ISSN 1846-6168
UDK 621.436:534.831

ANALIZA BUKE KOJU PROIZVODI DIZEL MOTOR SA ZAJEDNIČKIM VODOM

ANALYSIS OF NOISE RADIATED FROM COMMON RAIL DIESEL ENGINE

Sunny Narayan

Stručni članak

Sažetak: *Various noise regulations and consumer comfort needs are pushing automotive makers for investigating new methods for noise control. This work deals with experiments carried out on a 440 cc direct injection diesel engine which is commonly used for medium power automobiles. In order to investigate the acoustic behaviour of this engine various experiments were carried out at various loads and speeds. Useful data was obtained for source location of various noise sources and transmissions paths.*

Ključne riječi: *akustika, analiza buke*

Professional paper

Abstract: *Various noise regulations and consumer comfort needs are pushing automotive makers for investigating new methods for noise control. This work deals with experiments carried out on a 440 cc direct injection diesel engine which is commonly used for medium power automobiles. In order to investigate the acoustic behaviour of this engine various experiments were carried out at various loads and speeds. Useful data was obtained for source location of various noise sources and transmissions paths.*

Key words: *Acoustics, noise analysis*

1. INTRODUCTION

Various vibrations occurring in a diesel engine are due to mechanical an combustion forces [1]. These vibrations are transmitted through engine structure to surface of engine. These vibrations give rise to motion of air which leads to audible noise around us. Broadly the total noise can be divided into combustion noise, motion based noise and load based mechanical noise [2]. One key process to reduce the noise is by use of higher injection pressures, but it necessities use of bigger injection pumps which leads to higher noise from gear drives [3].

When a force is applied on a structure, the induced vibrations depends upon the application time as well as on natural frequency of vibration of structure. Combustion based noise can be reduced either by stiffening of structure or by controlling rate of pressure rise. Hence controlling pressure rate is a key to control combustion noise. Common rail injection systems are being used now days to control combustion noise as well as particulate emissions [3]. Controlling the injection parameters is the key to minimize the emissions from such type of engine [4]. In this work sets of experiments were performed to identify various sources of noises and study their reasons and effects.

2. EXPERIMENTAL RIG

Experiments were carried out on a lombardini LDW442CRS common rail double direct injection engine system having specifications as given in the Table no 1.This engine test rig has a piezo electric type Kistler 6056A make pressure transducer for in cylinder pressure measurements and a optical crank angle encoder for detection of TDC position as well as engine speed. The noise data obtained from the tests was processed using B&K Nexus device which amplifies and filters data at 22.4KHz.Experiments were carried out at fired and motored conditions by varying speed . The data thus obtained is presented in table no 2.

Table 1. Specification of Engine [5]

Parameter	Rating values
Bore	60.6 mm
Stroke	68 mm
Volume	440cm^3
Torque	25N-m @2000 RPM
Power	8.5kw@4400 RPM
Compression	20:1

Table 2. Experimental Data Acquired

Test case	P(Rail) (Bar)	Load	Speed	Q_{PRE}	Q_{MAIN}	SOI_{PRE}	SOI_{MAIN}
B1	508	50%	1600 RPM	1	6.3	19.9	5.08
B2	714	100%	1600 RPM	1	13.8	14.6	6.29
B3	-	0%	1600 RPM	-	-	-	-
B4	515	50%	2000 RPM	1	6.6	22.5	5.08
B5	710	100%	2000 RPM	1	13.8	16.5	6.29
B6	-	0%	2000 RPM	-	-	-	-

3. NOISE PREDICTION

To understand noise mechanisms it is necessary to understand the combustion base noise developed due to in cylinder pressure. This process is clear in figure no 2 where pressures were measured by means of pressure transducers at both fired and motored conditions. A rise in pressure was found to be about 18 Bars owing to combustion process. To better understand the events the pressure frequency analysis was done. The analysis of energy value of in cylinder pressure is seen in figure. It can be seen that the peak corresponds to resonance.

Further understanding of cylinder attenuation is useful to understand combustion noise. In cylinder pressure needs to be changed in order to understand the influence of pressure .This can be accomplished by changing the inlet air temperature to engine, changing centane ratings or by changing injection timings. It has been further assumed that mechanical noise remains constant and structural attenuation response is linearly dependent on change of in-cylinder noise.

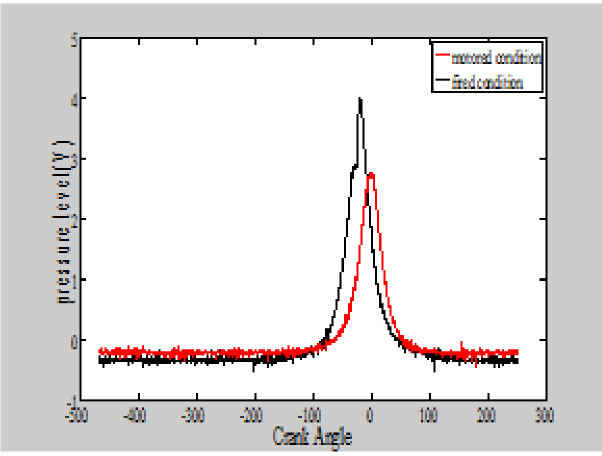


Figure 1. In-Cylinder pressure for both motored as well as combustion conditions (case1)

Based on these two assumptions it can be formulated that:

$$sp = m * cp + A \ [6] \qquad (1)$$

Where m is inverse of engine attenuation, sp is energy related to sound pressure levels n, cp is energy related to in cylinder pressure levels and A is energy level related to mechanical noise.

Further other parameters can be written as follows:

$$Mechanical\ noise = 10 * \log(a) \qquad (2)$$

$$Structural\ attenutaion = 10 * \log(\frac{l}{m}) \qquad (3)$$

$$Combustion\ noise = 10 * \log(b - a) \qquad (4)$$

Cylinder pressure can be expressed as sum of combustion noise & structural attenuation. Using these equations for the case of data collected for various test cases parameters have been plotted as seen from figures 2, 3, 4, 5.

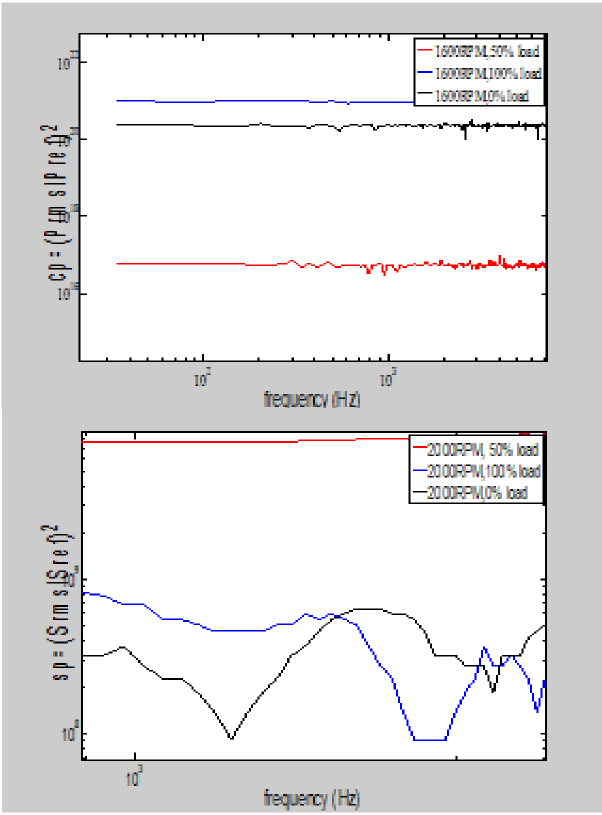
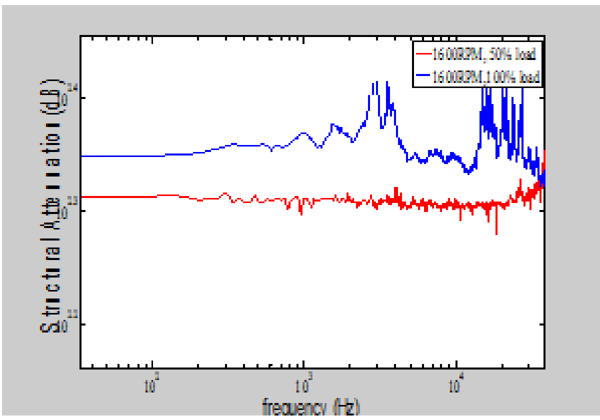


Figure 2. Variation of Energy Level Parameters



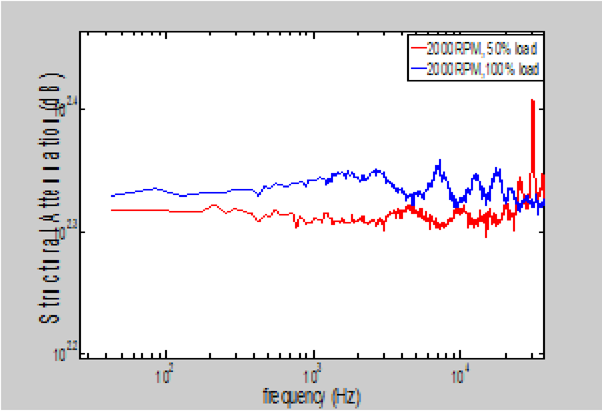


Figure 3. Variation of Structural Attenuation

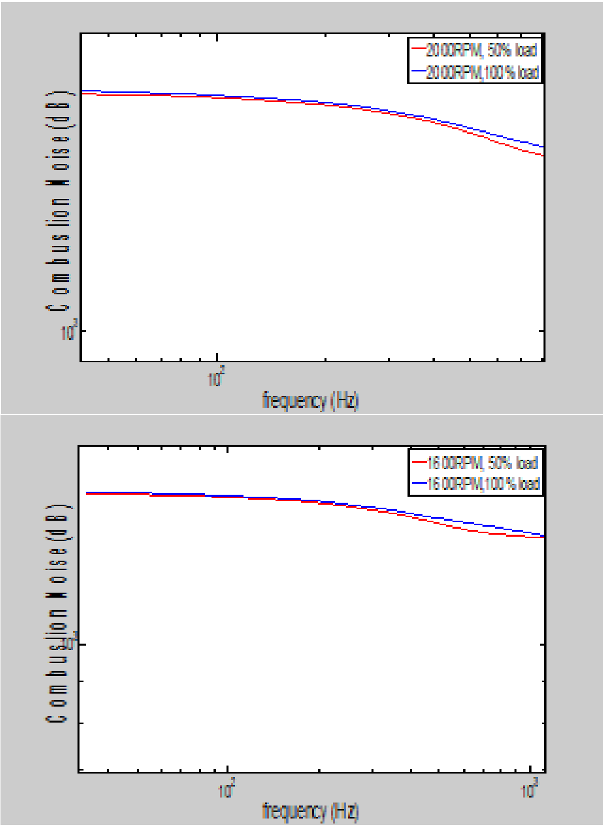
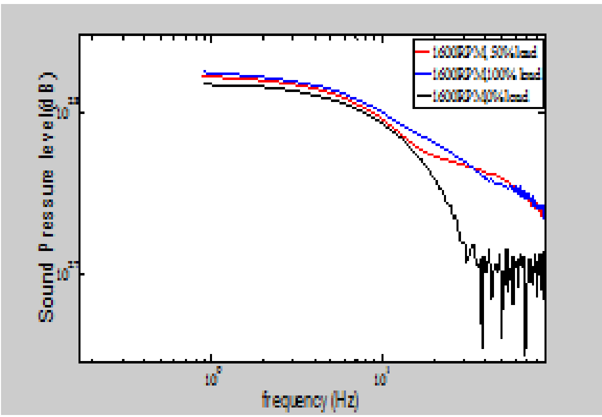


Figure 4. Variation of Mechanical Energy



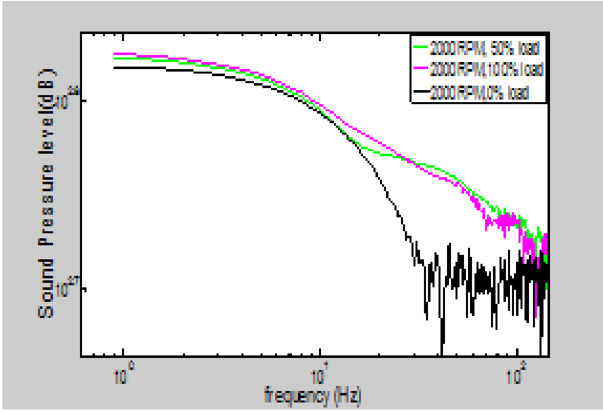


Figure 5. SPL for given testing conditions

Figure 5 shows the SPL for given testing conditions expressed as one-third of octave frequency band. From this figure it is clear that frequency band 0-10 Hz is most important band from engine acoustics view point. Hence trend of curve in this region can be used to calculate noise using empirical formula.

Table 3. Trend parameter Value

CASE	Trend(dB/ decade)
B1	6.27
B2	3.6925
B3	2.5233
B4	3.8218
B5	6.5706
B6	2.3197

An empirical formula relating intensity of noise radiated with engine bore can be expressed by relationship:

$$L_pA = A\log(N) + B\log(D) - C \qquad (5)$$

Where N is engine RPM, D is engine bore, A is trend of in cylinder pressure spectra (ref table 3), B is reference bore parameter C is structural feature of engine.

Values of B and C are 50, 31 respectively for this class of engines [1]. Using this relationship, an estimate of A level noise radiated from engine for given test conditions was calculated and the obtained results were compared with those evaluated by experimental data obtained from SPL as given in table no 4.

Table 4. Comparison of A level Noise Levels

CASE	Calculated	Experimental
B1	93.8816	169.9916
B2	92.0885	165.6622
B3	83.4381	164.9954
B4	111.1047	169.9998
B5	114.2520	169.9689
B6	82.3282	169.3807

The difference between the two sets of values was due to structural features of engine under test.

4. CONCLUSION

In this work the acoustic study of a dual cylinder CRDI diesel engine has been under taken for understanding of various components associated with radiated noise using both experimental & emperical apporcahhes have been studied.Based upon the results optimization of injection parameters can be carried out to reduce the noise radiated from engine to match human comfort levels.

5. NOMENCLATURE

CRDI-Common Rail Direct Injection
SOI pre -Start of Pre –Injection (°Before TDC)
SOI Main -Start of Main-Injection (° Before TDC)
P rail=rail injection pressure
Q Pre-amount of fuel injected per stroke (pre-injection)
QMain-amount of fuel injected per stroke (pre-injection)
db –decibel level

6. REFERENCES

[1] Hickling and Kamal, Engine Noise Extraction, Vibration and Radiation, Plenum Press, New York, 1982.
[2] Priede, "Noise and Vibration Control of the internal combustion Reciprocating Engine", Chapter 19, Noise and Vibration Control Engineering, Beranek, John Wiley Sons, New York, 1992.
[3] Taylor: The Internal Combustion Engine in Theory and Practice, vol2: Combustion, Fuels, Materials, Design, MIT press, 1968.
[4] http://service.lombardinigroup.it/english/man_index_gb.htm.Acessed on 18-11-2013.
[5] Beranek, "Acoustics", 1954.
[6] Corcione, Siano, Vaglieco, "Analysis and control of Noise Emissions of a small Single Cylinder D.I. Engine", SAE paper-2003-01-1459.

Kontakt autora:

Sunny Narayan
PhD student
University of Roma Tre, Italy
rarekv@gmail.com