

EXPERIMENTAL RESEARCH ON COMPREHENSIVE PERFORMANCE OF COUPLED MUFFLER BASED ON SPLIT-STREAM RUSHING PRINCIPLE

基于分流气体对冲原理的耦合消声器综合性能的试验研究

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ABSTRACT

Based on the split-stream rushing principle and multi-unit coupling theory, a new type of coupled muffler for diesel engine was designed, and the experimental study on the acoustic performance and exhaust resistance performance was completed. The results show that the growth rate of insertion loss of the coupled muffler within 200 Hz is 34.01% compared to the original muffler. The average fuel consumption reduction rate of the diesel engine with the coupled muffler is 19.16% lower than that of the original muffler. Therefore, the coupled muffler can achieve the comprehensive goal of good acoustic performance and low exhaust resistance.

摘要

依据分流气体对冲原理和分级耦合理论设计了一种柴油机新型耦合消声器，完成了声学性能和排气阻力性能的试验研究。结果显示，新型消声器在 200Hz 内插入损失相对于原机消声器的增长率为 34.01%。柴油机安装耦合消声器后相比原机消声器的平均油耗降低率为 19.16%。耦合消声器通过降低消声器内气流速度可以实现声学性能好且排气阻力低的综合目标。

INTRODUCTION

Diesel engines are still widely used in current transportation vehicles and agricultural machinery, but the noise of diesel engine is loud, and the main source of the noise is exhaust noise (He Su *et al.*, 2020).

Generally, reactive mufflers are installed to control the exhaust noise of diesel engines, but the traditional reactive mufflers existing have their own defects, and a single structure cannot meet the requirements of good acoustic performance in wide frequency range (Yongan Zhang *et al.*, 2017).

At present, passive mufflers are still widely used. Its noise elimination mechanism is to eliminate noise through the destructive interference of pressure waves and prevent sound energy from continuing to be transmitted downstream. In recent years, a large number of researches on passive mufflers have been carried out, but there is no major change in the principle of passive muffler. The main work is focused on optimizing the internal structure of the muffler to further improve its performance. For example, an expansion chamber structure with two inlets and one outlet was designed to optimize the insertion loss of muffler (Hua X. *et al.*, 2014), a type of multi-chamber perforated resonator (MCPR) was used to attenuate broadband noise (Rong Guo *et al.*, 2016), a multi-chamber micro-perforated muffler with adjustable transmission loss was studied (Longyang Xiang *et al.*, 2017), a simple expansion chamber muffler with U-shaped corrugated pipes was applied and its experiments of the comprehensive performance were carried out (Fei Xue *et al.*, 2018), the acoustic attenuation characteristics of three-pass mufflers with perforated inlet and outlet tubes were analysed (Yiliang Fan *et al.*, 2019).

In recent years, noise control idea of dual-mode mufflers or semi-active mufflers has been proposed to improve noise control of low frequency. A cross-flow semi-active impedance compound muffler was proposed and its internal structural parameters could be changed to adjust the noise sound pressure level and frequency characteristics at the outlet (Xiaotian Bai, 2016), and a semi-active muffler based on HQ tube to control low-frequency noise in the exhaust pipe was proposed, but the results showed that the acoustic

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performance of the semi-active muffler above 350 Hz was poor compared with the passive muffler (Yawei Zhu *et al.*, 2017).

The sound elimination principle of the active muffler is to generate a sound wave with the same magnitude and opposite phase as the original sound pressure through the active system to cancel out the original sound field in a certain area. However, the active muffler has not been well applied and promoted, which includes the accuracy of the addition of secondary sound field, signal detection of the original noise field and the controller design. At the same time, the exhaust system of diesel engine is under severe condition of high temperature, high pressure, high speed, strong chemical corrosion, large smoke and dust, which causes many difficulties in the realization of active mufflers (Zhu Congyun *et al.*, 2017; Sang-Myeong Kim., 2018).

It can be seen that the existing passive, semi-active and active mufflers have their own advantages and disadvantages. The noise reduction performance still needs to be improved and the stability of the low-frequency noise reduction effect for diesel engines should be improved.

Moreover, it is found that if the noise attenuation performance of a wide frequency band is guaranteed, the pressure loss of the muffler is often too large (He Su *et al.*, 2018). The most critical factor affecting the overall performance of the exhaust muffler is the airflow velocity in the muffler (Pei Wu *et al.*, 2010). In view of this, our research group has proposed a new type of split-stream-rushing exhaust muffler unit, which can effectively reduce the flow velocity of the internal muffler (Yongan Zhang *et al.*, 2018).

As we all know, a complete diesel exhaust muffler is composed of several muffler units, and a separate split-stream-rushing muffler unit also needs to be coupled with a traditional reactive muffler unit to form a complete muffler. Based on this, a structure of a new type of coupled muffler for diesel engine is proposed in this paper, and the multi-unit coupling problem of the split-stream-rushing muffler unit and the traditional reactive muffler units to achieve better acoustic performance in wider frequency band and lower exhaust resistance at the same time. The airflow velocity in the muffler will be reduced through split-stream-rushing muffler unit in front to avoid excessive airflow regeneration noise and exhaust back pressure, and then acoustic performance of the low frequency will be further improved through a small amount of traditional reactive muffler units so as to achieve comprehensive improvement of acoustic performance and exhaust resistance performance.

MATERIALS AND METHODS

MODEL DESIGN OF COUPLED MUFFLER

In order to reduce the middle and low frequency noise and some high-frequency noises of diesel engines, the new coupled muffler structure of diesel engines proposed by the author was to couple the outlet of the split-stream-rushing unit with an expansion chamber unit with intubation. In order to facilitate the test comparison, the chamber volume, length and internal diameter of the exhaust pipe of the coupled muffler for the diesel engine were all consistent with the original engine muffler. The design calculations of the internal structure parameters of the coupled muffler were completed by the design principle of muffler and multi-unit coupling theory. In order to reduce the exhaust resistance, according to the characteristics of the fluid, each cross-sectional area of the exhaust airflow flowing through the interior of the muffler was greater than or equal to the inlet cross-sectional area of the muffler. The structural optimization model of the coupled muffler was obtained by calculations. The structure diagram of the coupled muffler was shown in Fig.1.

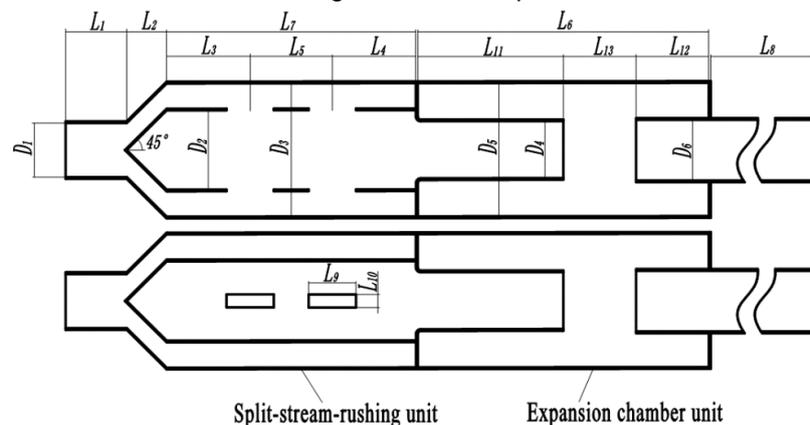


Fig. 1 - Dimensional diagram of coupled muffler models

As shown in figure 1, the length of the front tube of the muffler $L_1=65$ mm, the diameter of the front tube of the muffler $D_1=58$ mm, the length of the conical ring of the split-stream-rushing muffler unit $L_2=42.5$ mm, the inner diameter of the annular cavity of the split-stream-rushing muffler unit $D_2=85$ mm, the outer diameter of the annular cavity of the split-stream-rushing muffler unit $D_3=143$ mm, the length of the annular cavity of split-stream-rushing muffler unit $L_7=267.5$ mm, location dimension of the two sets of rushing holes $L_3=L_4=89$ mm, the distance between the two sets of rushing holes $L_5=89.5$ mm, the Length dimension of rectangular rushing holes $L_9=50.5$ mm, width dimension of rectangular rushing holes $L_{10}=14$ mm, outlet diameter of split-stream-rushing muffler unit $D_4=62$ mm, total length of split-stream-rushing muffler unit $L'=310$ mm, diameter of expansion chamber unit $D_5=143$ mm, the length of expansion chamber unit $L_6=310$ mm, the length of intubation at the entrance of expansion chamber unit $L_{11}=155$ mm, the length of intubation at the exit of expansion chamber unit $L_{12}=77.5$ mm, the length of straight tube in the middle of the expansion chamber unit $L_{13}=77.5$ mm, diameter of tail pipe $D_6=65$ mm, outlet length of tail pipe $L_8=700$ mm.

Based on the structural model of the coupled muffler, the new muffler of diesel engine was trial-produced. The four-cylinder diesel engine was used as a prototype to carry out comparative tests of the acoustic performance and exhaust resistance performance of the new muffler and the original muffler.

EXHAUST NOISE TEST

Noise test method

The insertion loss which is widely used in field measurement to test and evaluate the acoustic performance (Zhenlin Ji, 2016) of the coupled muffler was used in exhaust noise tests of the tractor in this research. The prototype of DF 900 tractor equipped with LR 4M5-23 four-cylinder diesel engine was used to complete the comparison test verification of the new muffler and the original muffler, including acoustic performance tests and exhaust resistance performance tests.

The required equipment includes: LR 4M5-23 diesel engine (rated power 66.2 KW, rated speed 2300r/min, fuel consumption rate ≤ 235 g/KWh), the coupled muffler, alternative straight pipe, lateral exhaust conversion tube, microcomputer multifunctional fuel consumption meter (JWY-1, China) and non-contact photoelectric tachometer (DT2234B, China), opacity meter (NHT-6, China), 2250 handheld noise analyser (B&K, Denmark), 4189 microphone (B&K, Denmark), 4231 calibrator (B&K, Denmark), tripod, heat-resistant silencer cotton, disassembling tools.

Putting the tractor indoors was equivalent to shielding the noise of the diesel engine and its auxiliary equipment to achieve the separation of exhaust noise and other noise sources. The exhaust pipe was outdoors, there were no other sources of interference noise outside, and there were no reflectors within 5 meters around the exhaust pipe interfering with the exhaust noise test. The test environment was similar to the free sound field, and the exhaust noise of the muffler was tested. The coupled muffler, the original muffler and the straight pipe were installed to the lateral exhaust conversion pipe of the LR 4M5-23 diesel engine in order. The measurement point of the BK2250 sound level meter was kept at 45° from the axial direction of airflow from the exhaust tailpipe, the distance was 0.8m. The height measuring point from the ground was 1.25m, and the distance to the attenuator was 0.57m and the same position of measuring point was maintained in all noise tests.

The exhaust noise tests of the new muffler, the original muffler and the straight pipe were completed at idle speed of 750 r/min, intermediate speed of 1500 r/min, and rated speed of 2300 r/min. Photos of mufflers for DF 900 tractor were shown in Fig.2.



a) Original muffler

b) Coupled muffler

Fig. 2 - Photos of mufflers for DF 900 tractor

RESULTS

Comparison tests of insertion loss

From the 1/3 octave exhaust noise spectrum of the original muffler, coupled muffler and alternative straight pipe at three rotation speeds, the insertion losses of the original muffler and coupled muffler were obtained respectively. The exhaust noises of the original muffler and the new muffler in tests were all more

than 10 dB higher than the background noise at the corresponding speed. Therefore, no background noise corrections were required in the exhaust noise tests (Zhenlin Ji, 2016). Photos of insertion loss test were shown in Fig.3.



Fig. 3 - Photos of insertion loss test for mufflers

Exhaust noise spectrum analyses at each speed

The frequency spectrums of 1/3 octave of the same measuring point at three rotation speeds of the coupled muffler and the original muffler were shown in Fig.4-Fig.6. At 750 r/min, 1500 r/min, and 2300 r/min, the average sound pressure levels of the coupled muffler within 2000Hz were lower than that of the original muffler.

The average sound pressure levels of the coupled muffler within 2000Hz at three speeds were 60.52 dB, 63.22 dB, 70.29 dB, the corresponding average sound pressure levels of the alternative straight pipe were 86.24dB, 90.01 dB, 94.01 dB, and the average sound pressure levels of the original muffler at three speeds were 64.88 dB, 67.34 dB, 74.16 dB, so the average sound pressure levels of the coupled muffler at each speed within 2000 Hz were reduced by 25.72 dB, 26.79 dB, 23.75 dB compared to the straight pipe and the coupled muffler reduced the average sound pressure levels within 2000 Hz at three speeds by 4.36 dB, 4.12 dB, 3.87 dB compared with the original muffler.

Moreover, the coupled muffler significantly reduced low-frequency noises. The average sound pressure levels of the coupled muffler at three speeds within 200 Hz were 71.68 dB, 72.19 dB, 76.67 dB, while the average sound pressure levels of the original muffler were 77.67 dB, 79.70 dB and 83.73 dB. The average sound pressure levels of the coupled muffler within 200 Hz at three speeds were reduced by 5.99 dB, 7.51 dB, and 7.06 dB respectively compared to the original muffler. It could be seen that the attenuation of low-frequency noise by the coupled muffler at each speed was significantly better than that of the original muffler.

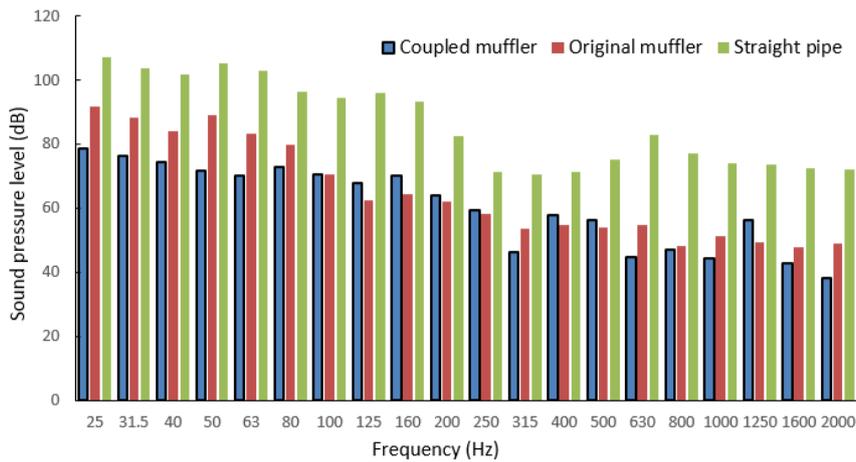


Fig. 4 - Comparison of noise spectrum at idle speed

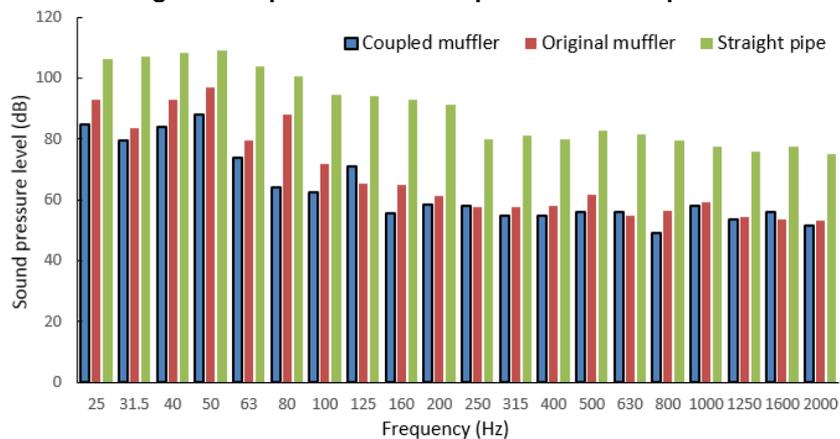


Fig. 5 - Comparison of noise spectrum at 1500r/min

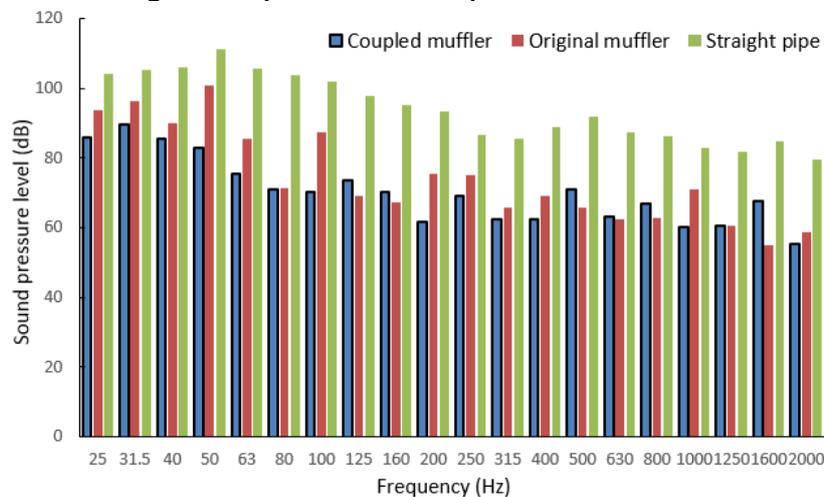


Fig. 6 - Comparison of noise spectrum at 2300 r/min

Since the exhaust pressure pulsation noise appears as periodic low-frequency noise, the control of the fundamental frequency noise can reflect the acoustic performance of the exhaust muffler. According to the calculation formula of the fundamental frequency of exhaust noise, $f_1 = nZ / 60 \tau$, where: n is the engine speed (r/min); Z -the number of cylinders; τ -the stroke coefficient, 4 stroke $\tau = 2$ (Zhihua Zhang et al., 1999).

From this, the exhaust noise fundamental frequencies of the LR 4M5-23 diesel engine at idle speed, intermediate speed and rated speed could be obtained respectively, and then the corresponding exhaust noise conditions at three speeds could be analyzed. At idle speed 750 r/min, the fundamental frequency f_1 of the exhaust noise was 25 Hz, and the sound pressure level corresponding to this fundamental frequency was the low frequency noise peak of the diesel exhaust noise spectrum of the diesel engine, which was 107.04 dB, so the control of fundamental frequency noise at 25 Hz at idle speed was a key to reflect the

noise reduction performance of the muffler. The sound pressure level of the original muffler at the fundamental frequency of 25 Hz was 91.83 dB, which was still the peak of the noise in the spectrum. The average value of the sound pressure level of the original muffler within 50 Hz was relatively high, which was 88.39 dB, so its attenuation effect of low-frequency target noise was limited. The noise sound pressure level of the new muffler corresponding to the fundamental frequency of 25 Hz was 78.82 dB, which was 13.01 dB lower than that of the original muffler.

In the same way, the fundamental frequency f_1 of the exhaust noise of the diesel engine at 1500 r/min and rated speed of 2300 r/min was calculated as 50 Hz and 76.67 Hz, and the corresponding low-frequency noise peaks at these two speeds appeared at 50 Hz in exhaust noise tests, and the noise peaks were 109.03 dB and 111.25 dB respectively. The sound pressure levels of the coupled muffler at the fundamental frequency of 50 Hz were 88.16 dB and 82.96 dB, which were 6.87 dB and 17.92 dB lower than that of the original muffler. The new muffler greatly attenuated the low-frequency noise peaks. The new type muffler was also superior to control the fundamental frequency noise at each speed compared with the original muffler.

Analyses of insertion loss at each speed

The comparison curves of the insertion losses at three rotation speeds between the coupled muffler and the original muffler were shown in Fig.7-Fig.9.

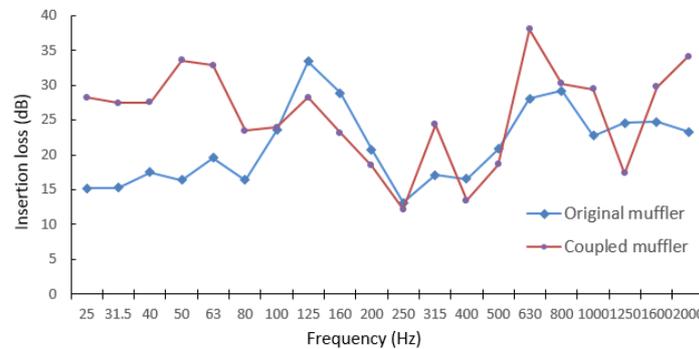


Fig. 7 - Contrast curve of insertion loss at idle speed

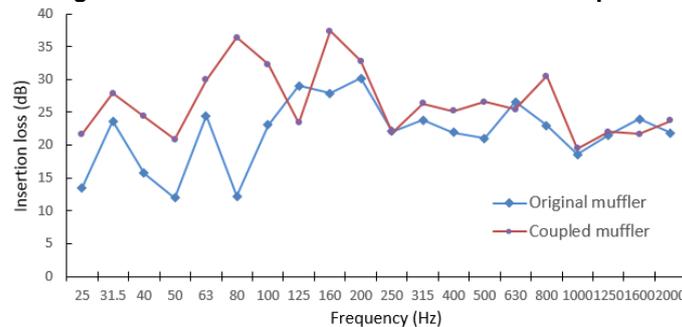


Fig. 8 - Contrast curve of insertion loss at 1500r/min

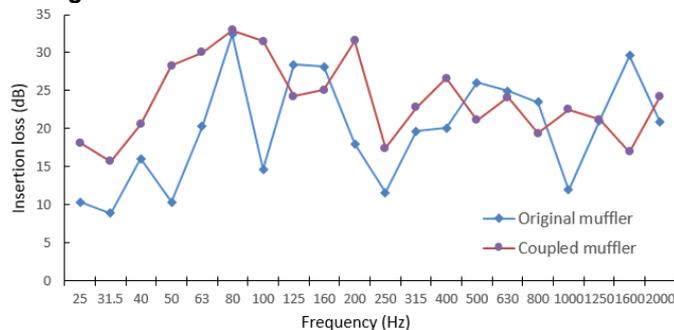


Fig. 9 - Contrast curve of insertion loss at 2300r/min

It could be seen from the insertion loss comparison curves of the new muffler and the original muffler at three rotation speeds that the insertion loss of the low frequency band of the new muffler within 200 Hz was better than that of the original muffler, and noise reduction of rest frequency band in 2000 Hz was also good compared to the original muffler, and the insertion losses at the fundamental frequency noise at each speed had been significantly improved. It could be found that the coupling structure of the new muffler was

conductive to the improvement of the acoustic performance of the diesel engine. The average insertion losses of the coupled muffler within 2000 Hz at 750 r/min, 1500 r/min and 2300 r/min were 25.72 dB, 26.80 dB, 23.72 dB. Compared with the original muffler, the average insertion loss of the new muffler was increased by 4.35 dB, 4.98 dB and 3.88 dB. The insertion losses of the new muffler at three speeds within 200 Hz of target frequency band were 26.69 dB, 29.30 dB, 25.81 dB respectively, which were 5.99 dB, 8.11 dB and 7.06 dB higher than that of the original muffler. The average insertion losses of the coupled muffler at three speeds within 50 Hz were 29.19 dB, 24.08 dB, and 20.67 dB, which were 13.08 dB, 7.85 dB, and 9.25 dB higher than that of the original muffler. The insertion losses of the coupled muffler about the fundamental frequency noise at three rotation speeds were 28.22 dB, 20.87 dB and 28.29 dB, which were 13.01 dB, 8.87 dB and 17.92 dB higher than that of the original muffler.

The comparison data of the average sound pressure levels (SPL) and the average insertion losses (IL) of the new muffler and the original muffler at each speed were shown in Table 1 and Table 2 below.

Table 1

Analyses of insertion loss at different speeds

Testing object	750 r/min			1500 r/min			2300 r/min		
	SPL [dB] (A)	IL in 2000Hz [dB] (A)	IL in 50Hz [dB] (A)	SPL [dB] (A)	IL in 2000Hz [dB] (A)	IL in 50Hz [dB] (A)	SPL [dB] (A)	IL in 2000Hz [dB] (A)	IL in 50Hz [dB] (A)
Straight pipe	86.24	-	-	90.01	-	-	94.01	-	-
Original muffler	64.88	21.37	16.11	68.19	21.82	16.23	74.16	19.84	11.42
Coupled muffler	60.53	25.72	29.19	63.22	26.80	24.08	70.29	23.72	20.67

Table 2

Analyses of insertion loss at different speeds

Speed [r/min]	IL within 200Hz [dB] (A)		Growth rate of IL [%]
	Original muffler	Coupled muffler	
750	20.70	26.69	28.94
1500	21.19	28.70	35.44
2300	18.75	25.81	37.65

The growth rate of the insertion loss of the coupled muffler within 200 Hz of target muffling frequency band at three rotation speeds were 28.94%, 35.44% and 37.65% respectively. The growth rate of insertion loss increased with the engine speed, because the higher the engine speed, the higher the airflow velocity at the muffler inlet, the greater the contribution of reduction of the internal velocity through the coupling structure, and the more obvious the effect of controlling the airflow regeneration noise, the acoustic performance of the diesel engine at high speeds was improved.

Compared with the original muffler, the average growth rate of insertion loss of the new muffler within 2000 Hz was 20.77 %, and the average growth rate of insertion loss of the target muffler frequency band within 200 Hz was 34.01 %. The average insertion loss within 50 Hz at three speeds was 68.95% higher than that of the original muffler. It could be seen that the full-band noise reduction performance and low-frequency noise reduction performance of the coupled muffler were significantly better than that of the original muffler, which was more suitable for the attenuation of low-frequency target noise for diesel engines.

COMPARISON TESTS OF EXHAUST RESISTANCE PERFORMANCE

In the comprehensive performance analysis of the coupled muffler, the exhaust resistance performance of the new muffler at each speed of the actual diesel engine needs to be evaluated. The variation in fuel consumption can be used to assess the pressure loss of the muffler. The fuel consumption is directly related to the power loss and the exhaust back pressure (*Wu Guipei et al., 2008*). The fuel consumption of a diesel engine equipped with a new muffler can reflect the overall change in its aerodynamic performance.

In this research, the diesel fuel consumption meter was used to test the fuel consumption index of LR4M5-23 four-cylinder diesel engine at various speeds, and the effects of the coupled muffler and the original muffler on the exhaust resistance of the four-cylinder diesel engine were analyzed.

Experimental approach of fuel consumption

JWY-1 microcomputer multifunctional fuel consumption meter was connected to the fuel circuit of the diesel engine. The test devices of fuel consumption meter were shown in Fig.10. The resolution of the fuel consumption meter is 0.1mL, the maximum flow rate is 60 L/h, and the measurement uncertainty is $\pm 1\%$.

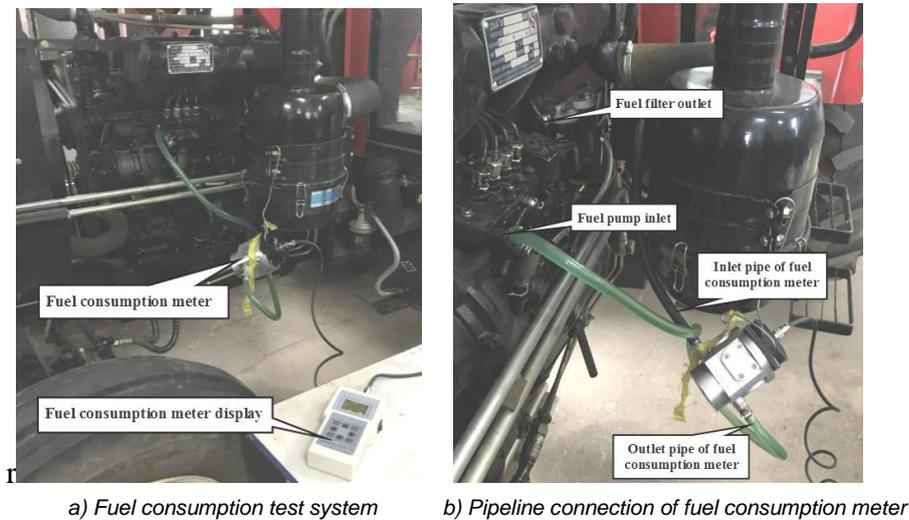


Fig. 10 - Photos of fuel consumption test

After the fuel consumption meter is connected to the fuel pipeline, it is necessary to press the manual fuel pump several times to eliminate the air in fuel circuit of the diesel engine, so that the engine can start normally. After 15 minutes of stable operation, the fuel consumption records are started to ensure the accuracy of the fuel consumption tests. The JWY-1 microcomputer multi-function fuel consumption meter is a digital display that can display and record three test parameters, including test time, fuel consumption L within the test time t , and fuel consumption per hour G . The test time t was set to 60 s, and the fuel consumption L (mL) and fuel consumption per hour G (L/h) were recorded, the fuel consumptions at each speed were recorded in three times, and the average value was taken.

The fuel consumption rate (specific fuel consumption) is the mass of fuel consumed (in units of g) in one hour for every 1 kW of effective power from the engine, and its unit is g/(kW·h). Specific fuel consumptions of the diesel engine equipped with the new muffler and the original muffler at the rated speed were further calculated. Based on the density of No. 0 diesel, which is 0.835 g/ml, the effective power P_e corresponding to 2300 r/min of the rated speed of LR4M5-23 four-cylinder engine is 66.2 kW.

The conversion formula of G and b_e is as follows:

$$b_e = 1000 \times 0.835 \times G/P_e = 835G/66.2 \quad (1)$$

where: G is fuel consumption per hour, L/h; P_e is effective power, kW.

The fuel consumption rate of diesel engines is generally 200...260 g/kWh, and the economy is better when the fuel consumption of the engine is lower. The fuel consumption rate of LR4M5-23 four-cylinder diesel engine is no more than 235 g/kWh.

Comparison results of fuel consumption

The average values of fuel consumption L at 60 seconds and fuel consumption per hour G of the diesel engines equipped with the coupled muffler and the original muffler at idle speed of 750 r/min, intermediate speed of 1500 r/min, and rated speed of 2300 r/min were shown in Table 3.

Table 3

Speed n [r/min]	Comparison of fuel consumptions				
	L [mL]		G [L/h]		
	Original muffler	Coupled muffler	Original muffler	Coupled muffler	Reduction rate of G
750	223.92	162.50	13.44	9.75	27.46%
1500	233.51	191.34	14.01	11.48	18.06%
2300	272.04	239.36	16.32	14.36	11.96%

The effective fuel consumption rate (specific fuel consumption) of the diesel engine equipped with the original muffler was: $b_e = 835G/66.2 = 835 \times 16.32/66.2 = 205.85$ g/(kW·h).

The effective fuel consumption rate of a diesel engine equipped with the new muffler was:

$$be = 835G/66.2 = 835 \times 14.36/66.2 = 181.13 \text{ g/(kW}\cdot\text{h)}$$

Furthermore, the effective fuel consumption rate of the diesel engine equipped with the new muffler at the rated speed was calculated to be 19.16% lower than that of the original muffler.

From the statistical results above, it could be seen that the fuel consumption L and G of the diesel engine with new muffler at three different speeds were both lower than that of the original muffler. And the lower the engine speed, the higher the reduction rate of fuel consumption, fuel consumption decreased the most at idle speed, and the effective fuel consumption rate at rated speed had also been significantly reduced. Compared with the original muffler, the fuel consumptions of the diesel engine equipped with the coupled muffler were significantly reduced, indicating that the pressure loss and power loss of the diesel engine with the new muffler were smaller than that of the diesel engine equipped with the original muffler. The new muffler can achieve the goals of good noise reduction performance and low exhaust resistance by reducing the airflow velocity in the muffler, and improve the overall performance of the muffler.

Simulation verification of the flow field in the muffler

Through the simulation analyses of the aerodynamic performance of the new muffler, the changes of the flow field in the new muffler under the common inlet airflow velocity of 0-50 m/s in diesel engines were discussed, and the velocity field and pressure field of inlet velocity at 50 m/s were shown as an example. It was verified that the pressure loss could be effectively controlled by reducing the airflow velocity in new muffler, thereby achieving an improvement in fuel consumption. The velocity cloud diagram and the full pressure cloud diagram of the new muffler at an inlet velocity of 50m/s were shown in Fig.11 and Fig.12.

From the analysis of Figure 11 and Figure 12, it could be seen that the inlet pressure was about 4500Pa at the inlet velocity of 50 m/s, and there was a partial pressure loss when the airflow velocity was slightly increased at the first bend of the conical ring.

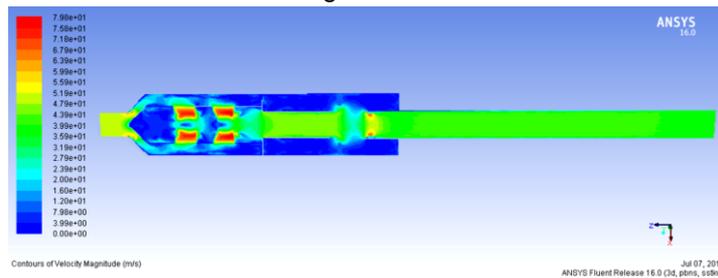


Fig. 11 - Velocity contours at inlet velocity of 50 m/s

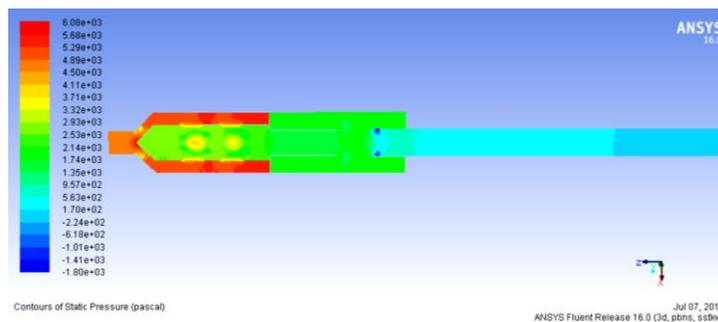


Fig. 12 - Total pressure contours in the muffler unit at inlet velocity of 50 m/s

After the airflow entered the two sets of opposing holes, the reverse airflow accelerated to rush at a velocity of about 71.8 m/s, and the pressure value dropped from 3320 Pa to 1740 Pa. After the rushing, the velocity in the central area decreased significantly to about 3.99 m/s, and the pressure returned to about 3500 Pa. There was a short acceleration after the airflow changed into an axial flow. The velocity at the junction of the front and rear muffler units was about 31.9 m/s, and the pressure here was reduced to 1740Pa. There was a brief acceleration phenomenon at the inlet of the inner cannula from the rear section, and then the velocity dropped to 35.9 m/s and this velocity was maintained to reach the outlet of the tail pipe. The outlet pressure was about -224 Pa, therefore, the total pressure loss of the new muffler at an inlet velocity of 50 m/s was 4724 Pa, and the pressure loss was well controlled.

It is verified that the airflow velocity of the coupling structure in the new muffler can be quickly reduced, which effectively controls the pressure loss, exhaust back pressure and fuel consumption.

CONCLUSIONS

The acoustic performance, exhaust resistance and economy of the new muffler are superior to the original muffler. It can be seen that the new muffler is more conducive to the attenuation of low-frequency noise of diesel engines. The use of the new muffler reduces the engine exhaust back pressure and power loss. The coupled muffler can achieve the comprehensive goal of good acoustic performance and low exhaust resistance by reducing the airflow velocity in the muffler. It is verified that the design of the coupled muffler based on the split-stream rushing principle and multi-unit coupling theory is reasonable and feasible.

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