The noise analysis of micro combined heat and power system

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Abstract

This paper presents an analysis aimed to evaluate the noise of micro-CHP systems. Based on the field test of insertion loss, the spectrum characteristics of CHP before and after the heat exchanger were analyzed. Finally the main source of noise is estimated, and the influence of speed and heat exchanger on noise is analyzed. The results show that the fundamental frequency noise is the main noise source, accompanied by other resonance noise. The increase of the rotation speed will cause the noise to move to the high frequency direction. System with heat exchanger can reduce high frequency noise.

Introduction

In recent years, more and more attention has been paid to the CHP system, especially in residential buildings with distributed generation [1]. It is an advanced technology with high energy utilization. Natural gas combustion is used to produce high-grade electric energy, and low-grade heat energy emitted by the engine is used for heating. This technology enables energy stepped utilization so that the energy utilization ratio is high. It has become a new way of public building energy supply in the city. Its basic components are shown in figure 1[2, 3].

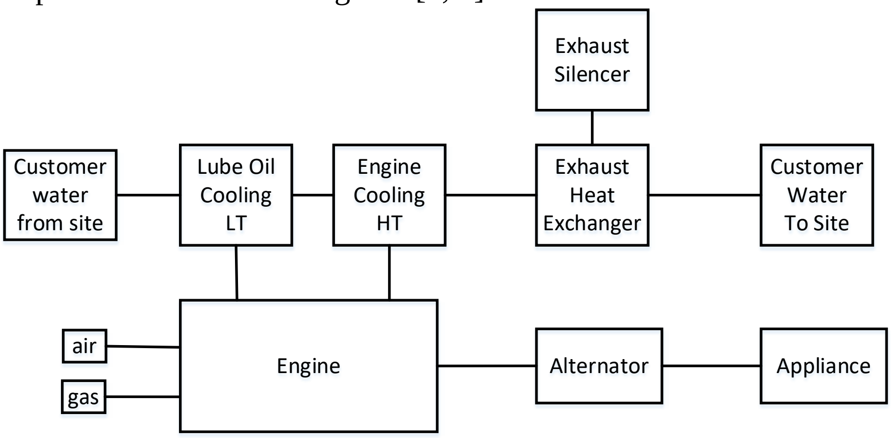

Fig. 1 Schematic diagram of CHP

The system is composed of gas internal combustion engine, generator, transmission system, gas distribution system, cooling water circulation system, waste heat recovery system and control system [4, 5]. Natural gas and air are mixed into the engine, the energy is released by combustion on the application of the mixed gas (gas and air), the generated flue gas will drive the piston movement, and then the output of the mechanical power is connected with the crank connecting rod mechanism or other mechanisms to operate the generator. The waste heat mainly belong to cooling liquid and flue gas, the water is used as a medium to absorb and utilize the residual heat in the heat exchanger [6, 7]. The exhaust gas generated by the engine is finally discharged by the heat exchanger and the silencer. The CHP noise is mainly produced by the engine. As the main exhaust system noise components, the muffler performance determines the noise level of the CHP. In order to design the muffler, the noise sources need to be judged, and the influence of the speed and the heat exchanger on the engine exhaust noise is analyzed.

Fig. 2 Experimental prototype

Noise source analysis

Figure 2 shows our experimental prototype, the engine is connected with the heat exchanger through the bellows. It is important to choose the noise monitoring points. To determine the position of the measuring points in the muffler exhaust noise measurement, it is necessary to measure the noise according to the standard of acoustic measurement [8-11]. The measuring point is 50 cm away from the muffler outlet, and it has an angle of 45 degrees from the outlet axis of the muffler [12]. The relative positions of the measuring points and the exhaust nozzles are kept constant during the measurement. Background noise is about the 50dB, which is far less than the experimental noise value so that it can be ignored.

The engine used in the experiment has single cylinder with four-stroke. Its displacement is 249 cubic centimeters. The engine has a total of 6 gears, and the gear transmission are showed in Table 1. With the increase of the gear, the ratio will be reduced. Adjust the engine to 5 gear so that the output shaft speed n_1 is1500r/min, the engine speed n_0 is 4190r/min. Acquisition Time domain noise signal are shown in Fig3. After the conversion of the frequency spectrum, we select the range of 0 ~ 500HZ in figure 4, the noise peak is located in 36HZ, 72HZ, 110HZ, 147HZ, etc... The peak value of the noise is an integer multiple of 36HZ and the maximum amplitude is 147HZ.

Table 1. Engine gear ratio

gears	1gear	2gear	3gear	4gear	5gear	6gear
ratio	7. 5078	5. 238	3. 8703	3. 201	2. 7936	2. 5608

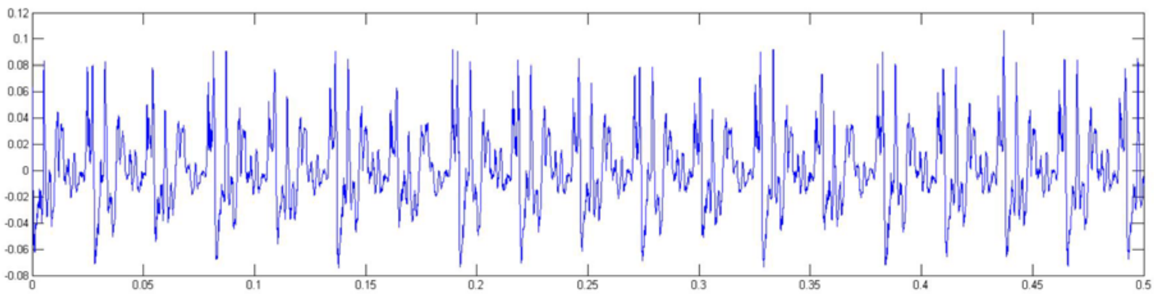

Fig. 3 Time domain noise signal while n_1=1600r/min

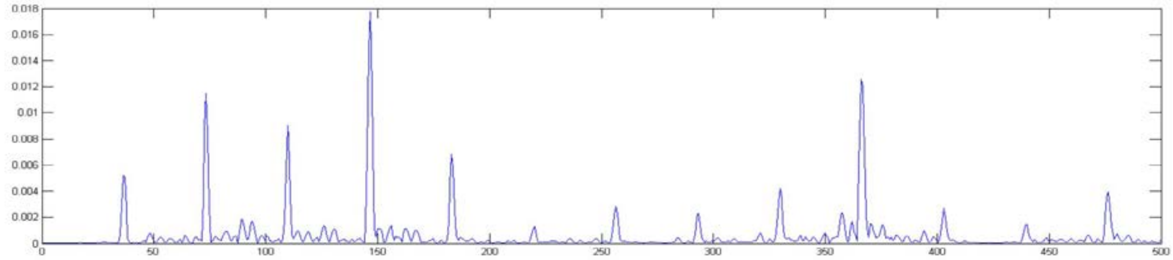

Fig. 4 frequency domain noise signal while n_1=1500r/min

When the exhaust valve of each cylinder of the engine is opened, the exhaust gas in the cylinder will be ejected at high speed, which impact on the gas in the exhaust pipe near the valve resulting in pressure changes violently, thus aroused noise. Since the exhaust of each cylinder is carried out in a specified phase according to the period, the law of fundamental frequency noise is periodic [13, 14]. It is typical of low frequency noise. The frequency of the fundamental frequency is the same as the number of times per second, which is the same as the frequency of the exhaust gas. It is called the fundamental frequency noise and it can be calculated by the following formula:

$$f = Zn/(30i). \quad (1)$$

Where Z is the number of cylinders; n is the engine speed (r/min); i is the number of strokes. It can be calculated that the fundamental frequency noise is 35HZ, so it can be judged that the exhaust noise of engine is mainly the fundamental frequency exhaust noise accompanied by other resonance noise, and the fourth harmonic generation is maximum.

Noise factor analysis

In order to analyze the influence factors of noise, we set the engine output shaft speed to 1500rpm, shift the ratio with 4, 5 and 6, and the engine speed is 4800rpm, 4190rpm, 3840rpm. Converting the time domain signal into frequency domain and extract the useful value. The effect of rotating speed and heat exchanger are evaluated as below.

Effect of rotating speed on exhaust noise. Table 2 shows the noise without heat exchanger, with the increase in speed, the total noise showed an increasing trend. Figure 5 shows the spectrum data without heat exchanger. The peak noise mainly located in 125HZ 500HZ and 1000HZ. There is a noise Valley at 250HZ and 4000HZ. Noise is mainly located in the medium frequency band. As the rotating speed increases, medium frequency band has risen. This result is consistent with reference [15].

Table 2. Noise without heat exchanger

speed	4gear-4800rpm	5gear-4190rpm	6gear-3840rpm
AP(dB)	119.32	118.54	116.40

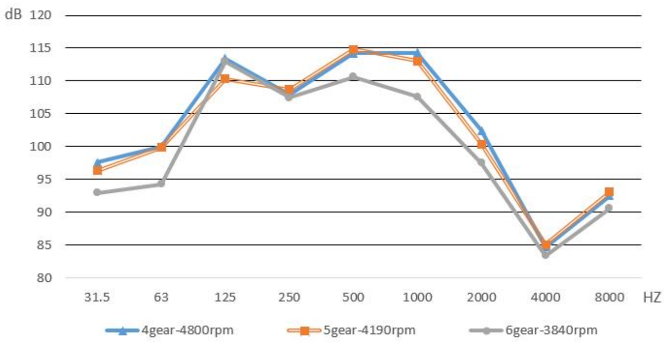

Fig. 5 Spectrum of different speed without heat exchanger

Table 3 shows the noise data with heat exchanger. Its trend is the same as that without heat exchanger. Figure 6 shows the spectrum data with heat exchanger. The peak noise mainly located in 125HZ. There is a noise Valley at 250HZ and 4000HZ.After 500HZ, with the increase of frequency, the value of DB decreases, as the rotating speed increases, the value of DB will rise obviously whether high frequency or low frequency.

Table 3. Noise with heat exchanger

speed	4gear-4800rpm	5gear-4190rpm	6gear-3840rpm
AP(dB)	116.40	114.70	113.93

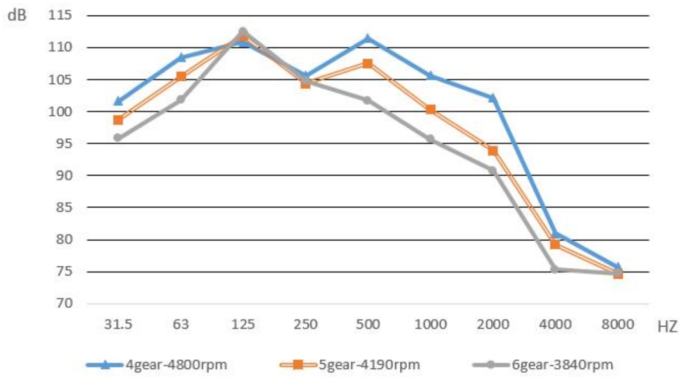

Fig. 6 Spectrum of different speed with heat exchanger

Influence of heat exchanger on exhaust noise. By comparing the data in Table 2 and table 3, we can see the total noise can be reduced by 3dB after adding heat exchanger on the same engine speed. Fig7 and fig 8 show the spectrum while the engine speed is 3800rpm and 4300rpm. By contrast, it can be seen that the existence of the heat exchanger will cause resonance in the low frequency range and increase the low frequency noise, but it will suppress the high frequency noise. The noise peak is located at 125HZ.

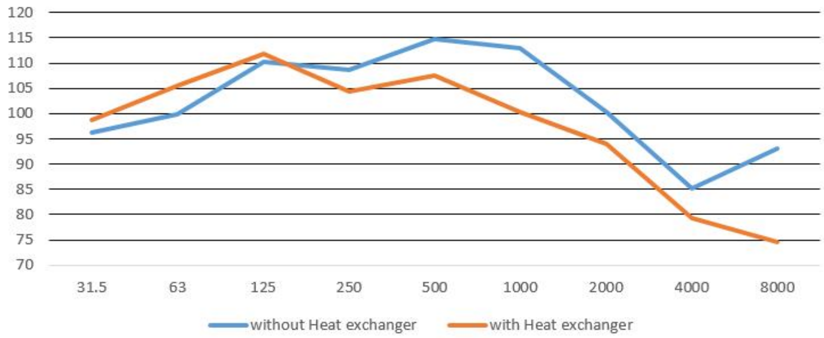

Fig. 7 n_0=3800rpm

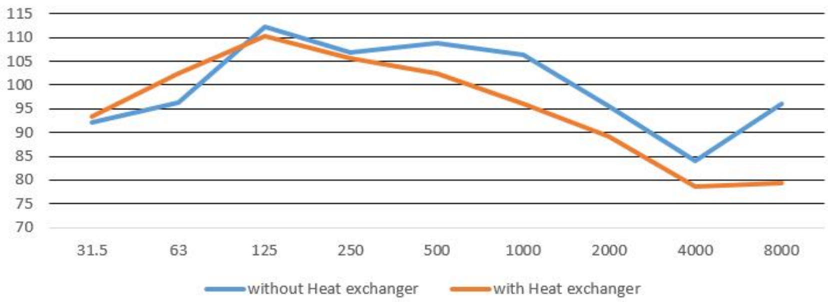

Fig. 8 n_0=4300rpm

Summary

In this research, the basic principles of micro-CHP systems is described and the noise is evaluated. From the analysis results, we can see that the fundamental frequency noise is the main noise source, accompanied by other resonance noise. The increase of the rotation speed will cause the noise to move to the high frequency direction. System with heat exchanger can reduce high frequency noise.

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