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NEW DESIGN OF THE TRACTOR EXHAUST MUFFLER BASED ON COMPUTATIONAL FLUID DYNAMICS ANALYSIS

New regulations and standards for noise emission increasingly compel the automotive firms to make some improvements in exhaust systems of engines which include the muffler. First of all such improvement concerns the decreasing of engine noise. Nowadays, the perforated reactive mufflers which have an effective damping capability are specifically used for this purpose. New designs should be analyzed with respect to both acoustics and back pressure. In this study, a new design of reactive perforated mufflers are investigated numerically by using computational fluid dynamics (CFD) tools. Back pressure was obtained based on the flow field analysis and compared for commercial and new design mufflers.

Introduction

Muffler design is an important research area for automotive companies because of new regulations and standards for noise emission. To examine the performance of any muffler, certain parameters are used. These parameters are transmission loss and back pressure. The transmission loss gives a value in decibel (dB) that corresponds to the ability of the muffler to dampen the noise. Transmission loss is independent from the noise source, thus this property of muffler does not vary with respect to noise source. New designs to improve the acoustical properties of a muffler cause a resistance against the flow of exhaust gases and this resistance stems the flow. This is called back pressure and it causes an extra pressure inside the engine. Because of the back pressure, volumetric efficiency decreases and specific fuel consumption increases. Therefore, there must be specific limitations for the back pressure [1]. Numerical analysis programs make the acoustic investigation of the muffler easier. In 2005, Daniel explained the general design principles of a muffler and advantages of different types of mufflers [2]. Mo and Huh calculated the acoustic transmission loss of muffler with basic and complex geometry using NASTRAN and the analytical results were compared with the experimental results [3]. Munjal calculated the back pressure of a perforated, cross-flow and reactive muffler with CFD method and examined the effects of different parameters such as diameter and area expansion ratio. In a study published in 2007, Fairbrother and Varhos investigated the transmission loss and back pressure of a muffler with perforated pipe and baffle numerically [4].

In this study, a new design solution of the muffler for reducing the overall diametrical size of the muffler for wheel tractor while improving its aerodynamic characteristics is offered. Back pressure of the present muffler was obtained using CFD analysis.

New muffler design

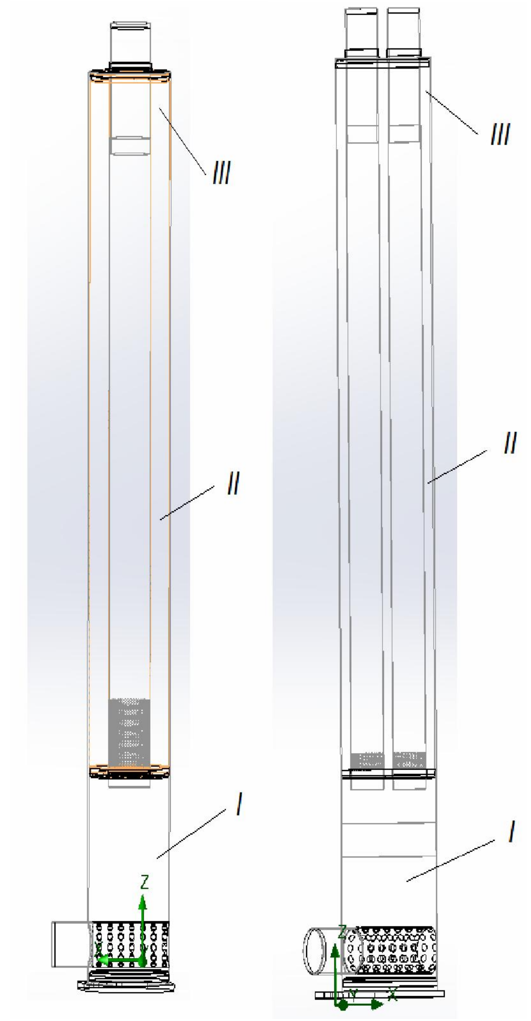
Minimizing the overall dimensions of the muffler is requirement of special importance for tractors. This requirement is determined by the normalized current standards, the location of the exhaust gases flow and visibility for the operator.

This paper provides a new design solution of the muffler for reducing the overall diametrical size of the muffler for wheel tractor while improving its aerodynamic characteristics.

Currently, wheel tractors used reactive-dissipative type of the muffler. General view of such muffler is shown in Fig. 1,a and Fig.1 b. Muffler consist of expansion chamber (I), passing in the dissipative part as a one-pipe absorber chamber (II) and has in its composition three quarter-wave resonator (III). Such Muffler has acceptable performance, hydraulic resistance and acoustic efficiency, but has a relatively large overall diameter. For example, for a wheel tractor HTZ-172 the diameter is 180 mm, which creates a degraded visibility for the operator when the unit is installed along the front cabin. When reducing the diametric dimension it should be taken into account that the reduction of the muffler usually leads to a deterioration of its acoustic characteristics [5].

Accordingly, the original muffler solution proposed having an elliptical cross-section of its body. Muffler is reactive-dissipative type. Its design is shown in Fig. 1, b. It consists of an expansion chamber (I) 180 mm in diameter which narrowed on his way to dissipative part to the diameter of 120 mm at one of his axes. Also muffler include two-pipe absorber chamber (II) and has in its composition three quarter-wave resonator (III). The predetermined acoustic effect, despite reduction in the equivalent sectional diameter in comparison with the commercial design is maintained by dividing the stream into two outlet pipes. This increases the area of contact with the absorbing material in $\sqrt{2}$ times.

An important structural difference from commercial muffler is that it has an elliptical cross section with a minor axis of 120 mm and a major axis of 180 mm. Thus, we obtain a significant improvement in visibility from the operator's cabin.



a) b)

Fig. 1. Muffler designs:
a – Commercial, b – New Design

Numerical calculations

In this study, flow characteristics and pressure drop were analysed for commercial and new design mufflers and the simulation results were compared.

For flow analysis and pressure drop estimation of the mufflers, present mufflers were drawn via a 3D CAD program SolidWorks. These 3D muffler models was meshed and calculated using SolidWorks Flow Simulation. In Table 1 is shown the mesh statistics for commercial and new designs of the mufflers.

Table 1. Mesh statistics for commercial and new designs of the mufflers

Name of mesh parameter	***Commercial muffler***	***New design muffler***
Number of fluid cells	22729	43579
Number of solid cells	14815	13652
Number of partial cells	34303	46864

The greater number of mesh cells for new design muffler could be explained by more multiplex geometry of the new design muffler. After the muffler was meshed, flow field analysis was performed with Flow Simulation. The flow inside the muffler is assumed to be turbulence. Mass flow rate and temperature were defined as inlet boundary conditions. Pressure and temperature were defined as outlet boundary conditions; the physical properties of air were defined for flow analysis. Boundary conditions are given in Table 2.

Table 2. Boundary conditions

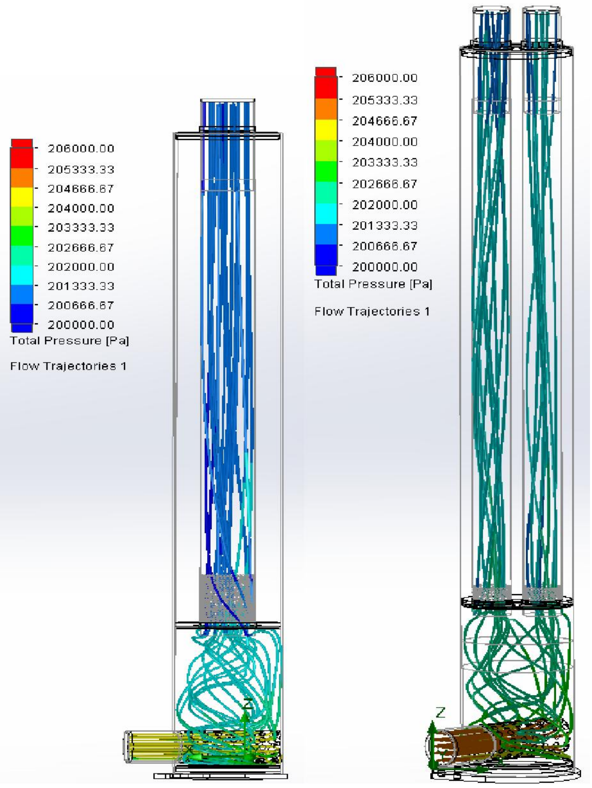
Parameters	**Value**
Inlet mass flow	0.215 kg/s
Gas density	Air defined as a real gas
Inlet flow temperature	650 ^{0}C
Inlet turbulence intensity	10 %
Outlet Pressure	101325 Pa (Atmospheric pressure)
Outlet temperature	650 ^{0}C

Results and discussions

Flow fields of commercial and new design mufflers are shown in Fig. 2. According to results of calculation, the values of total pressure drop are next: for commercial muffler – 4032 Pa, for new design muffler – 3346 Pa. The difference is 686 Pa. That means a new design muffler has less back pressure effect for the engine. Such difference can be explained by the next statement. It can be seen from Fig.3 that in case of new design muffler the flow trajectories entering two pipes have less turbulence in comparison with the on-pipe commercial muffler. That means the pressure drop in this case will be less.

Conclusion

New regulations and standards for noise emission increasingly make the automotive improvements about decreasing the engine noise. Considering the cost and the volume of the muffler in the vehicle, the aim is to develop smaller and more compact designs without any loss from the back pressure in muffler. Proposed new designs should be analyzed with respect to both acoustics and back pressure. In this study, a new design reactive perforated muffler is investigated. The present new design muffler was analyzed to obtain minimal back pressure affects for the engine. Back pressure values from numerical analysis were calculated. It was established that new design muffler has less back pressure effect for the engine. The difference between total pressure drops is 686 Pa which is essential. Next step for investigation should include simulation of acoustic effects and temperature fields in the muffler units for new design muffler.



a) *b)*

Fig. 2. Flow trajectories and total pressure values: a – Commercial, b – New Design

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НОВА КОНСТРУКЦІЯ ГЛУШНИКА ТРАКТОРНОГО ДИЗЕЛЯ, РОЗРОБЛЕНА ЗА РЕЗУЛЬТАТАМИ АНАЛІЗУ ГАЗОДИНАМІЧНИХ РОЗРАХУНКІВ

Д.Є. Самойленко

Нові стандарти та нормативи щодо рівня шуму автотракторних двигунів примушують виробників вдосконалювати випускні системи ДВЗ. В першу чергу, такі покращення стосуються зниження рівня шумую. В наведеному дослідженні нова конструкція реактивного глушника запропонована для тракторного дизеля. Виконані газодинамічні розрахунки з використанням програм обчислювальної газової динаміки (CFD). Рівень протитиску було встановлено за результатами аналізу течі газу через глушник, та виконано порівняння цього параметру для серійної та нової конструкції глушників.

НОВАЯ КОНСТРУКЦИЯ ГЛУШИТЕЛЯ ТРАКТОРНОГО ДИЗЕЛЯ, РАЗРАБОТАННАЯ ПО РЕЗУЛЬТАТАМ АНАЛИЗА ГАЗОДИНАМИЧЕСКИХ РАСЧЕТОВ

Д.Е. Самойленко

Новые стандарты и нормативы по уровню шума автотракторных двигателей заставляют производителей совершенствовать выпускные системы ДВС. В первую очередь, такие улучшения касаются снижения уровня шума. В приведенном исследовании новая конструкция реактивного глушителя предложена для тракторного дизеля. Выполнены газодинамические расчеты с использованием программ вычислительной газовой динамики (CFD). Уровень противодавления был установлен по результатам анализа течения газа через глушитель, и выполнено сравнение этого параметра для серийной и новой конструкции глушителей.