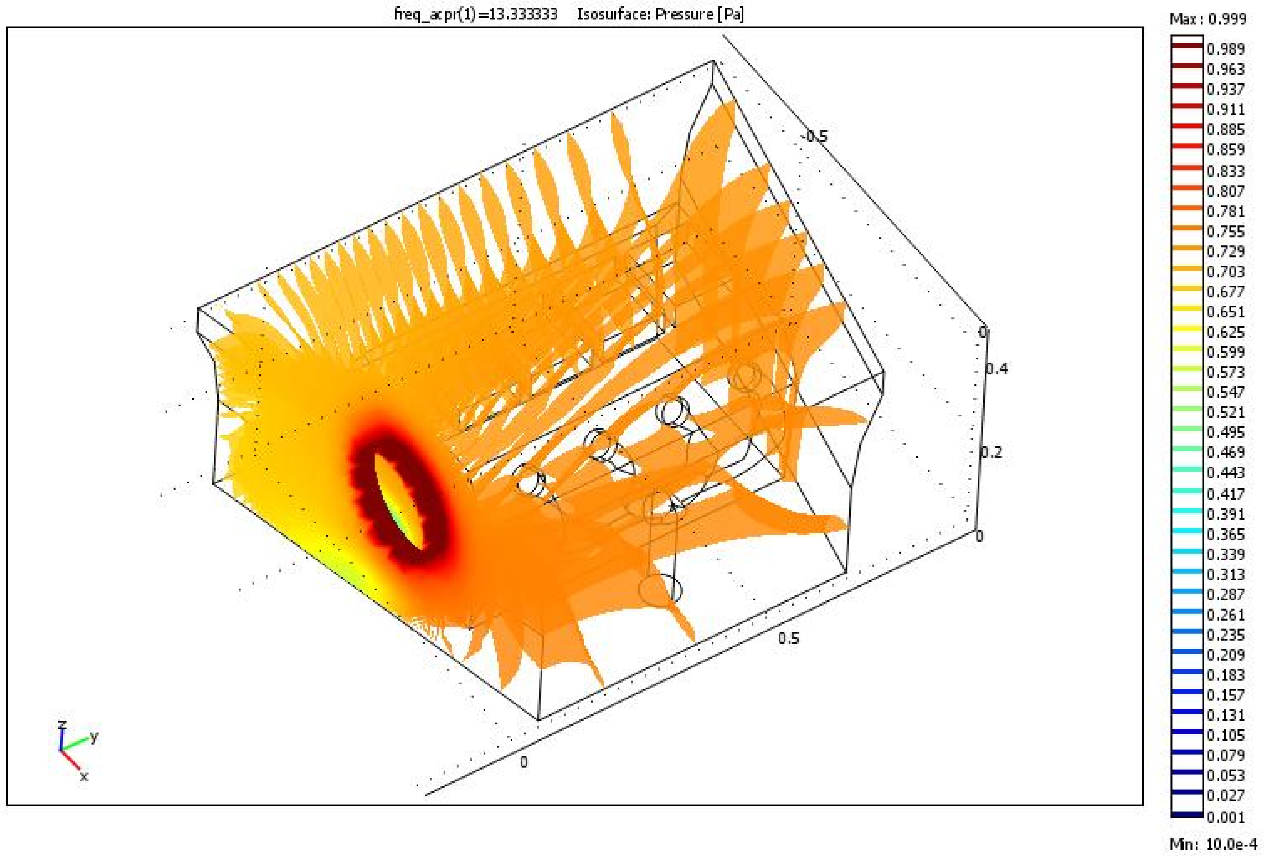

Fig. 3. Isosurfaces of sound pressure at a frequency of 13.33 Hz.

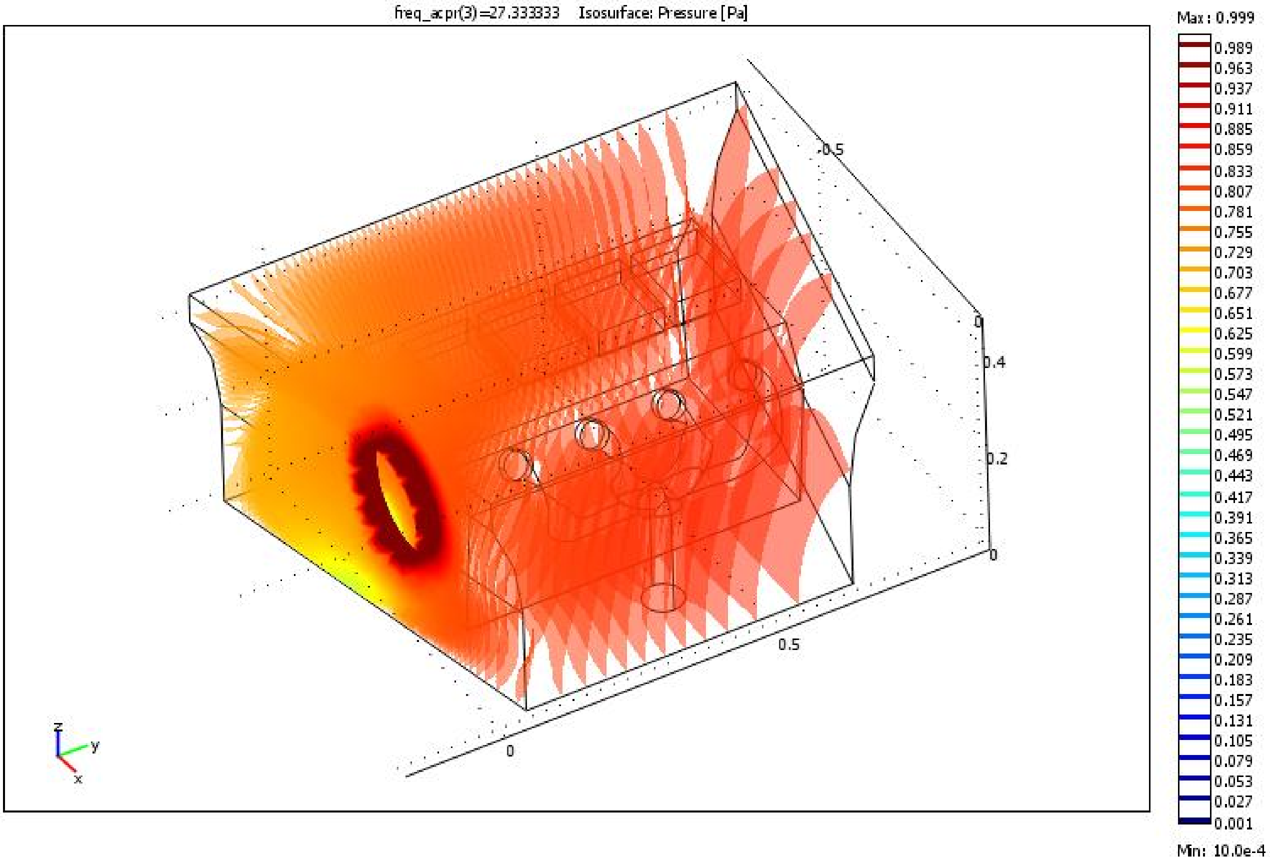

Fig. 4. Isosurfaces of sound pressure at a frequency of 27.33 Hz .

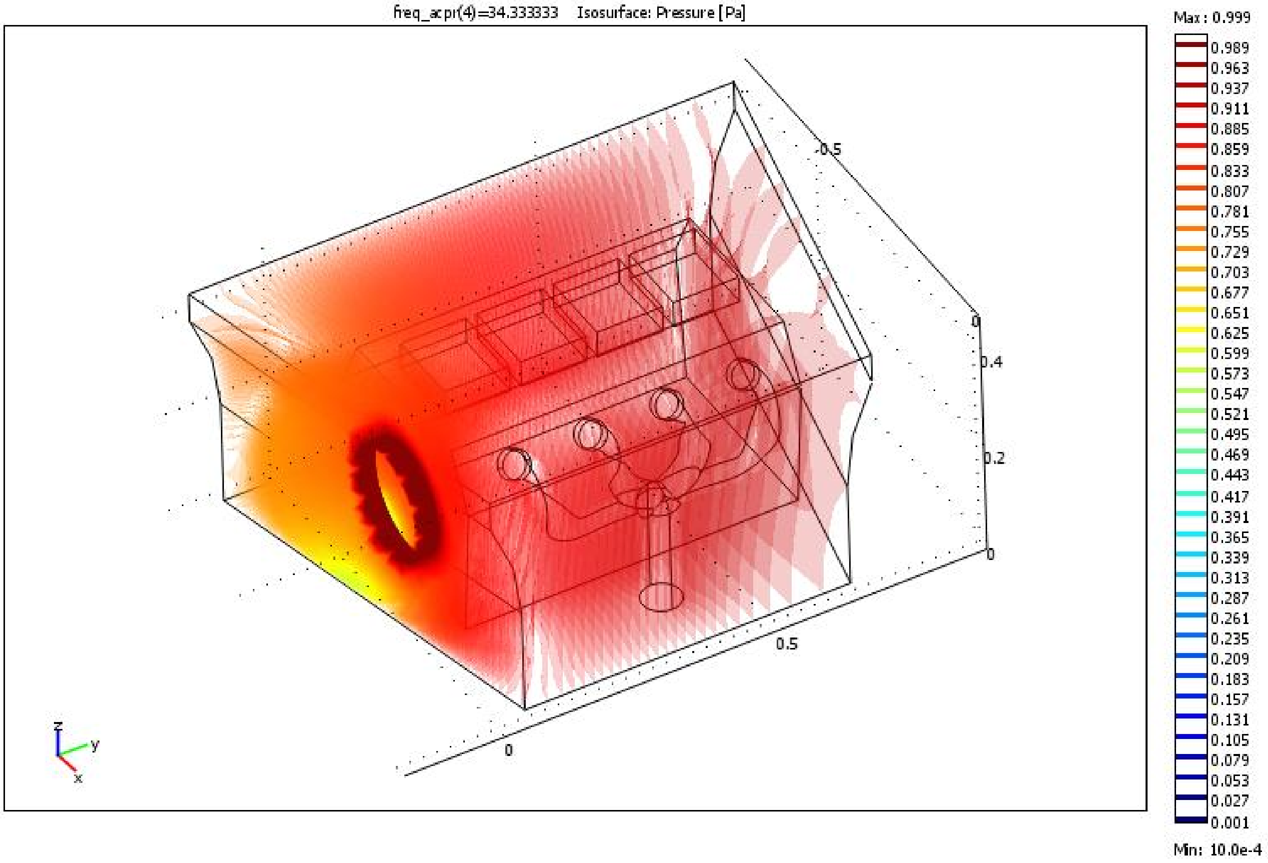

Fig. 5. Isosurfaces of sound pressure at a frequency of 34.33 Hz .

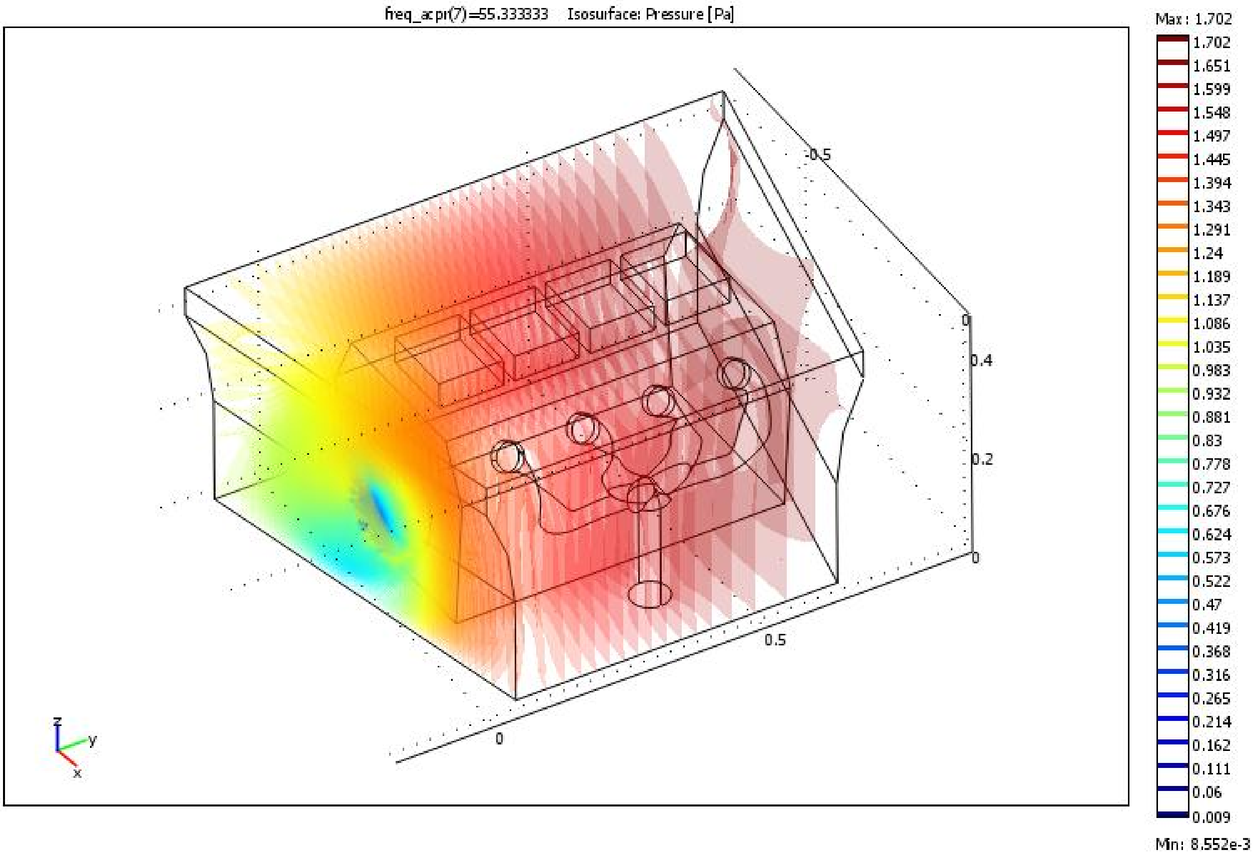

Fig. 6. Isosurfaces of sound pressure at a frequency of 55.33 Hz .

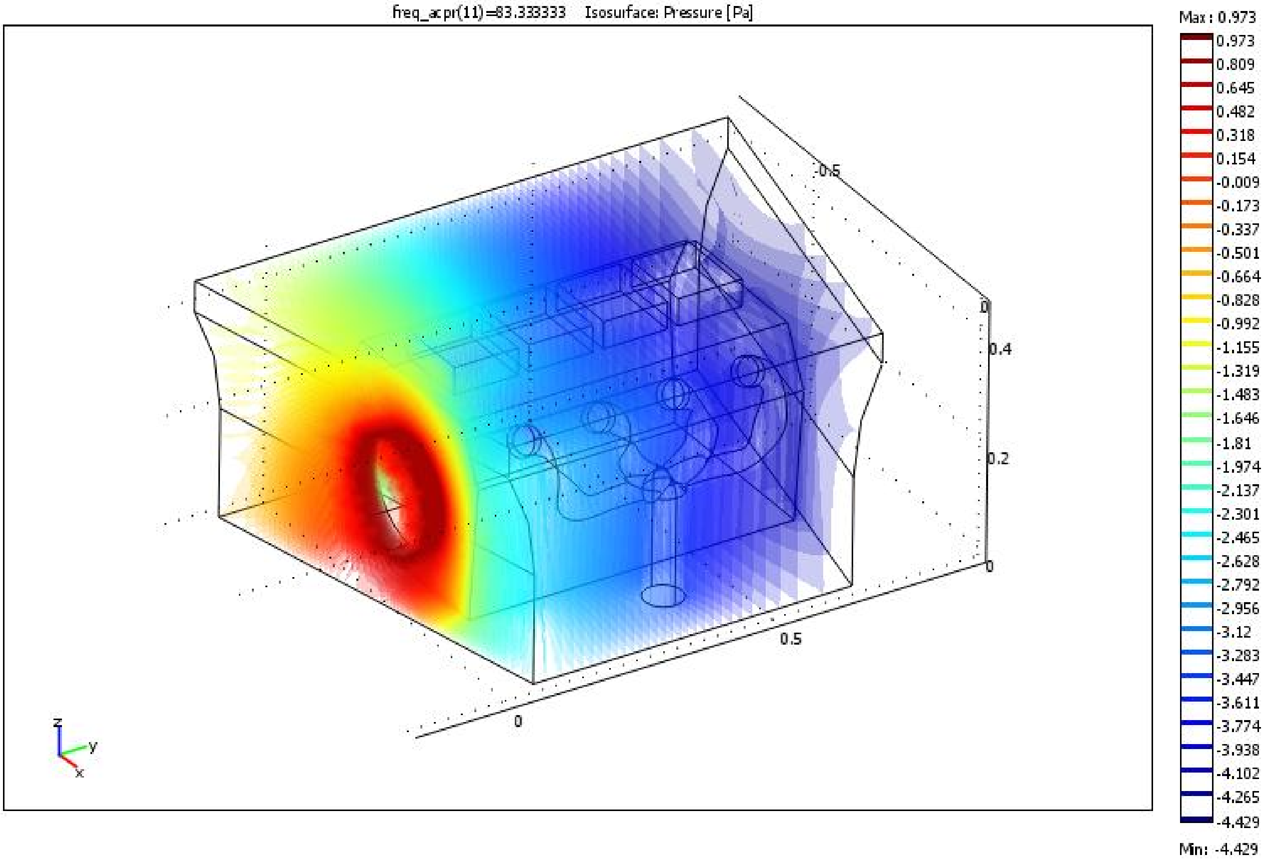

Fig. 7. Isosurfaces of sound pressure at a frequency of 83.33 Hz .

4. CONCLUSIONS

Analyzing simulation results, it can be seen from the presented diagrams that sound pressure field waves are changing direction with increasing frequency. As the frequency grows higher, the direction of waves are more side to side than side to front as in low frequency plots. This means that the noise will be higher in front and at rear of the casing, at low frequencies and at high frequencies (higher engine RPM) the noise will diminish in these parts and will grow in the lateral parts of the casing.

The analysis will help to establish what kind on materials and where to place phonic insulation on the casing walls.

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