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AN ANALYSIS ON COMBUSTION NOISE IN ENGINES

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INTRODUCTION

This paper describes an attempt to find the transmission-radiation coefficient of combustion noise generated by a single combustion impact in the combustion chambers of stationary engines. The tests, focused on an analysis of transmission paths of combustion impact, were performed on a small air-cooled gasoline engine, and this technique was also applied to a water-cooled diesel engine.

TRANSMISSION-RADIATION COEFFICIENT OF COMBUSTION NOISE

The engine structure is assumed to be a linear system concerning the transmission and radiation of combustion noise. From this assumption, the conversion ratio of combustion impact to the noise remains constant in each frequency band with various processes of cylinder pressure. Therefor, the transmission-radiation coefficient of combustion noise G is defined as

$$G = W_s / W_c \tag{1}$$

where W_s is the sound power radiated from engine surface and W_c is the corresponding amount of combustion impact due to the abrupt rise of pressure in the combustion chamber. W_s is obtained from the energy average of sound pressure levels L_{sp} (re. 20 μPa) measured on the imagined hemi-spherical surface with area A_s. In a practical way, the value of W_c can be evaluated with the cylinder pressure level L_{cp} (re. 20 μPa) and the area of combustion chamber wall A_c.
The following equation gives the value of G in decibels:

$$10 \log G = \overline{L_{sp}} - L_{cp} + 10 \log (A_s/A_c) \quad \text{dB} \tag{2}$$

Considering that the combustion impact is transmitted through a number of paths, superimposed on each portion and radiated as noise, the total sound power can be regarded as a sum of the powers supplied through all the paths. The transmission-radiation coefficient of combustion noise G is expressed by

$$G = \sum_{i=1}^{n} (W_{si} / W_c) = \sum_{i=1}^{n} G_i \tag{3}$$

where subscript i denotes the ones for each transmission path of combustion impact.

TEST PROCEDURE AND RESULTS

Apparatus and procedure

Two four-stroke single cylinder engines were tested. One was an air-cooled gasoline engine (D×S 75×65 mm, 4.0 kW/3600rpm; hereinafter Engine I) and the other was a water-cooled diesel engine (102×106 mm, 11.0 kW/2400rpm; Engine II). The crankshaft was fixed to the base by a stopper in order to prevent rotation, so that the crank angle was set at combustion T.D.C.. A baffle was set up around the engine to make it possible to calculated the sound power by measuring the sound pressures in a semi-free field.

To generate the combustion impact, four kinds of substances were examined: a fire cracker, an electric igniter with explosive, an electric detonator and the LPG-O_2-N_2 mixture. These were ignited in the combustion chamber by a spark plug. Finally, the electric igniter with explosive was selected as the exciter source from the view point of stability and the impact speed of the excitation force.

Single combustion test on stationary engine

The time histories of the responses for the single combustion impact are shown in Fig.1(a). The rate of pressure rise in the combustion chamber dp/dt shows approximately 2.7 MPa/ms, and this value corresponds to 0.13 MPa/°CA at 3600rpm and/or 0.20 MPa/°CA at 2400rpm in dp/dθ of running engine.

The frequency characteristics of each impactive response are shown in Fig.1(b). The sound pressure level L_{sp} of combustion noise and the vibration acceleration level L_v (re. 10 μm/s^2) of the cylinder block gradually increase in spite of the decrease of the cylinder pressure level L_{cp} in the high frequency range.

Figure 2 shows the transmission-radiation coefficient of combustion noise, G, of Engine I for different cylinder pressure processes calculated by Eq.(2). The deviations of the value G in each band are small(less than +1 ∼-3 dB).

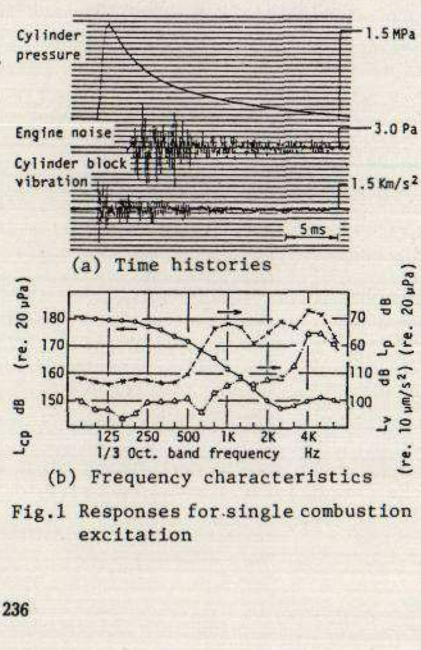

Fig.1 Responses for single combustion excitation

Transmission paths of combustion impact

The combustion impact excites the chamber walls. It is transmitted through several paths, superimposed on each portion of the external surface, and finally radiates the combustion noise outward. The following three primary transmission paths are taken into account.

Path (1): gas excitation path, through the engine head and liner

Path (2): piston-liner path, through the side wall of the piston and pistonrings/liner

Path (3): piston-crankshaft path, through the piston/connecting rod/ crankshaft, and the lower portion of the engine block

To identify the characteristic of each transmission path individually, three kinds of arrangements in the same engine were examined.

The first arrangement is the original one. This provides the combustion noise which is transmitted through all three paths. The second arrangement is the same as the first one except that the piston rings are replaced by O-rings to isolate the piston with liner, and provides the combustion noise through paths (1) and (3) only. Figure 3 shows the third arrangement replacing the piston and connecting rod by a model piston. This provides the noise only through path (1). Thus we can estimate the frequency characteristics of G for each transmission path employing the references of G's for these three arrangements.

Figure 4 shows the results of the transmission-radiation coefficient of combustion noise, G, obtained for each path. It is found that the combustion impact easily generates the noise through path (2) in the frequency range of 1.6k~4kHz and through path (3) in 1k~1.25kHz, while there is no significant difference in G between these three paths in the range of 400~800Hz.

Comparison of G's between two engines

The G's of the two kinds of engines are compared in Fig.5. Engine I is an air-cooled gasoline engine. In cutting off the fins, a considerable

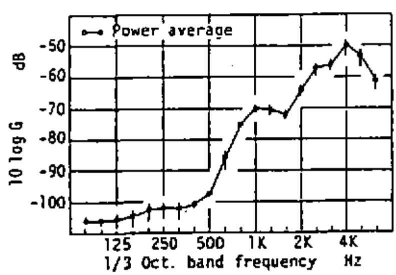

Fig.2 Transmission-radiation coefficient of combustion noise (Engine I)

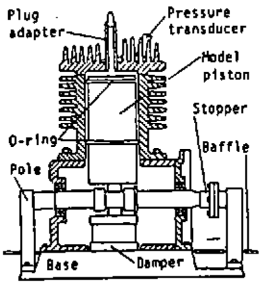

Fig.3 Schematic of Engine I structure for testing the air excitation path

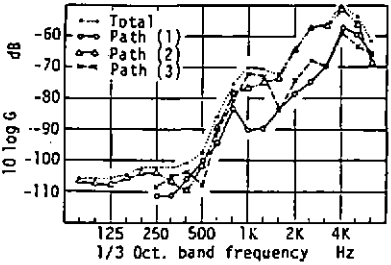

Fig.4 The coefficients G for each transmission path

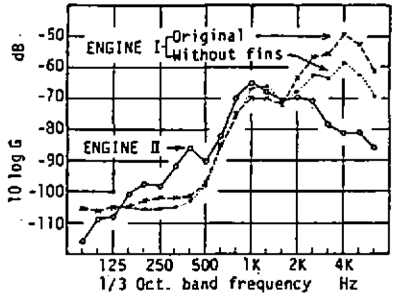

Fig.5 Comparison of G's between two engines

decrease in the value of G was observed.
From this fact, it was confirmed that the cooling fins strongly radiate combustion noise in the high frequency range.

In Engine II, the value of G is much smaller in the high frequency range and a little larger in the low frequency range than that of Engine I. The reasons for these tendencies may be due to the fact that Engine II has a wet type liner, a more rigid structure and bigger walls.

As is found in the above examples, we can assess the characteristics of transmission and radiation of combustion noise by investigating many different engines.

CONCLUSIONS

(1) Single combustion tests were conducted to make the relationship between combustion impact and noise clear by exploding an electric igniter with explosive in the combustion chamber of stationary engines.
(2) Transmission-radiation coefficient G was introduced in order to find the frequency characteristics of the conversion of combustion impact into noise ratio.
(3) The coefficient G was studied for three separate transmission paths. For Engine I (air-cooled gasoline engine), it is found that combustion noise is most strongly radiated through the piston-liner path.
(4) The frequency characteristic of G for Engine II (water-cooled diesel engine) is smaller in the high frequency range than of Engine I.
(5) This technique offers a promising way to assess combustion noise generation and for clarifying the transmission and generation mechanisms of combustion impact in each engine.

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