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Developing prototype of single cylinder diesel pump to meet emission standards

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ABSTRACT

The single cylinder diesel pump is the main device in fuel injection system of a single cylinder diesel engine. The existing fuel injection pump is designed for Bharat stage III engine compliance as the Bharat stage IV fuel is regulated only in 13 cities in India. The running three wheeler single cylinder engines are in Bharat stage III compliance. As the auto fuel policy panel has recommend the Bharat stage IV fuel specifications nationwide in the upcoming year the single cylinder diesel engines emission are to be optimized using parameters like Nozzle injection, Catalyst converter and Fuel injection pumps to meet the emission standards. The aim of the project is to design a new prototype of fuel injection pump. The newly developed pump is tested to meet the Emission Standards, Engine Requirements and Pump Requirements of the end user.

KEY WORDS: single cylinder diesel fuel injection pump, nozzle injection, Bharat stage IV emission standards

1. INTRODUCTION

An Injection Pump that pumps fuel into the cylinder of a diesel engine. The injection pump is driven directly by the camshaft. It rotates at half crankshaft speed in a conventional four-stroke engine. The fuel is injected slightly before the piston reaches the top dead centre at the end of the cylinder's compression stroke. The pump housing has a low-pressure fuel gallery surrounding the pumping elements. This gallery is sealed from the rest of the pump housing so fuel is available only to the inlet/spill ports of the pump barrel. An excess supply of fuel is supplied to the gallery by the transfer pump in most applications and a return line drains unused fuel to the tank. This excess flow removes any bubbles that form in the fuel. The camshaft causes reciprocating movement of the pumping plunger. The pumping plunger and barrel assembly, performs two functions. It forces fuel past the delivery valve, into the injection line, and to the nozzle by way of its reciprocating action, it also controls the quantity of fuel by rotating action. The roller tappet, ride directly on the camshaft and transmit its motion to the pumping plunger. The plunger spring, keep the roller tappets in contact with the camshaft. The metering sleeve transmits the action of the governor to the pumping plunger. The delivery valve seals off the high pressure line from the barrel during the plunger downward stroke and also reduces pressure in the line to a predetermined level to prevent secondary injections in the combustion chamber.

(Sundarraman, 2012) Particulate size–number, surface area, volume distributions were investigated in a diesel fuelled single cylinder engine operating at 1500 rpm. The experiments were carried out at different engine loads and fuel injection pressures. Particulate number concentration in the exhaust increases with increasing engine load. Increasing the fuel injection pressure reduces the number concentration of particulates along with mass of particulates at all loads. At higher fuel injection pressures, advancing the injection timing reduces the particulate number concentration because advanced injection timings provide more time for mixing of fuel droplets with surrounding air before start of combustion. At lower fuel injection pressures, concentration first increases and then decreases with retarding the injection timings because fuel–air mixing at lower fuel injection pressures is more sensitive to in-cylinder pressure and temperature along with time available for mixing before start of combustion. Particulate surface area and volume distribution also increases with increasing engine load and decreases with increasing fuel injection pressure.

(Avinash Kumar Agarwal, 2013) Modifications in the in-line injection pump offer new opportunities for its use, mainly due to the occasion to shape the fuel injection process. Developing electronic control system that also allows for controlling the so called no combustion in the cylinders that manifests as irregularity of engine operation is an important element that enables to limit dumping and pollutants emission by the diesel engine. Research results indicate the opportunity to use alternative method in order to detect irregularity of engine operation and to shape fuel injection process, while properly adjusting load and engine operations to the conditions. The research also confirms that multi-phase injection process decreases irregularity of engine operation, which results in reduced vibrations and emission of harmful substances.

(Xin-jun Wang, 2014) It is proposed to develop a portable signal acquisition and analysis system for diesel engine Pressure Time (PT) fuel system. First, the PT pump work Principle was analyzed, and the PT pump failure mapping relation between reason and failure phenomenon was analyzed; Second, the diesel engine PT pump failure fuel pressure characteristics were analyzed; Last, using the portable signal acquisition and analysis system to diagnose the diesel engine PT fuel system, experiment results show that the system can correctly detect the diesel engine PT fuel system state. The link between the cause of the fault and the phenomenon of each fault is analyzed in

the time and frequency domain. From the frequency distribution of the signal it can be seen that the change in the amplitude of the fault frequency is mainly concentrated in the frequency band of 0~1000Hz when the fuel pressure is a low-frequency signal.

In this present study, existing single cylinder (rack and helix type) diesel engine pump was chosen and changes had been made in certain parameters of the pump to meet the following requirements shown in Table 1.

Table.1. Standards to be met

Engine specifications to be met	
Rated Power / Speed	7.5 HP/ 3600 rpm
Max. Torque / Speed	19 Nm / 2200 rpm
Max. Smoke limit	1.1 FSN
High / Low Idle speed	3600 rpm / 1100 rpm
Cranking Speed	300 rpm
SFC at rated speed	1.9 kg/hr
SFC at max. Torque	1.2 kg/hr
Pump specifications to be met	
Peak Torque speed Rack	9 mm
Idle speed Rack	10 mm
High Idle speed Rack	14 mm
Cranking speed Rack	18 mm

After finalizing the pump design, three test pumps of different helix angle are made and it is tested on the single cylinder engine to meet the specification shown in Table 1.

Pump Design: The existing pump design and new proposed designare shown in Table 2.

Table.2. Existing & New pump Design

Parameter	**Existing Pump**	**New Pump**
Total Lift	8 mm	9 mm
Pre Stroke	4.50 – 4.65mm	5.50 – 5.65mm
Effective Stroke	3.00 – 3.50mm	3.50 – 3.65mm
BDC	59 mm	59 mm
Tappet diameter	22 mm	24 mm
TotalRack movement	18 mm	21.2 mm
Helix Type	Forward	Reverse
Smoke limit	2.2 FSN	1.1 FSN

Table shows the different components in the diesel pump

Table.3. Pump Components

s.no	**components**
1	Barrel
2	Plunger
3	Spill Port
4	Metering Sleeve
5	Inlet Port
6	Delivery Port
7	Spill Port

Figure shows the CATIA model of exploded view of the pump and pump in assembled manner

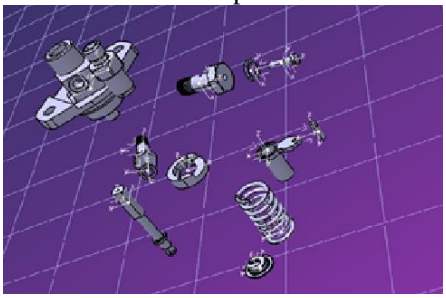

Figure.1. Exploded View of the pump Figure

Figure.2. Assembled Pump

2. METHODOLOGY

Different design changes made in the single cylinder diesel pump and the various tests conducted to verify the performance of the pump requirements. The various steps in the method are shown below

(i) Design the pump specifications
(ii) Develop a CATIA model
(iii) Process the components of new designed pump
(iv) Pump Performance Testing
(v) Engine Performance Testing
(vi) Pump Consistency testing

Finalize design of pump based on satisfactory results

3. RESULTS AND DISCUSSION

Various test are conducted on the pump by mounting it on the engine test stand

Pump consistency test: Pump consistency is done to compare the peak pressure, duration of injection and dynamic timing in the pumps using piccoscope software. Picodiagnostic is a self-contained software package for use with the PicoScope 4000 Series automotive oscilloscopes. With PicoDiagnostics you can quickly check the parametersof diesel pumps. The results are achieved in wave format as shown in figure. Test shows that pump parameters are satisfactory

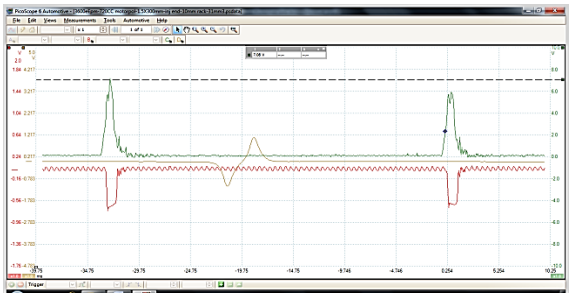

Figure.3.Consistency test results on Pump

Pump Performance Test Results: The fuel injection pump is mounted on the test stand which is capable of testing 2 to 8 cylinders. The pump is mounted in the test bench and the fuel delivery for the pump is taken forrated speed(3600rpm), peak torque speed(2200rpm), low idle speed(1100rpm), high idle speed(3600rpm), cranking speed(300rpm) at rack movement 0-20mm

Prototype of three pumps with different specifications is made for testing the pump. Table shows details of the test pum

Table.4. Specifications of test pump

Parameters	Test pump 1	Test pump 2	Test pump 3
Helix angle	40°	41.5°	40°
Nozzle seat washer	1.5 mm	1.5 mm	2.5 mm
BDC	60 mm	60 mm	59 mm

The pump is mounted in the test benchand the fuel delivery for the pump is taken forRated Speed(3600rpm), Peak Torque speed(2200rpm), Idle speed(1100rpm), High Idle speed(3600rpm), Cranking speed(300rpm) at rack movement 0-20mm. Fuel delivery measurements for the pump were conducted at all rack movements from 1mm - 20 mm, but the test results shown here are only for critical rack movements at certain speed.

Table.5. Test pump1 Fuel Delivery Test

Parameters	Rack movement (mm)			
Speed (rpm)	9	10	14	18
3600	31	35	45	81
2200	25	25	43	63
1100	26	28.5	55	90
300	5	10	51	80

Table.6. Test pump2 Fuel Delivery Test

parameters	Rack movement (mm)			
Speed (rpm)	9	10	14	18
3600	32	35	49	78
2200	25	28	54	83
1100	25	30	55	88
300	5	15	50	80

Table.7. Test pump3 Fuel Delivery Test

parameters	Rack movement (mm)			
Speed (rpm)	9	10	14	18
3600	26.5	30.5	45	70
2200	25.5	32.5	50	80
1100	21	29	60	97
300	0	8	50	100

Comparison of Fuel delivered by the test pumps at different speeds such as 300 rpm, 1100 rpm, 2200 rpm, and 3600 rpm are shown in below figures. Test results shows that all the three pumps are satisfactory.

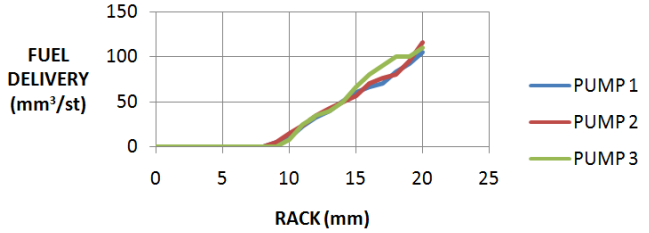

Figure.4. Fuel Delivery at 300rpm

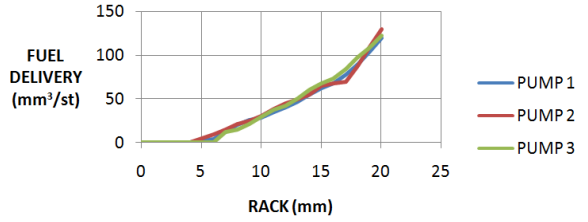

Figure.5. Fuel Delivery at 1100 rpm

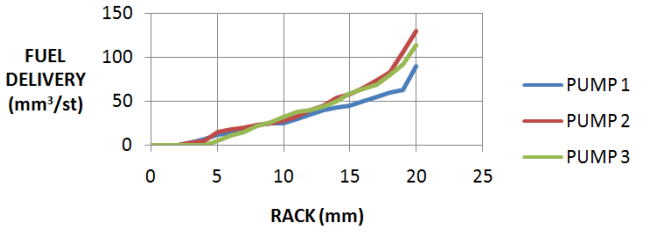

Figure.6. Fuel Delivery at 2200 rpm

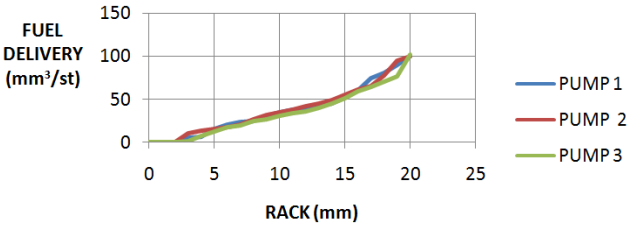

Figure.7. Fuel Delivery at 3600 rpm

Engine Performance test results: To decide the final design of the pump, three test pumps are assembled on the single cylinder engine to be operated at full throttle condition. Various parameters such as smoke, torque, power and specific fuel consumption values are taken from high idle speed (3600rpm) to low idle speed (1100rpm).Readings are noted for every reduction of 100rpm. Figure 8 -11shows the comparison graph of the three test pumpsfor smoke, torque, power &SFC at various speeds.

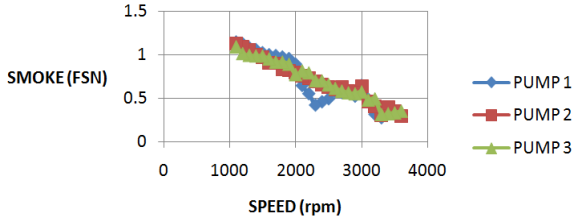

Figure.8. Speed vs Smoke (FSN)

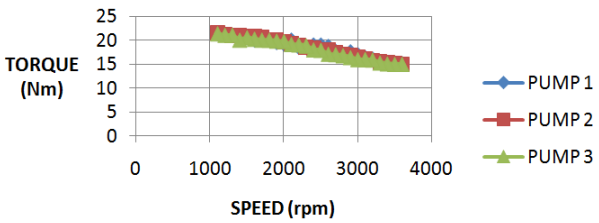

Figure.9. Speed vs Torque

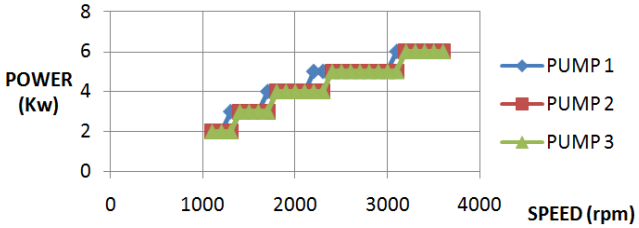

Figure.10. Speed vs Power

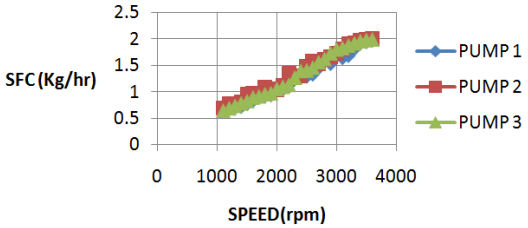

Figure.11. Speed vs SFC

Pump consistency test is done to compare the peak pressure, duration of injection and dynamic timing of test pumps. Obtained results are compared for the test pumps shown in Figure 12 - 14.

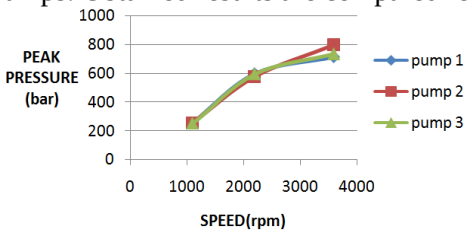

Figure.12. Speed vs Peak Pressure

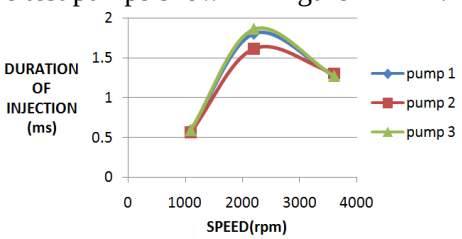

Figure.13. Speed vs Duration of Injection

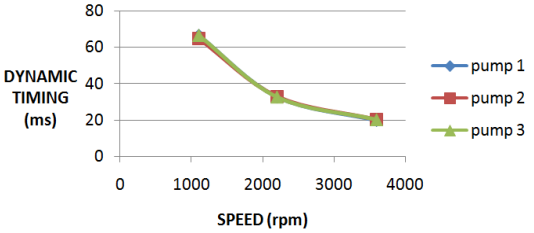

Figure.14. Speed vs Dynamic Timing

4. CONCLUSION

The designed single cylinder diesel pump has been conducted with pump performance test from rack movement 0-20mm to find the fuel delivery at idle speed (1100rpm), rated speed (3600rpm), peak torque speed (2200prm) the achieved results met the customer requirements and the pump was mounted in engine to check the full throttle performance of engine from low idle speed (1100prm) to rated speed (3600rpm) the engine performance parameters such as Power, Torque, SFC, Smoke has been verified for the customer requirements and the consistency of the pumps is checked by verifying the Peak Pressure, Dynamic Timing, Duration Of Injection. Test pump 3 with helix angle 40^{O} and BDC of 59 mm has met the requirements.

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