



## DESIGN OF DRIVE MECHANISM FOR HIGH PRESSURE FUEL INJECTION SYSTEM

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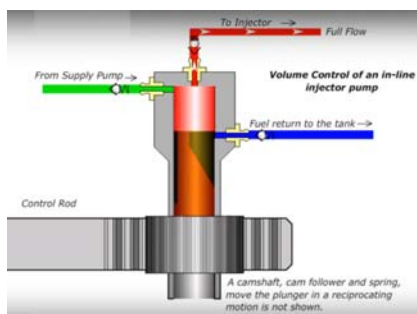
### ABSTRACT

The emissions regulations for diesel engines in applications such as ships, trains and heavy duty off-road vehicles and gensets worldwide are becoming more stringent and make extensive modifications to the power units necessary. At the same time, customers are constantly calling for more economical engines. Exhaust after treatment systems such as selective catalytic reduction (SCR) catalytic or diesel particulate filters are one way of lowering emissions, but also have a greater space requirement and potentially increase the engine's maintenance needs. Therefore exhaust emissions can be reduced by primarily reducing emissions by internal enhancements. Fuel combustion inside the engine is improved so that, if at all possible, emissions are not produced in the first place. The OEMs are moving ahead for high efficiency Fuel Injection Systems in order to stay alive in the competitive environment. High fuel efficiency and High Power Engines are not confined only to the passenger car segments of the market. The commercial vehicles are also demanding high power along with high torque. Owing to Government's regulations on emission it has become mandatory for OEMs to emphasis more on low emission vehicles. This paper shows the method to design a suitable drive mechanism for the diesel engine fuel injection pump capable of delivering high pressure up to 1600 bar. This enables better atomization of the fuel in combustion chamber and thereby reducing the emission of pollutants.

**Keywords:** common rail system, emission and inline pump.

### INTRODUCTION

Some diesel engines use in-line injection pumps to meter, and raise the pressure of the fuel. The basic principle is for a plunger to act on a column of fuel, to lift an injector needle off its seat. Inside the pump is a pumping element, and a delivery valve for each cylinder of the engine. Figure-1 shows the arrangement of in-line pump.



**Figure-1.** Internal arrangement of in-line pump.

The element has a barrel, and a plunger that fits inside it. Their accurate fit and highly-polished finish ensures only minimal fuel leakage past them, without needing positive seals. The barrel usually has two holes, or ports, called the inlet port, and the spill port. They connect the inside of the barrel with the gallery. The gallery contains filtered fuel from the low-pressure system. At the top of the barrel is a delivery valve, delivery valve holder, and the pipe to carry fuel to each cylinder. The upper end of the plunger has a vertical groove, extending from its top to an annular groove. The top edge of this annular groove

is cut in a helix, also called the control edge. Some pumps have a helix cut on top of the plunger. A camshaft, cam follower and spring, move the plunger in a reciprocating motion.

When the plunger is below the ports, fuel from the gallery enters the barrel above the plunger. This ensures the barrel is full of fuel. As the camshaft rotates, the plunger is pushed past the ports. The highly polished surfaces cause a sealing effect, trapping the fuel above the plunger. Moving the plunger further raises the pressure of the fuel. This forces the fuel out past the delivery valve, along the fuel line to the injector. Fuel flows to the injector until the control edge uncovers the spill port. The pressurized fuel above the plunger then moves down the vertical groove, to the annular groove, and into the spill port. The delivery valve stops fuel leaking from the pipe back into the element. It reduces pressure in the fuel line to ensure there is no dribbling by the injector.

The delivery valve has a relief plunger, and a conical face which is held against its matching seat by the delivery valve spring. When the fuel pressure rises, the delivery valve is lifted off its seat. When the plunger is clear of its bore, fuel flows to the injector. When injection ceases, the pressure below the delivery valve drops to gallery pressure. Fuel pressure above the delivery valve forces the valve towards its seat. The relief valve enters the seat bore, sealing the volumes above and below the delivery valve. Further movement of the delivery valve towards its seat, increases the volume in the injector pipe, and reduces the pressure in there. This drop in pressure causes the injector needle to snap shut, helping to prevent fuel dribble from the injector. The conical face of the delivery valve then contacts the seat, further sealing the



plunger from the injector pipe. Figure-2 shows the mounting arrangement of inline pumps.

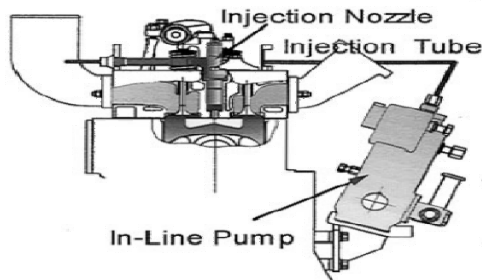


Figure-2. Inline pump mounting.

### PROCEDURE

In the Common Rail system, an accumulator, or rail, is used to create a common reservoir of fuel under a consistent controlled pressure that is separate from the fuel injection points. A high-pressure pump increases the fuel pressure in the accumulator up to 1600 bar. The pressure is set by the engine control unit and is independent of the engine speed and quantity of fuel being injected into any of the cylinders. The fuel is then transferred through rigid pipes to the fuel injectors, which inject the correct amount of fuel into the combustion chambers. Schematic arrangement of common rail system is shown in Figure-3.

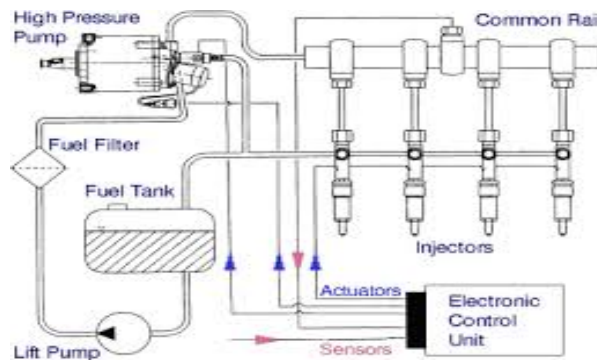


Figure-3. Schematic arrangement of common rail system.

The injectors used in Common Rail systems are triggered externally by an Electronic Diesel Control unit, which controls all the engine injection parameters including the pressure in the fuel rail and the timing and duration of injection.

### MODEL AND DESIGN

Figure-4 shows the gear train arrangement used in engine. The Fuel pump gear is driven by crank shaft gear through idler. This fuel pump gear drives power steering pump and air compressor gears. Crank shaft in addition to fuel pump drives lube oil pump and cam shaft. The gears are validated for new arrangement and respective calculations are as per IS 4460 standard.

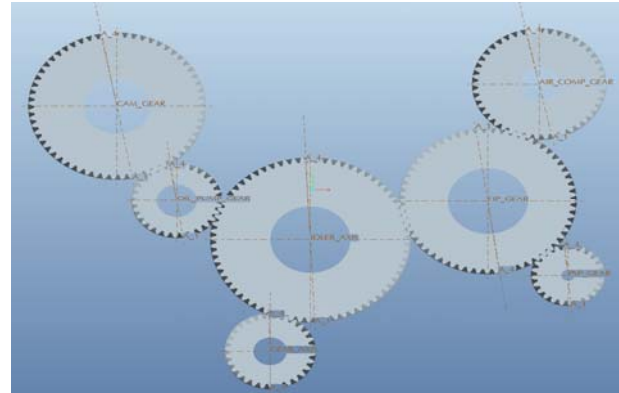


Figure-4. Gear-train arrangement.

Table-1. Gear sizing.

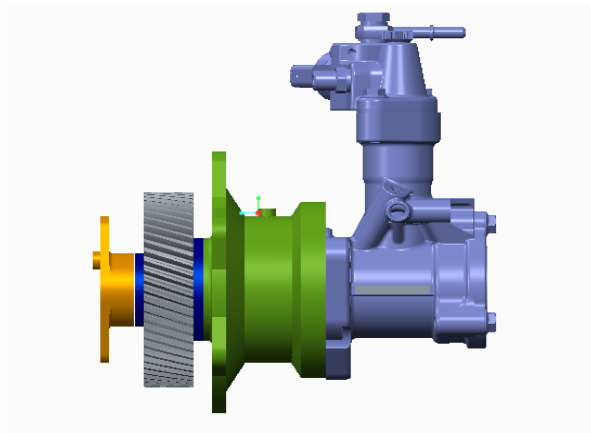
Description	Crank shaft	Idler	FIP
Module, m	2	2	2
No of teeth, Z	30	68	60
Helix angle $\Psi$	21	21	21
Normal pressure angle $\phi$	20	20	20
Tangential pressure angle $\phi_t$	21.3	21.3	21.3
Gear ration(with crank shaft) $(N_L/N_F)$ , G		0.44	0.5
Pitch Circle Diameter, D (in mm)	64.27	145.7	128.5
Addendum circle diameter, $D_a$ (in mm)	68.27	149.7	132.5
Dedendum circle diameter, $D_d$ (in mm)	59.27	140.7	123.5
Base circle diameter, $D_b$ (in mm)	55.9	126.7	111.8
Diametrical pitch, P (teeth/mm)	0.467	0.467	0.467
Circumferential pitch, p (in mm)	6.73	6.73	6.73
Tooth thickness at pitch circle, t (in mm)	3.365	3.365	3.365
Speed N (rpm)	2500	1103	1250
Power Required (in kW)			15.08
Design power (in kW), P	52.88	52.88	47.84
Torque, T (in Nm)	201.99	457.8	365.5
Tangential force, $F_t$ (in N)	6285.7	6286	5687
Calculated face width (in mm)	45	45	30

The material selected for gear is alloy steel having minimum surface endurance for contact stress as



1400 MPa, nominal endurance limit of the material as 800 MPa with modulus of elasticity as 206 GPa and surface hardness of 650 HB.

Figure-5 shows the arrangement of pump assembly in engine. Pump assembly contains pump mounted on main housing, coupled to gear through shaft and thrust housing to take care of axial loads.



**Figure-5.** Pump housing.

#### Design of shaft

The shaft connects gear with pump. Due to helical gear train arrangement, the shaft has to be designed for axial force in addition to bending and torsion.

#### Design of bearing

Bearing used in configuration is journal bearing. Designing is carried out using values from Raimondi & Boyd for  $L/D = 1$ . Load carrying capacity of bearing is checked for oil with required viscosity and maximum pressure acting on the housing is determined. Since arrangement of shaft is cantilever type, bearing is designed for  $L/D = 1$ .

#### Design of housing

The shaft is supported on housing. Housing mounted on engine. Housing is designed to withstand maximum pressure of bearing, axial thrust load due to helical gear arrangement and uniform pressure along oil passage. Since engine is subjected to acceleration and deceleration, provision for arresting axial thrust force on both sides of gear is required. Axial thrust housing is mounted on engine front side. Axial thrust housing is designed for uniform pressure acting along its surface.

#### SUMMARY AND CONCLUSION

The usage of common rail system leads to higher injection pressure at lower engine speed. This leads to better atomisation of fuel thereby reduction in emission.

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