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Computational and Experimental Determination of Acoustic Impedance of Internal Combustion Engine Exhaust

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Abstract : The topic of the presented materials concerns the design of the exhaust system for a certain internal combustion engine. The exhaust system can be divided into two parts. The first is the engine exhaust manifold, turbocharger, and catalytic converters, which are called “hot part.” The second part is the gas exhaust system, which contains elements exclusively for reducing exhaust noise (mufflers, resonators), the accepted designation of which is the "cold part." The design of the exhaust system from the point of view of acoustics, that is, reducing the exhaust noise to a predetermined level, consists of working on the second part. Modern computer technology and software make it possible to design "cold part" with high accuracy in a given frequency range but with the condition of accurately specifying the input parameters, namely, the amplitude spectrum of the input noise and the acoustic impedance of the noise source in the form of an engine with a "hot part". Getting this data is a difficult problem: high temperatures, high exhaust gas velocities (turbulent flows), and high sound pressure levels (non-linearity mode) do not allow the calculated results to be applied with sufficient accuracy. The aim of this work is to obtain the most reliable acoustic output parameters of an engine with a "hot part" based on a complex of computational and experimental studies. The presented methodology includes several parts. The first part is a finite element simulation of the "cold part" of the exhaust system (taking into account the acoustic impedance of radiation of outlet pipe into open space) with the result in the form of the input impedance of "cold part". The second part is a finite element simulation of the "hot part" of the exhaust system (taking into account acoustic characteristics of catalytic units and geometry of turbocharger) with the result in the form of the input impedance of the "hot part". The next third part of the technique consists of the mathematical processing of the results according to the proposed formula for the convergence of the mathematical series of summation of multiple reflections of the acoustic signal "cold part" - "hot part". This is followed by conducting a set of tests on an engine stand with two high-temperature pressure sensors measuring pulsations in the nozzle between "hot part" and "cold part" of the exhaust system and subsequent processing of test results according to a well-known technique in order to separate the "incident" and "reflected" waves. The final stage consists of the mathematical processing of all calculated and experimental data to obtain a result in the form of a spectrum of the amplitude of the engine noise and its acoustic impedance.

Keywords : acoustic impedance, engine exhaust system, FEM model, test stand
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