THE INFLUENCE OF EXHAUST EMISSION CONTROLS ON THE COMBUSTION NOISE LEVEL OF AN I.D.I DIESEL ENGINE

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The pronounced "knock" of a diesel engine is generally considered to be the result of differences in the form of the cylinder pressure development as opposed to variations in engine structure. The more abrupt the change of slope from the compression curve upon combustion, the greater the combustion noise level. Typically, diesel engine combustion noise is the result of the high rate of pressure rise in the initial stages of combustion, while the subsequent rise of pressure up to the peak pressure, which is at a much lower rate, has a negligible effect [1]. In general, it is the premixed volume of the fuel and air that is the fundamental factor that directly influences the level of combustion noise. This volume can be linked to the length of the ignition delay; a long delay is generally assumed to be an indicator of high combustion noise levels due to the larger amount of premixed fuel and air at the time of ignition.

The combustion noise research to date has primarily focused upon identifying the various engine design and operational parameters that affect the level of combustion noise produced. Unfortunately, with the introduction of more stringent exhaust emission standards, there is a lack of information regarding the influence of the ensuing pollution control techniques on the levels of combustion noise generated. One of the more promising exhaust emission control methods for diesel engines is the application of exhaust gas recirculation (EGR), which involves mixing part of the exhaust gas with the fresh intake air charge to act as a diluent in the combustion process. However, the influence of the exhaust gases in the intake mixture on the combustion noise level is unknown. Consequently, an experimental investigation to determine the effects of these non-conventional atmospheres on the level of combustion noise was carried out using a specially designed test rig at the University of Calgary.

In order to delineate the effects of different intake working fluid compositions on the level of combustion noise the experimental investigation was performed in four segments: (i) the effects of atmospheric air, (ii) the effects of various intake O_2/N_2 ratios, (iii) the effects of CO_2 addition ($CO_2/O_2/N_2$ mixtures), and (iv) the effects of synthetic EGR.

(i) Naturally Aspirated Condition: The results obtained when operating with a conventional, naturally aspirated atmosphere were similar to those published in the literature [1]. The combustion noise level increased with speed at a rate of 31.8 dBA/decade and was generally independent of load. Additionally, for the conditions investigated the combustion noise level was found to be a function of the maximum rate of pressure rise (dP/dt_{max}).

(ii) Variable O_2/N_2 Ratios: The experimental results obtained when operating with various O_2/N_2 ratios indicated that the combustion noise level exhibited a slight decreasing trend as the intake O_2 concentration was increased. However, unlike the naturally aspirated condition, these noise levels were influenced by the engine load. The decrease in the combustion noise level was believed to be primarily due to the decreased ignition delay as the intake O_2 concentration was increased. However, the decrease in the combustion noise level was not at significant as expected. This was attributed to the mechanism by which the ignition delay was altered. Variations in the intake mixture O_2/N_2 ratios modified both the chemical and physical elements of the ignition delay. However, the most influenential factor that affected the ignition delay under these conditions was the variation of the O_2 concentration which altered both the diffusion/mixing rates between the fuel and O_2 and the chemical oxidation reactions that occur to form a flammable mixture.

(iii) CO_2 Addition: The results obtained when operating with various $CO_2/O_2/N_2$ mixtures indicated that the combustion noise level exhibited a generally increasing trend whose magnitude was also dependent upon the engine load. Similar to the O_2/N_2 mixtures, the change in the combustion noise level was attributed to a change in the ignition delay, however, the mechanism by which the ignition delay period was altered was different. The presence of CO_2 in the intake, at a constant intake O_2 concentration of 23.3% by mass, primarily influences the chemical portion of the ignition delay by altering the specific heat capacity of the mixture. Therefore, the increase in the combustion noise level was much more significant when compared to the O_2/N_2 data because during the extended ignition delay period a larger volume of premixed fuel and air was formed. Hence upon ignition rapid burning rates and high rates of pressure rise result.

(iv) Synthetic EGR: The first three stages of this experimental program have been designed to illustrated how various diluents affect the combustion noise in order to provide some insight into the effect of EGR on the combustion noise level. The introduction of EGR involves a reduction of the intake oxygen concentration and an increase in the carbon dioxide concentration. Therefore, based on the above experimental results, it is expected that EGR would increase the combustion noise level. However, the preliminary results indicated that the combustion noise level of the engine remained constant and independent of load when operating under EGR conditions. Although, at excessive levels of EGR (above 80% recirc) the combustion noise level increased which was attributed to the poor combustion characteristics within the cylinder.

Similar to the previous stages, the combustion noise characteristics were determined by the ignition delay period. An increase in the amount of EGR resulted in an increase in the delay period because of the lack of O_2 which hindered the diffusion/mixing rates between the fuel and O_2 as well as the chemical oxidation reactions that are necessary to form a flammable mixture. However, as the quantity of EGR increased the intake CO_2 concentration also increased thereby modifying the polytropic exponent of the engine compression characteristics which lowered the pressure at the start of combustion. This lower pressure counteracts the effects of the longer ignition delay and hence the combustion noise level remains constant.

The results of this experimental investigation have shown that when operating on both naturally aspirated and non-conventional atmospheres, the main engine parameter that influenced the level of combustion noise was the ignition delay period, and hence the volume of premixed fuel and air at the time of ignition. However, as illustrated by the EGR results, it would also appear that the pressure at the start of combustion, as determined by the compression characteristics of the cycle, is also an important factor. Nevertheless, contradictory to some non-conventional atmospheres, the application of EGR to the intake mixture of a diesel engine for exhaust emission control does not affect the level of combustion noise generated, thereby enhancing it's potential for future use.

REFERENCES

[1] T. Priede, et. al., 1968, "Combustion Induced Noise in Diesel Engines", Diesel Engineers and User Association, Publication 317.