ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 1, Issue 7, November 2016

The Study of CI Engine Sound Control

[1] R.Saravanakumar[2] Durai.J [3]V.N.Kameswar
[1][2] Assistant Professor [3]Sr.Lecturer
[1][2][3]Department of Mechanical Engineering, Sri Sairam College of Engineering

Abstract:-- **CI engine will have a great sound when it works. The sound sources include combustion sound, mechanical sound and intake and exhaust sound, etc. To reduce the internal combustion engine sound, the sound source and dissemination way must be considered. Reducing the source sound is the most basic and the most direct effective action that it includes reducing the sound exciting force and exciting force response and so on. The main method in the CI engine burning sound aspect is formerly to adjust feed time and advance angle, to use the new combustion chamber and so on. The most effective and the most common methods are to improve and optimize exhaust silencer for intake and exhaust sound.**

Keywords- **CI Engine; Sound control; Combustion Sound**

I. INTRODUCTION

CI Engine is highly versatile thermal power machinery which is used as major power source in ships, automobiles, tractors, construction machinery, agricultural machinery and locomotives. It will produce vibration and noise. Vibration caused by CI engine damaged engine components, deterioration of engine performance; on the other hand, vibration will directly send out sound by the exciting force, transfer the torque to the body and produce very big sound. With development of industrial and transportation industries, on the one hand, engine power is constantly increased and speed is improved; the other hand, vibration and sound problems become more prominent as new materials such as various alloys of applications make the machine more light and thinner. Therefore, how to control the engine sound will be of great significance.

II. CI ENGINE SOUND

A. CI Engine Sound

Sound sources include fuel combustion sound, mechanical sound, and air intake and exhaust sound. According to the mechanism of sound generation and radiation methods, sound can be divided into direct engine sound radiation to the atmosphere (aerodynamic sound) and radiated through the surface of diesel engine (also called the surface structure of the noise radiated sound) two categories.

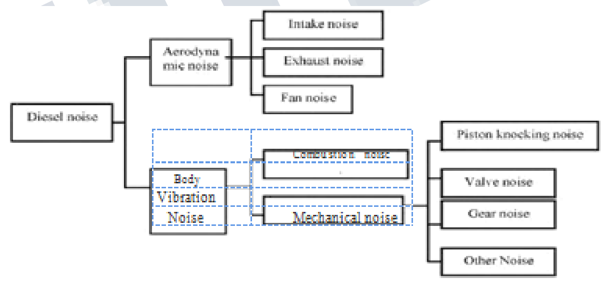

Figure 1.Engine sound chart

The composition of diesel engine sound is shown in Figure 1. Combustion sound is generated by the combustion of mixed gas generating direct structure excitation by engine pressure, and transmitting it through the external and internal of CI engine to the surface, that is attenuated by the engine structure, engine surface vibration and radiation form the air sound; mechanical sound is due to cyclical changes of mechanical action between the moving parts and fixed parts or between the moving parts. Mechanical sound is mainly the sound of percussion piston, valve train friction, and impact, meshing gears, bearings, belts, oil system, auxiliary systems and other sound. Mechanical sound can be further divided into two parts: First, CI engines produce mechanical rotation sound, and second, indirectly inspired by the burning power of the mechanical sound. Aerodynamic sound includes the sound of air intake system, exhaust system radiating directly to the atmosphere. As air sound has been effectively controlled currently, so the surface sound mixed between mechanical sound and combustion sounds become the first CI engine sound

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B Fuel Combustion sound

Combustion sound of CI engine is the main sound source. Generation of combustion sound has two aspects: structural vibration is caused by dynamic loads with the increasing cylinder pressure. CI engine itself is a complex vibration system. The sound is easy to spread when the power load on the vibration in the body and the body's natural frequency is in the same band. The second is high-pitched sound in the cylinder caused by high frequency vibration of gas. Structural vibration is caused by the impact of piston, cylinder head, cylinder block and connecting rods when sharp pressure increases as combustible mixture bums. For direct injection combustion chamber, sound of the open chamber is the largest, semi-open chamber follows, and the sound of the oblique spherical and cylindrical combustion chamber is relatively low. In separate combustion chamber, the sound of swirl chamber and pre-combustion chamber combustion is low.Combustion sound is focused on the speed combustion period followed by slow burning period. In the fast burning period, growth of large pressure is high, the impact is strong so the sound is large. In the low load, less fuel is injected due to the ignition delay, pressure rate is low, the corresponding combustion sound is decreased and the injector sound decreased. When the injection advance angle decreases, injection pressure increases as compression temperature and pressure increases and air turbulence in combustion chamber increases, mixture formation accelerates, thereby reducing the ignition delay period. On the other hand the number of the formation of combustible mixture will increase in the ignition delay period. Experiments show that the latter's impact is larger. As the speed increases, the maximum burst rate of pressure increases, the combustion sound also will increase.

C. Mechanical Sound

Mechanical Sound comes mainly from: i) Piston knocking sound The knock between piston and the cylinder wall is usually the biggest sources of mechanical sound. The knocking sound of piston cylinder depends on the maximum explosion pressure and the gap between piston and cylinder wall. The sound is not only relevant with combustion but also with the specific structure of the diesel engine. Clearances between piston and cylinder wall, engine speed, load and cylinder lubrication are major factors.

The knock sound of piston increases with increasing speed. When speed is a constant value, the impact energy E and the cylinder wall clearance C is proportional to growth, the relationship is E=KC.

In the formula: K is a constant.

Therefore, the engine speed increases with the sound increasing, the outbreak pressure is largest , the hit increases, the sound also increases. If there is enough oil which has damping and sound absorption effect, it will reduce the piston knocking sound.

2) Valve opening and closing sound

The major factor that affects the valve opening and closing valve sound is the velocity which is proportional to the sound. Especially the irregular movement of valve at high-speed is generated mainly due to the inertia force which is too large beyond the valve spring elasticity.

3) Timing Gear Sound

Gear Sound factors conclude gear design and processing and the structural factors of gear room.

4) Fuel injection system sound and other sounds

The sound of fuel injection system is mainly caused by the vibration of fuel pump, injectors and high pressure pipeline system. It can be divided into the fluidic sound and mechanical sound. Fluidic sound includes pump pulse sound and the pipeline acoustic resonance. Mechanical sound is mainly the cyclical impact and friction sound between the fuel pump cam and the scroll wheel body. In addition, camshaft, bearing vibration, speed and other institutions will produce sound.

The structural stiffness is also relevant with the mechanical engine sound. The structural stiffness can be improved by rational design. Resonance is avoided as the vibration frequency is inconsistent with the maximum frequency of sound such as reasonable ribbed in the cylinder wall to enhance its natural frequency, enabling the sound down 2 - 3dB (A).

D. Air Sound (intake and Exhaust Sound)

CI engine intake and exhaust sound includes: low and intermediate frequency sound generated by pressure fluctuation of air flow in the intake and exhaust pipe; high-frequency caused by the eddy currents when high-speed air flow is through the valve inlet section; gas vibration will be produced in the cylinder vibration process when the valve closes quickly and sound come through the surface.

Reasons of the formation of CI engine exhaust sound: When the exhaust valve opens, a gap appears and the exhaust gas comes out from the gap in pulses, then high

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energy, complex spectrum sound is formed. Figure 2 shows a typical CI engine exhaust sound spectrum. The CI engine sound increases with the increasing of engine capacity, efficient power, efficient torque and mean effective pressure and effective exhaust area. CI engine exhaust sound is the strongest sound source.

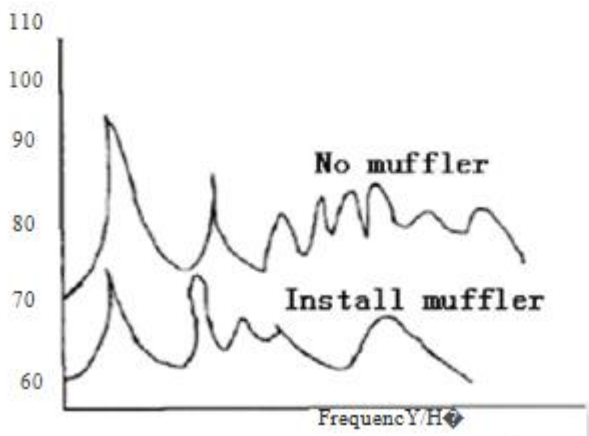

Figure 2 CI engine exhaust sound spectrum (2000r/m in full load)

E. *The Exhaust Gas Turbocharger Sound*

Exhaust gas turbocharger is essentially also a fan, its sound composition is similar to the fan sound. However, the speed of exhaust eddy current is much higher, so rotation sound is dominant and it has the high frequency characteristics.

F *Fan Sound*

Fan sound is mainly composed of rotating sound (or blade sound) and vortex sound. Fan air flow and diameter larger, speed higher, the sound is greater; the fan efficiency the higher sound is lower.

III. MEASURES TO REDUCE CI ENGINE SOUND

A. *Combustion Sound Control Measures*

The main way to reduce the burning incentive is to reduce the pressure rise value at the beginning of the combustion. Generally the following methods:

- ♣ Shorten the ignition lag. Delaying injection timing, increasing the compression ratio, turbocharger, intake heating and other methods;
- ♣ Reduce the ignition delay period, the amount of fuel injection, fuel injection control of the initial rate, and phased injection methods;
- ♣ Limit air and fuel to mixture in the ignition lag period. Control the fuel and air mixture efficiently by controlling the piston top fuel evaporation method and application of high swirl air.

i) Valve opening and closing sound

The main way to reduce the burning incentive is to reduce pressure rise value at the beginning of the combustion. Generally have the following: reducing the ignition lag. Reducing the amount of fuel injection in ignition delay period, controlling the initial rate of fuel injection which phased injection methods can also be used; restricting air and fuel mixture in the lag period of fire.

2) Using high compression ratio

The higher the compression ratio, the shorter the ignition delay time and the pressure rise rate. Therefore, the combustion sound is reduced.

3) Booster

As the turbo, the compression pressure and temperature are increased, which reduces the ignition delay period, easing the pressure rise rate, the combustion process is relatively soft. Therefore, the turbo can make the sound reduction. At the same time, also due to the use of turbo CI engine performance cannot deteriorate significant thereby, further reducing combustion sound. The cylinder pressure at full load, at high frequency spectrum on the sound level dropped dramatically in turbocharged CI engine, compared with non-turbocharged CI engine,

4) Inlet heating

The purpose of intake is to increase the heating temperature inside the cylinder, reduce ignition lag, which reduces the rate of pressure rise and the burning incentives. However, the intake air temperature rises, affecting the amount of intake charge, thus affecting fuel consumption, smoke and other properties, and therefore its effects should be considered.

B. *Mechanical Sound Control Measures*

For the mechanical sound, improving the balance performance of moving parts and reducing torsional vibration is the key to maintain low sound. The most commonly used measure is to reduce the impact of piston to the cylinder walls, such as reducing the gap between the

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pistons and cylinder silver and using of center-biased approach.

i) Cylinder center-biased

The crankshaft center is made off the cylinder center with center-biased approach for cylinder CI engine. Lateral pressure is reduced 30% after the piston offset to reduce piston knocking sound.

2) Control measures of reducing piston knocking

Reducing the impact piston cylinder is a relatively simple way better. Reducing the gap of the piston and cylinder sleeve can help reducing the impact energy to reduce mechanical sound. Figure 3 shows the sound curve changes when the gap between piston and cylinder is O. 1 � 0.12mm, the gap is larger, the sound significantly increases. It shows that reducing the gap between piston and cylinder can reduce engine sound.

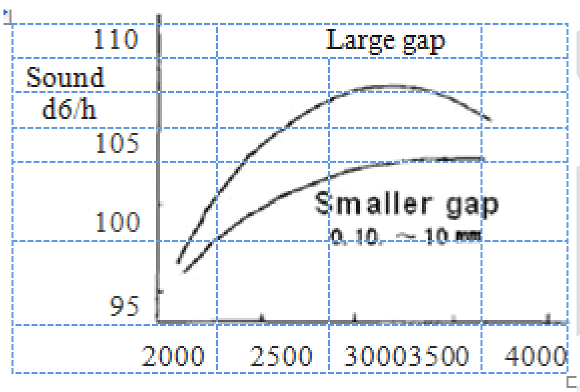

Figure 3 Gap on the impact of sound between piston and cylinder

3) Control measures of reducing gear sound

Controlling the gear tooth strictly, improving accuracy of gear processing, reducing gear mesh clearance are effective measures to reduce sound. But the effect is not significant and costs will increase by improving the precision when it is high.

Mechanical sound can be reduced by using plastic gears to absorb impact energy. In a CI engine with the two grades of MC nylon gear to replace the original steel idler gear, the measurements show that the gear sound at the front of 1m is 0.5dB (A), the machine also reduces the average sound level 0.2dB (A).

Control measures of Fan sound are: choosing the right cross-section shape of fan and the installation angle; designing high efficiency, low sound fan; choosing small nylon fan of low sound, power consumption or the flexible fan with the installation angle that can be changed with speed changes; Reasonable preparation cooling system components (such as fans, wind cover, radiator, etc.) between the position. In the cooling system design, a good sound reduction effect can be got with a relatively lower fan speed,

4) Using torsional mechanical device to reduce incentives

A large number of experimental show that the sound generated by the crankshaft torsional vibration is often important in determining the sound source of engine sound. The total engine sound can be reduced by 3dB

5) Assembly quality

CI engine may not be able to achieve low sound only with good structure, the assembly quality has a greater impact on the sound. Especially the balance performance of moving parts is an important factor affecting the machine sound. Good assembly quality is important parts which can make the moving parts has a good balance and ensure lower sound.

C. Airflow Sound Control Measures

i) Exhaust sound control measures

The control of exhaust sound, on the one hand is to start from the analysis of the sound source mechanisms, to take corresponding countermeasures, make the exhaust channel to avoid sharp turns; the other hand, the exhaust muffler can be used to make the sound down to a finite value less' this is the most effective and simplest way. Another way is to reasonably determine the structure of the exhaust pipe to avoid resonance and to reduce the vortex. The exhaust pipe itself is a resonant cavity. When the engine speed n and the exhaust pipe length I are in line with the following formula, the exhaust gas resonates in the exhaust pipe and exhaust sound will strengthen.

$$n = (30t/m) + (2k-1) \times (a / 4L) \text{ r/min}$$

In the formula: a is velocity of the exhaust gas in pipe at temperature m, L is the length of the exhaust pipe; m is the number of fluctuations; k is the harmonic number; t is the number of strokes (usually 4); k and m are positive integer, with k = I and m = I based.

2) Intake sound control measures

Intake sound increases with the increase of engine speed. Intake sound is not a major sound source for the non- turbocharged CI engine when air filter is mounted on it. Only when other sound sources are under control, it is necessary to control the air intake sound when it is a major sound source. When the CI engine turbocharger, the intake sound increases significantly. The main control technology of intake sound is the use of air intake silencer.

D. Reducing the Acoustic Radiation

CI engine sound is radiated out of the surface structure. Cylinder block (crankcase), cover, oil pan, cylinder head covers, etc. are the main sound sources.

1) Improving cylinder

Radiated source of cylinder CI engine accounts for 25% to 30% of the total sound. It is of great significance to decrease cylinder sound radiation. The key part of reducing the cylinder acoustic radiation is to improve rigidity of the crankcase and to reduce its amplitude and change its frequency.

2) Improving cover parts

Front cover of gear chamber and side cover of cylinder are major parts of radiation sound. Front cover of CI engine is cast iron, the sound radiation is strong, and it shows a good sound reduction effect when it is changed into steel stampings.

3) Improving pulley

Pulley that is used to drive the fan belt and other auxiliary equipment is also an important source of radiation sound that can account for 14% to 16% of all of the sound radiation. Thereby reducing the sound radiation on the lower pulley front of the engine sound has a greater role.

4) Increasing mechanical damping sound reduction Wall coatings with

In order to increase the damping of mechanical wall, the surface of friction body (such as the cylinder wall, cover wall, etc.) is covered with high-performance polymer materials which can reduce the radiated sound1 � 2dB (A).

E. Local Shielding

The easiest way of reducing radiated engine sound is closed method. We can greatly reduce the sound radiation altering shielding engine.

IV. CONCLUSION

Engine sound is generated by burning, mechanical and air incentive. The main way to reduce the burning incentive is to reduce the pressure rise rate at the start of burning. Injection timing delay, a phased injection and the turbocharge are relatively simple and effective ways for existing CI engines. Changing the torsional vibration characteristics, improving balance and reducing the impact energy of the piston to the cylinder are effective measures; reducing the structure radiation is also an important way to reduce engine sound. The main method is to improve the structural stiffness, to increase the structural damping of vibration transmission and to reduce the interference of its vibration response.

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