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MODIFICATION OF INJECTION PRESSURE AND AUXILIARY AIR SUPPLY ENGINE HARDWARE TO CREATE HIGHER SOOT LEVELS FOR EXAMINING DIESEL ENGINE OILS

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Abstract: Increase in wear and lubricant breakdown is experiential worldwide, due to mixing of soot with lubricating oil; thereby degrading its performance and pumping ability. Need was identified to develop lubricating oil, which can withstand the increased soot values with increasing stress, for turbocharged engines without affecting the lube oil performance. Engine hardware parameters like Injection pressure and Auxiliary air supply does affect the fuel consumption (increase or decrease) ability of an engine thereby increasing its soot values (if fuel consumption is increased) in lube oil.

The test was conducted on an Ashok Leyland Ecomet four cylinder, water cooled direct injection, In-line overhead valve, BSII diesel engine without Exhaust Gas Re-circulation (EGR). A test engine was developed for evaluating soot related oil thickening properties by modifying Injection pressure (OEM-240bar) to 220 & 190 bar and auxiliary air supplied (0.50-0.55bar) to make engine capable of delivering nearly 2.3% of soot levels. Experiments were performed in two stages of 15 hours; 15 hours each, with increasing test severity. Six different oil samples (25ml each) were taken for analysis during engine operation. The lube oil was analysed using Thermo gravimetric analysis (TGA) for its thermos-physical properties like kinematic viscosity (@40^{o}C and 100^{o}C) and Total Base Number (TBN). The results obtained confirms that the oil viscosity surges with increase in soot levels and the total base number slightly decreases with increase of soot in lubricating oil.

Keywords: Diesel Engine, Lubricants, Oil viscosity, Total Base Number, Thermo-Gravimetric Analysis.

INTRODUCTION

Soot and NO_x emissions are the two biggest challenges faced in making diesel engine more efficient. With improvement in injection equipment technology the task has become achievable. Injection Pressure and Auxiliary air supply are the two major parameters which influence the fuel consumption rate and fuel velocity. Researchers are working on injection technologies to find its effects on soot emission**. Cenksayin et al [1**] performed experiments on a single cylinder, four stroke with direct injection system at four different injection pressure (18, 20, 22 and 24 MPa) and stated that with decreased injection pressure fuel consumption per output power increased. Further, K. Ryu**[2]** studied effect of injection pressure on Dual Fuel Combustion (DFC) by performing experiments on single cylinder, 4 stroke commercial direct injection diesel engine at four different pilot injection pressure (30, 60, 90, 120 and 150MPa) at constant speed 1800 rpm and constant injection timing (17^0 CA BTDC) and reported that ignition delay was longer in DFC than single diesel combustion but it decreases with increasing the pilot injection pressure. To find the effect of injection pressure on soot particle emission in terms of particle mass and particle number **Chongming Wang et al [3]** performed experiments on single cylinder,4-stroke GDI research engine at four different injection pressure (50, 100, 150 and 172 bar), speed (1500 rpm) and

found that soot emission mass and soot emission number decreases 22% and 78% respectively with increasing the injection pressure from 50-150 bar. **B. jayashankar et al [4]** performed experiments at three different intake pressure (1.01, 1.21 and 1.71 bar),

speed (1000rpm) and reported soot emission reduced 8.82% and 51.47% at 1.21 bar and 1.71 bar with respect to soot emission at 1.01 bar.

Further to find to effect of injection pressure with injection timing on soot emission **Avinash et al [5]** performed experiments on single cylinder engine having common rail direct injection system at three injection pressures (300, 500 and 750bar), injection timing (9.375^{o}CA BTDC to 0.375^{o}CA BTDC) and reported that particle size number reduces with increasing the injection pressure. **IsmetCelikten [6]** performed experiments to find the relation between throttle position and injection pressure with soot emission on 4-cylinder,4-stroke indirect diesel engine at four injection pressure (100, 150, 200 and 250bar) and three throttling position (50%, 75% and 100%) and reported that emission of CO_2 decreased when injection pressure increases. This concludes that injection pressure and compressed air supply do have effect on the performance of the diesel engine thereby hampering the performance parameters of the engine.

In this work, the modifications in injection pressure and auxiliary air supply were done in order to make an engine ready to deliver higher soot levels to evaluate the lubricating oils for their soot dispersions. The test and operating conditions were set as per the standard ASTM-D7156 test method used for evaluation of diesel engine oils on the MACK T-11 test engine. The test severity was generated in order to match real time environment which includes change in injection pressure and altering the values of compressed air supply to diaphragm valve of fuel injection pump.

EXPERIMENTAL SET UP

AVL Puma 1.5.3 test bed automation system controls the dynamometer, fluid controlling systems and emissionmeasuring equipment which is interfaced with the engine test bed. The test cycles are programmed in the Puma for the automatic operation of test run. The system is equipped with a coolant and oil temperature control systems that is capable of maintaining the coolant temperature of 70 to 120°C and oil temperature of 70 to 140 °C. The fuel used in this study is the commercial diesel fuel which meets the 50 ppm fuel sulphur limit of Bharat stage IV Indian emission regulation norm. The temperature of the fuel was controlled by AVL fuel temperature control unit and the fuel flow mass was regulated by AVL fuel mass flow meter. Lubricating oil of SAE 20W-40 viscosity grade was used for the test. The engine specification is shown in Table 1.

Table 1: Engine Specification

Type	Diesel, four strokes, four cylinder, Watercooled direct injection, In-line overhead valve
Aspiration	Turbo charged with inter cooler
Compression Ratio	17.5:1
Max Power	88.25kw (120ps) @ 2500rpm
Injection Pressure	220 bar
Sump Capacity	8.5L

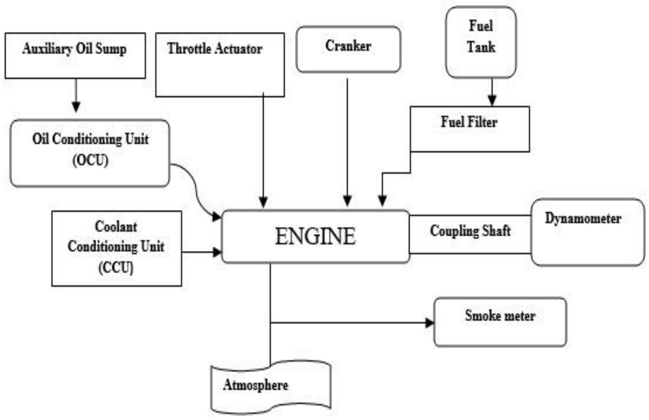

Figure 1: Schematic Diagram of the Experimental Setup

Duration of Test, hrs	**5, 10 and 15 hrs.**
Fuel Flow rate, kg/hr	13-14
Air intake temp, ^{o}C	25 to 35
Load, Nm	350
Oil Pressure, bar	2.7

Table 2: Operating Conditions Employed

Test Conditions:

Test 1

During 1st test run, change in injection pressure was set to 190bar (modified) and the engine was made to run at wide open throttle and 1200 rpm. Three oil samples of 15ml each were taken at the end of every 5thhour during engine operation for analysis and oil top-up was done. These oil samples were analysed for soot %, KV @ 100° C and TBN. No soot was found in the engine oil at the end of 150 hrs.

Test 2

Test 2 was conducted after supplying compressed air at 0.55bar to diaphragm valve of Fuel Injection Pump. Oil samples were taken after every 5th hour and tested for thermo-physical properties of lube oil.

Test 3

The engine was made at run at combined modification of Injection pressure and compressed air supply at WOT and 1200 rpm. The oil sample were collected at every 5th hour for thermogravimetric analysis.

RESULTS AND DISCUSSION

Effect of Injection Pressure on FSN Value (Soot)

Alteration in injection pressure has imperative effects on emission in Diesel engine. With increase of injection pressure shorter ignition delay and higher peak in-cylinder pressure were observed [1,2]. The test is performed at three different injection pressure (240, 220 and 190 bar) at constant speed (1200 rpm) and constant load (350 Nm). Increase in the FSN value was noticed with decrease in injection pressure possibly due to less spraypenetration may lead to poor mixing rate and improper air utilization.

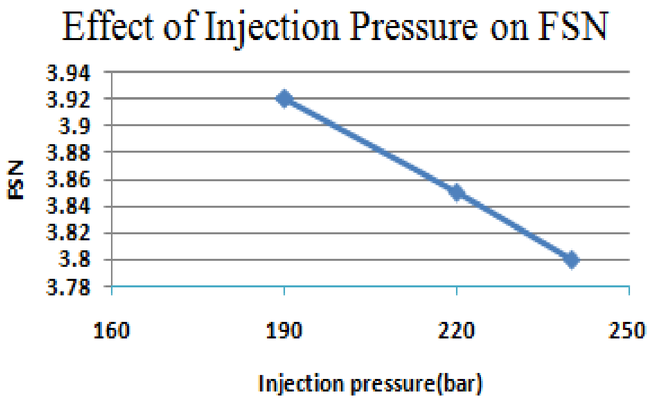

Figure 2: Variation if FSN Value with change in Injection Pressure.

Higher value of FSN was observed at low injection pressure and FSN value Decreased by 3.06% at high injection pressure. Good atomization and higher cylinder pressure could be possible reason for this trend. This trend was also observed by Hwang et al. [7] and reported that at lower load and higher injection pressure decreases the peak-in- cylinder pressure which was associated as an amount of prepared fuel in the ignition delay. In shorter ignition delay smaller fuel droplets enhanced atomization of fuel. On the other hand, with increasing load air-fuel ratio retarded and provide favourable condition for soot formation and agglomeration.

Table 3: FSN Value obtained at different Injection Pressure at constant load.

Setting	Load (Nm)	FSN
Reformed Setting (190 bar)	350	3.92
Reformed Setting (220 bar)	350	3.85
OEM Setting (240 bar)	350	3.80

Effect of Compressed Air Pressure

Rising turbulence and increasing fuel valuein the combustion chamber are the primary objectives for introducing theauxiliary air injection system. With increasing compressed air pressure the diaphragm of the fuel injection pump widely open which injects more fuel inside the combustion chamber without the fluctuation of pressure inside the intake manifold, possibly, the favourable condition for higher value of FSN. This trend was observed with increasing the compressed air pressure from 0.50 bar-0.55 bar and FSN value increased by

18.75%.

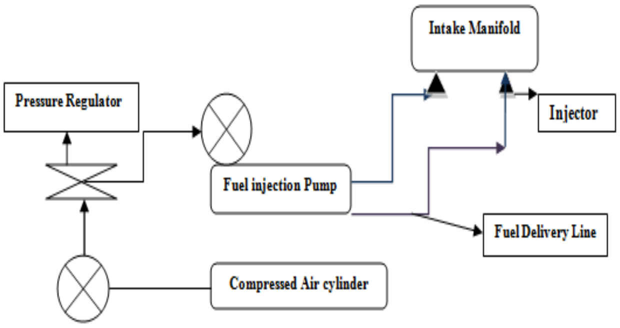

Figure 3: Layout of Compressed Air supply system connected to Intake Manifold.

Table 4: Variation of FSN Value with change in Compressed Air Pressure at constant Load (350Nm)

Compressed Air Pressure (bar)	FSN Value
0.50	2.34
0.51	2.38
0.52	2.45
0.53	2.56
0.54	2.69
0.55	2.88

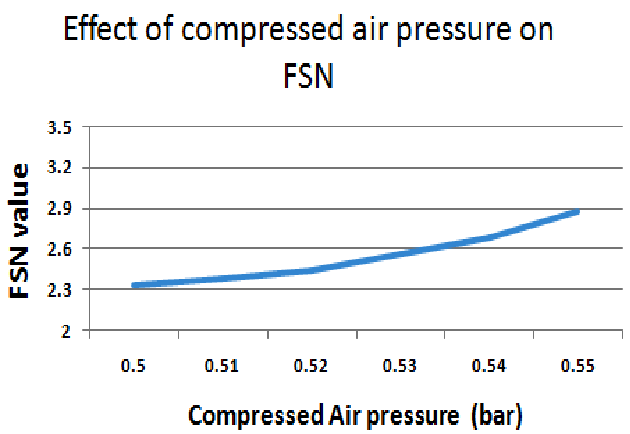

Figure 4: Variation of FSN Value with increasing Compressed (Auxiliary) Air Pressure to diaphragm valve.

Effect of Speed on FSN value

Speed has significant effect on fuel consumption and un-burnt hydrocarbon emission. To identify better speed to achieve higher value FSN experiments were performed at five different speeds with the difference of 100rpm at constant load 350Nm (as per MACK T11 test method). It was observed that at around 1200rpm the FSN value generated is more, possibly because of the idling range. As the speed is increased the pressure difference between the intake manifold and combustion chamber decreases (with closing and opening of intake valve) thereby decreasing the FSN value. With increasing speed fuel consumption rate increases and amount of soot emission also increased.

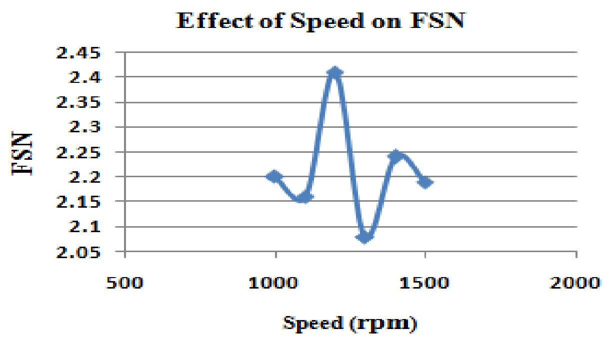

Figure 5: Variation of FSN with engine speed.

Kinematic Viscosity and Total Base Number

The effect of various hardware modification of kinematic viscosity and Total Base number is shown in table 5. Properties of lubricating oil degrade with test severity. Investigation was performed on lube oil whose Viscosity Grade was 10W30, three interval of time. Increase in the kinematic viscosity of oil (both @ 40°C and 100°C) was noticed (as shown in figure 6 and 7). The viscosity increases as increase in soot content promotes the agglomeration of soot particles.Decrease in TBN values shows the depletion of additive like corrosive inhibitors in the lubricating oil due to oxidation thereby increasing the creation of organic acids, which drops the standby alkalinity of lube oil.

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Table 5: Effect of modifications on KV and TBN.

Duration	Speed (rpm)	Modification in injection pressure(190 bar)			Modification in Auxiliary air pressure (0.55 bar)			Modification in Injection pressure and Auxiliary air pressure (190, 0.55 bar)		
		KV @ 40 °C	KV@ 100 °C	TBN	KV @ 40 °C	KV@ 100 °C	TBN	KV @ 40 °C	KV@ 100 °C	TBN
After 5hrs.	1200	89.31	12.41	6.48	129.1	13.95	6.49	131.9	14.54	6.53
After 10hrs.	1200	89.11	12.55	6.46	129.6	13.98	6.47	132.01	14.70	6.52
After 15hrs.	1200	89.39	12.58	6.45	130.08	14.11	6.46	132.06	15.01	6.51

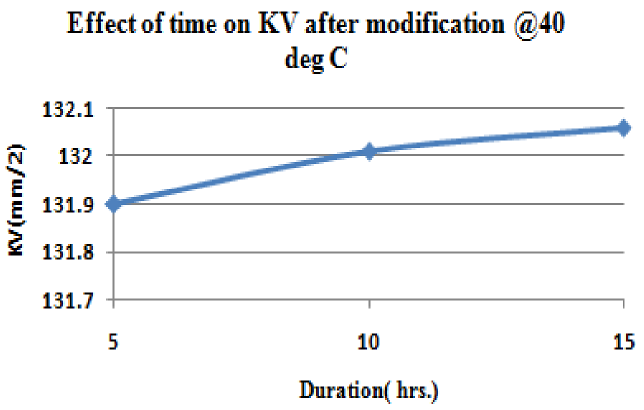
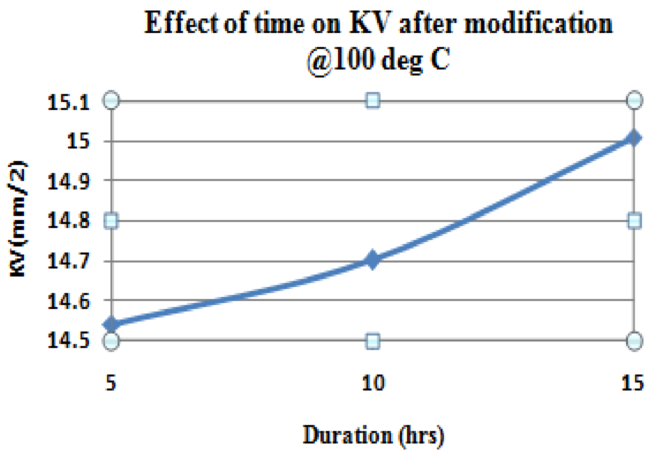


Figure 6: Variation of kinematic Viscosity @40deg C after modification with test duration.



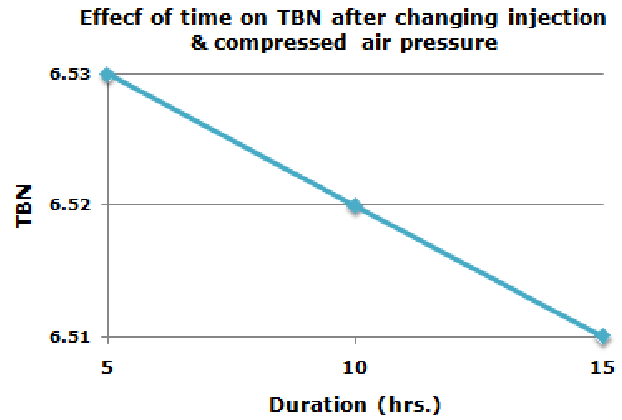


Figure 7: Variation of kinematic Viscosity @100deg C after modification with test duration

Figure 8: Effect of test severity (duration)on TBN after changing injection pressure (190 bar) and compressed air pressure (0.55 bar).

CONCLUSION

The effect of variation in injection pressure and compressed air supply on FSN values, Kinematic Viscosity and Total Base Number are investigated and the following conclusion could be drawn after the test:

- With reduction in injection pressure from OEM setting (240 bar) to reformed injection pressure (190 bar, 220 bar), FSN value increased by 3.06%.
- Speed has significant effects on fuel consumption and FSN value. FSN variation with respect to speed follow meander motion. First with increase in engine speed at constant load 350Nm FSN value increases then decreases.

- FSN value increases with increasing in compressed air pressure when supplied to diaphragm valve of fuel injection pump.
- Kinematic viscosity both at 40°C and 100°C increase with increase in test severity.
- TBN decreases with increment in test duration and severity.

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