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Noise Optimization in Diesel Engines

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Abstract

Euro 6 norms emphasize on reduction of emissions from the engines. New injection methods are being adopted for homogenous mixture formation in diesel engines. During steady state conditions homogenous combustion gave noise levels in lower frequencies. In this work noise produced in a 440 cc diesel engine has been investigated. The engine was run under various operating conditions varying various injection parameters.

Keywords: Engine Acoustics, Noise,Vibrations

1. Introduction

Development of Diesel engines calls for reduction of NOx emissions at the same time maintaining fuel economy .One of the methods to reduce emissions is exhaust gas after treatment, however this method is expensive[1]. Another promising way is to obtain homogeneous mixture in combustion mixture[2].There may be deterioration of mixture in this methodology, hence other factors must be taken into account while studying radiated noise from engine like structural attenuation.

In modern diesel engines dual injection methodology has been used for achieving homogenous mixture formation. Analysis of in cylinder pressure spectrum for a dual injection engine has shown lobes with distance between lobes inversely proportional to dwell time between two injections. With this method majority of noise emissions have been found to be in low and medium frequency range [3]. However most of current study of noise reduction is focused on high frequency ranges, this calls for study of other factors like structural attenuations of engines. Structural attenuation is defined as transfer function between in cylinder pressure and combustion noise radiated from engine. The in cylinder pressures can be measured directly by pressure transducers installed in the engine, however direct measurement of combustion noise is difficult owing to fact that microphones record total noise emitted which includes other factors like motion based noise, flow noise, transmission noise etc.Seperation of noise sources can be effectively done by Wiener filters so that attenuation factor can be computed[4].

2. Wiener Filter

Let x(n) be a signal which is contaminated by unknown noise b(n) resulting in resultant signal y(n). Mathematically [5]:

y(n)= x(n) +b(n) (1)

Let r(n) be a reference signal that is coherent with x^(n) but not related to b(n).As shown in figure no 1 the aim is to design a filter H(n)which when applied to r(n) gives an estimate of x(n).In frequency domain this filter is given by H(f).

$$H(f) = \frac{S_{yr}(f)}{S_{rr}(f)} \quad (2)$$

Where

H(f) denotes Fourier tranformation of H(n), $S_{yr\,(f)}$ is cross spectral density between y(n)& r(n), S_{rr} (f is auto spectrum of r(n).

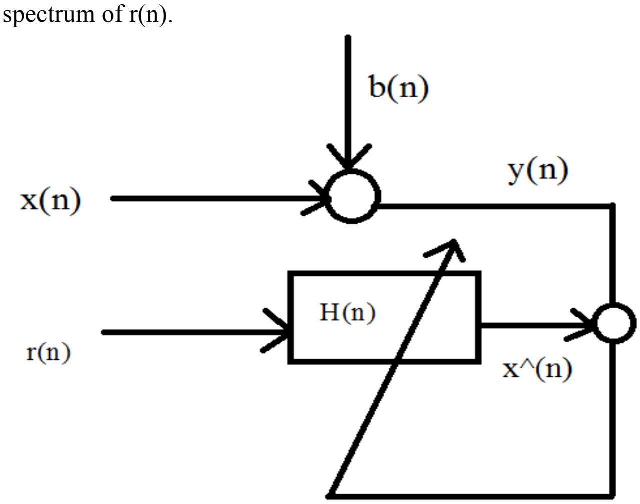

Fig. 1. Principle of Wiener Filter

The Wiener filter under consideration is best applied only to cyclostanionary signals. For application purpose the

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signals obtained from engine are studied from cycle to cycle basis instead of time averages.

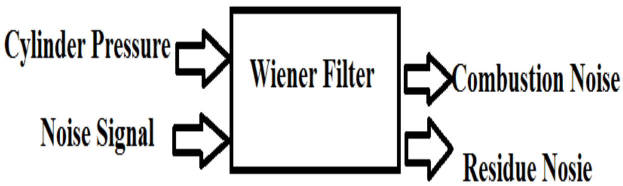

Fig. 2. Application of Wiener Filter

For application of this filter average values of noise emissions and cylinder pressures are computed over various engine cycles. The variable part of signals is computed as the difference between average and original values. The average values thus obtained have similar levels at low frequency ranges and reduced levels at higher frequency ranges. Hence the filter designed has good accuracy in higher frequency ranges as compared with lower one which is an ideal condition for separating combustion noise as majority of combustion based excitations lie in higher ranges.

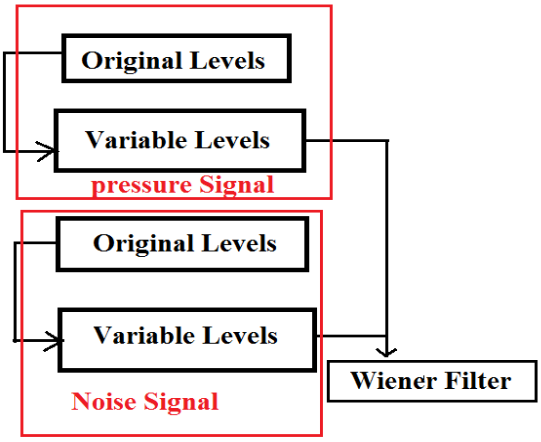

Fig. 3. Design of Wiener Filter

Using these filters it is possible to separate the combustion noise from mechanical noise and compute the structural attenuation factor. This method is simple, quick and reliable for higher frequency ranges[6].

3. Experimental Test Rig

Experiments were conducted on a dual cylinder lombardini LDW442CRS common rail direct injection test rig having specifications as presented in table no 1.This engine test rig has a piezo electric type Kistler 6056A make pressure transducer for in cylinder pressure measurements and an optical crank angle encoder for detection of TDC position as well as engine speed. The given system can do maximum of 2 injections per cycle. The injection strategy for the engine is shown in figure no 1.

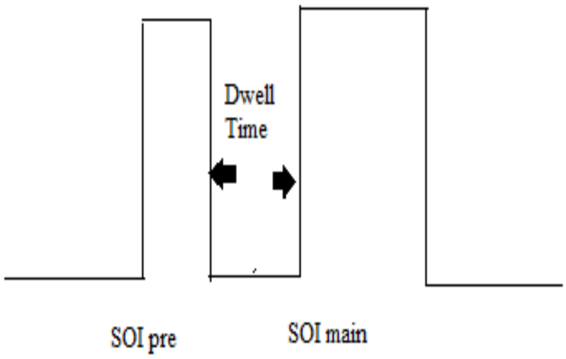

Fig. 4. Injection Process

The engine was run at 1600RPM & 2000 RPM at various load condition. The data obtained is shown in table no 2 & 3.

Table 1. Engine Specifications

Type	Direct Injection
Number of cylinders	2
Bore	68 mm
Stroke	60.6 mm
Displaced Volume	440cm^3
Compression Ratio	20:1
Maximum Power	8.5kw@4400 RPM
Maximum Torque	25N-m @2000 RPM

Table 2. Testing Cases

Condition	Load	Speed
B1	50%	1600RPM
B2	100%	1600RPM
B3	50%	2000RPM
B4	100%	2000RPM

Table 3. Data Acquired

Case	P_{rail} (Bar)	Q_{pre} (mm^3/stroke)	Q_{main} (mm^3/stroke)	SOI_{pre}	SOI_{main}
B1	700	1	6.3	19.9°	5.09°
B2	714	1	13.8	14.6 °	6.29 °
B3	515	1	6.6	22.5°	5.68°
B4	710	1	13.8	16.5°	6.29°

4. Results and Discussions

Using the filter stated above on the testing conditions noise levels were separated the results are shown in figure 6-8.

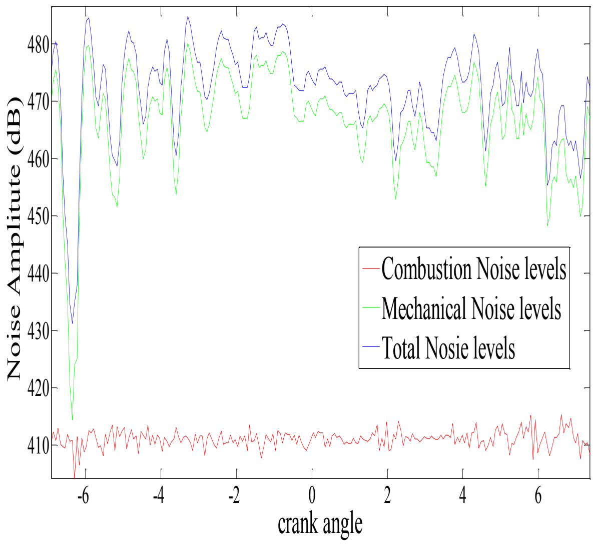

Fig. 5. Noise Separation(B1)

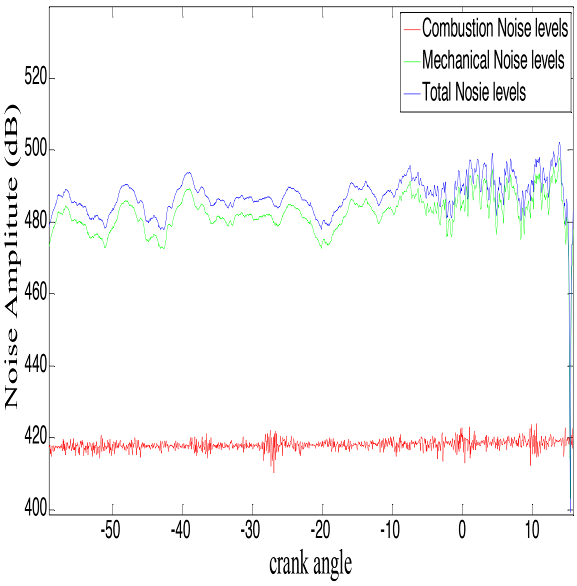

Fig .7. Noise Separation(B2)

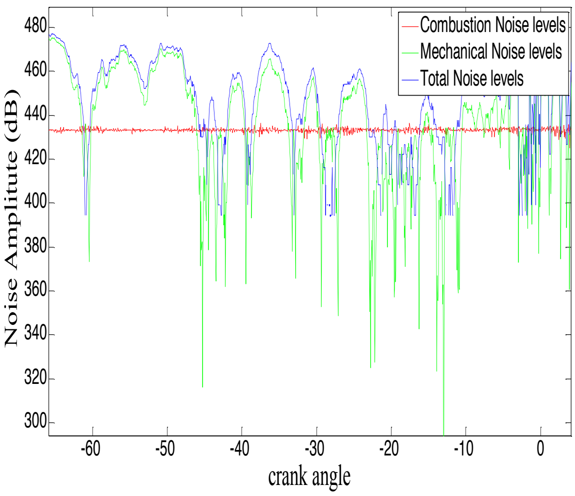

Fig. 8. Noise Separation(B3)

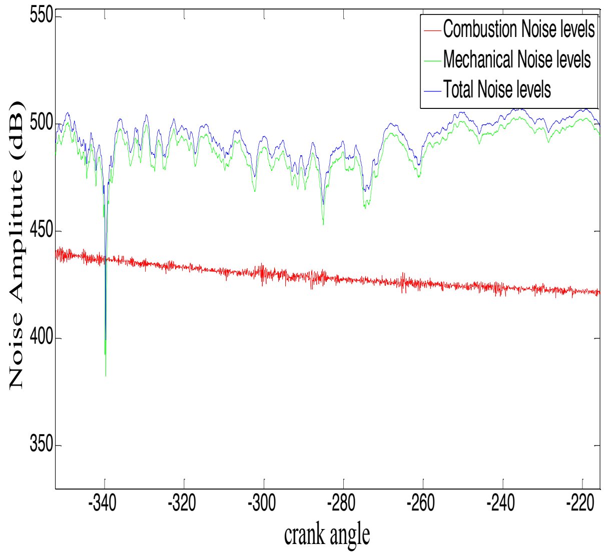

Fig. 9. Noise Separation(B4)

As evident from these plots noise levels rose with an increase in fuel injection angles& mechanical noise dominates total noise levels. These results are accurate only in high frequency range not in lower or medium range due to filter characteristics.

For these ranges alternative structural attenuation method can be used. Actual attenuation can be expressed as difference of cylinder pressure(dB) & combustion noise(dB).i.e.

$$AS(dB) = P_{cylinder}(dB) - \text{Combustion Noise}(dB)$$

$$= P_{cylinder}(dB) - [\text{Total Noise}(dB) - \text{Mechanical Noise}(dB)]$$

$$= P_{cylinder}(dB) - \text{Total Noise}(dB) + \text{Mechanical Noise}(dB)]$$

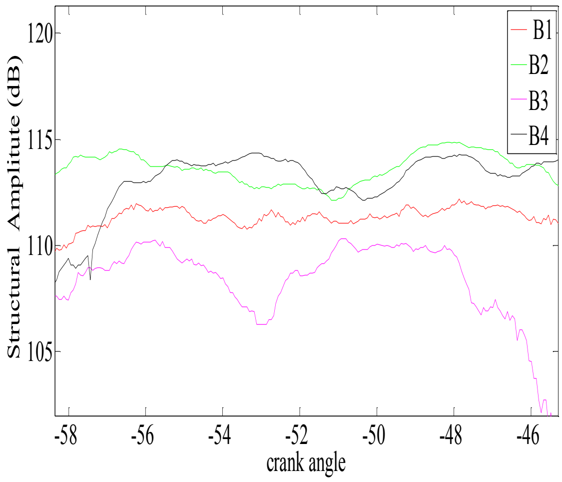

Fig. 10. Structural Attenuation

5. Conclusion

In steady state conditions homogenous mixtures gave high level of combustion excitations. Hence engine structure must be improved in this frequency range to reduce the noise radiated form engine. For measuring engine structural attenuations Wiener filters are not accurate at low and medium frequency ranges. Hence a suitable attenuation factor was developed .During transient operations other transient noise indices can be developed form the area under noise diagramme.

Nomenclature

- SOI-Start of Injection
- TDC-Top dead Center
- Q_{Main} -Amount of fuel injected per stroke in pilot(pre)injection
- P_{rail} –Common rail injection pressure
- Q_{Pre}-Amount of fuel injected per stroke in pilot(pre)injection

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