TYPES OF DIESEL INJECTION SYSTEMS

As observed previously, fuel-air mixing is a very important phenomenon that affects diesel combustion. We know that organized air motion, which can be amplified by appropriate combustion chamber designs, may be used to promote fuel-air mixing. The other side of the "mixing equation" is controlled by the nature of the fuel injection process itself. Thus, the type of fuel injection system employed with a particular combustion chamber design, assumes importance. Based on the overall injection system design and control, the three main types of diesel injection systems are:

(i) Mechanical injection systems
   (a) In-line injection systems
   (b) Rotary/distributor-type injection systems.

(ii) Unit injection systems — either mechanical, electronic or hydraulically-controlled electronic injection systems (ECU or AECU).

(iii) Common rail injection (CRI) systems.

Of these systems, CRI gives the maximum control over the injection process. Before considering the essential differences of these systems, let us first discuss the important requirements of a good diesel
injection system. Any fuel injection system directly influences diesel combustion by (possible) changes in:

(i) Fuel injection pressure
(ii) Injection timing
(iii) Injected fuel quantity
(iv) Rate of fuel injection
(v) Quality of spray “atomization”
(vi) Possibility of multiple-injection events (which are controlled)
(vii) After-injection, dribble & secondary injection (to be avoided)

It is usually desirable to have independent and complete control of several of the above variables. Based on the design of the fuel injection system and the method of control (mechanical or electronic), one or more of the above variables can (or will) be varied.

**Mechanical Injection Systems**

These systems were in common use in the U.S., till the 1980s. Of late, due to increasingly restrictive environmental regulations, electronically controlled injection systems have become standard. Conventional mechanical injection systems were designed in different configurations to suit different purposes. In-line and rotary injection systems had the pumping element separated from the fuel injectors while mechanical unit injectors...
MECH SYSTEMS NOTES:

(i) Fuel injection pressure > pressure at delivery valve in all cylinders.

(ii) Connecting pipes → some length to maintain same “injection lag” in all cylinders.

had the pumping elements integrated with the injectors. Some of the applications of these systems were:

(i) In-line systems – heavy duty truck engines, industrial equipment engines, power generation units, etc.

(ii) Rotary systems – medium-sized passenger car engines and small IDI diesel engines.

(iii) Mechanical unit injection systems – large bore marine engines, locomotive engines, etc.

Of these, the maximum injection pressures were achieved in the unit injection systems (MUI). These systems avoided the necessity to carefully design the connecting pipes between pumping elements & the injectors. This was especially useful when large quantities of diesel were required to be injected in large diesel engines. In-line systems produced high injection pressures to be used in most typical heavy-duty truck DI engines. Rotary systems were cheaper and capable of the loudest (among the three types) injection pressures and were readily suitable for small IDI engines used in passenger cars.

In all these mechanical systems, the following characteristics were observed:

(i) Injection pressure → could not be controlled independent of engine speed; Injection pressure usually increased with engine speed, so at
NOTE: In mechanical systems, the governor is an essential feature to control fuel flow for safety and for control of fuel-gas emissions. Low-idling speeds, injection pressures were low, causing poor atomization of the spray and hence poor performance and emissions.

(ii) Injection timing - Injection timing may be changed to a limited extent using an additional device known as "injection timer." But this is not available in all mechanical injection systems.

(iii) Injected quantity - can be changed by changing duration of injection, usually controlled by a centrifugal governor.

(iv) Injection rate - no control over this parameter.

(v) Multiple injection/atomization quality - multiple injections were not possible, atomization quality was acceptable.

(vi) After-injection - problems such as dribble & secondary injection were common.

The lack of control or flexibility in mechanical injection systems led to the advent of electronically controlled injection systems.

**Electronic Injection Systems**

Electronic injection systems, including electronic unit injection (EUI) and common rail injection (CRI) systems, offer different degrees of flexibility. For instance, EUI eliminates connecting pipes and associated problems and can also be used to effect multiple injection events to improve combustion.
and emissions. On the other hand, CRI can also yield independent control of injection pressure. Fuel injection pressure does not depend on engine speed, thus engine performance and emissions at low speeds are improved.

**EUI systems** - The high pressure pumping element is integrated with the injector nozzle. The EUI is placed on the cylinder head & driven by the camshaft (could be the engine camshaft, after modifications). Injection timing & qty are electronically controlled using a solenoid actuator. Fuel metering is very accurate and consistent from cycle to cycle. EUI systems are now widely used in heavy-duty truck applications and enable satisfactory trade-offs between NOx, efficiency & particulate emissions.

**A modified EUI system developed by Caterpillar Inc. uses a hydraulic actuation system (hence known as HEUI) and can control even the rate at which fuel is injected.**

**CRI systems** - Since the pressure generation process in these systems is decoupled from the injection process, CRI systems offer the greatest flexibility currently available. Very high injection pressures (~1600 bar) can be generated and consistent and accurate fuel metering is possible even at low injection pressures.