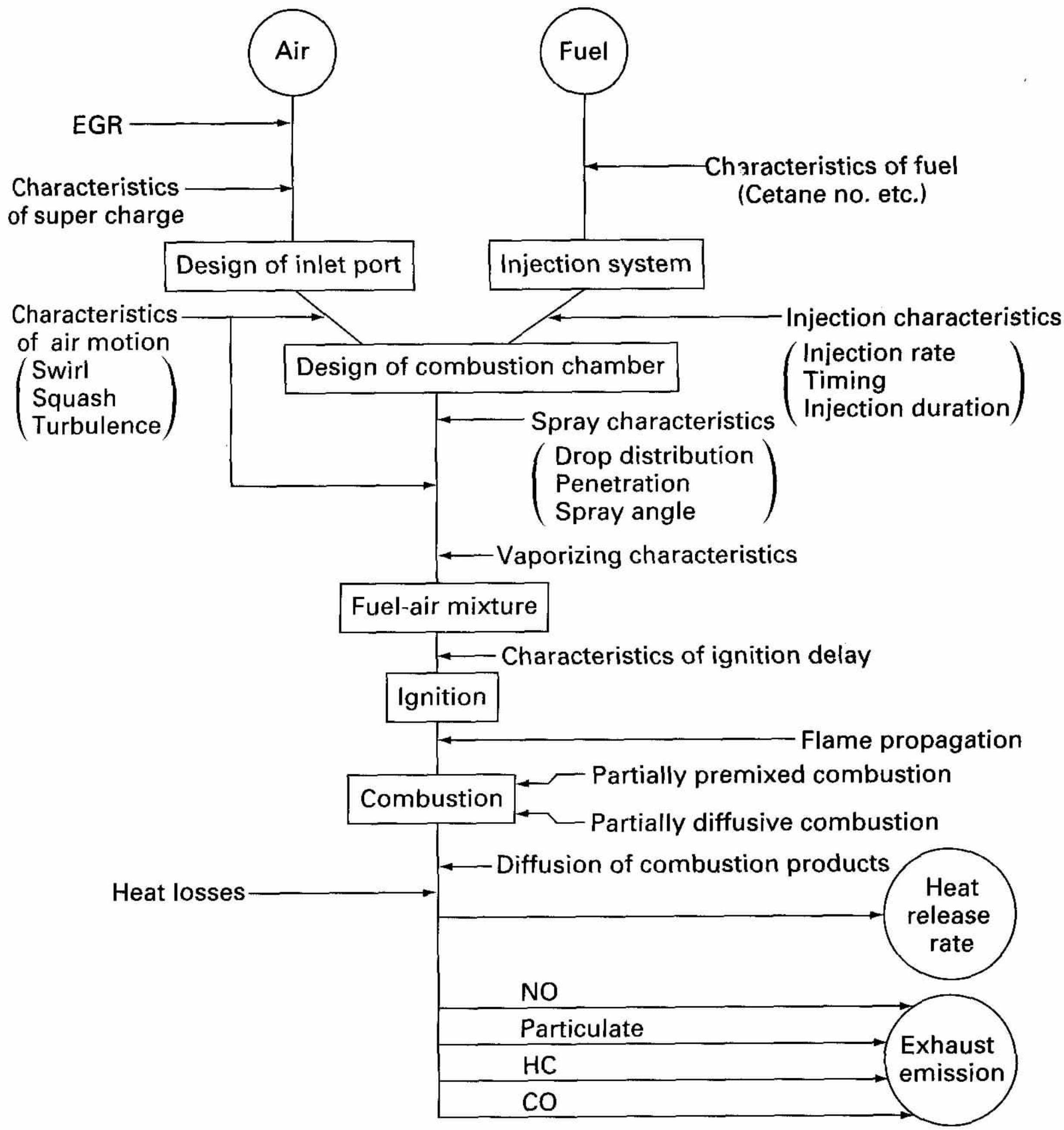
Essentials of Compression Ignition Diesel Engine

Diesel engine is by far the most efficient engine in operation as a power plant. Although there are similarities between conventional homogeneously-charged spark-ignited gasoline (or petrol) and diesel engines, there are six major differences, some of which, contributing to diesel engine's high efficiency attribute. They are listed below:

1. Type of the fuel
2. Fuel is injected into the combustion chamber directly (DI) or indirectly into a pre-chamber connected to the main chamber (IDI) in diesel engine
3. Combustion is primarily mixing-controlled
4. Power level is changed through the amount of fuel injected in diesel engine
5. Negligible pumping losses in diesel engine
6. Higher compression ratios for the diesel engine

Items 2, 4, 5, and 6 are primarily responsible for its high efficiency. A typical cycle of a four-stroke diesel engine is as follows. Fuel is injected by a fuel injection system into the combustion chamber (cylinder) nearly at the end of the compression stroke, prior to the desired start of combustion. The liquid fuel, injected at high velocity (~100 m/s), is introduced through multitude of small holes (~ 150 to 300 μm) into the chamber, feels the high density of the chamber condition. The liquid fuel must first be atomized into ligaments and droplets, vaporized, and finally mixed with the high pressure and temperature chamber air for chemical reactions of importance to diesel operation to begin. These three processes are simultaneously occurring after the start of each injection. Because the air temperature (and pressure) is above the ignition point of the type of fuel used, spontaneous ignition (autoignition) of the portion of the mixed vaporized fuel and air occurs only after a delay period called "ignition delay" time. Hence, it is highly desired to have a low ignition delay period (i.e. high Cetane number rating) for the type of the fuel used, an attribute to be avoided in homogeneously-charged spark-ignited gasoline engine due to knock phenomenon. The Cetane number rating used for commercial diesel fuels is between 40 to 55. Immediately after the ignition delay period all the fuel that was vaporized and mixed with air burns in what is referred to as the "premixed burn phase" of the diesel combustion process. The remainder of the liquid fuel is consumed as it is being injected, atomized, vaporized and mixed. This phase of the combustion, being the major portion of the total,   is controlled by the mixing process and is named as the "mixing-controlled combustion phase." Hence, the overall rate of combustion process is mixing-controlled in diesel engines. Injector design is by far the most complex and critical component of the normal combustion in diesel engines for performance, efficiency, and emission of pollutants. Good liquid fuel atomization and optimum spray penetration for air utilization are essential. Over-penetration causes liquid fuel impingement and adherence to the cylinder walls, leading to a poor vaporization and mixing, reflecting to high hydrocarbon emissions from the engine. Under-penetration causes poor in-cylinder air utilization and again produces inefficient combustion and high emissions. Degree of mixing is also important for proper operation of different engine sizes. As engine size decreases, more vigorous air motion is needed for better mixing while less fuel penetration is necessary. Figure 1 attempts to portray the important processes involved in consumption of the liquid fuel in a typical compression ignition diesel engine.

Contrary to the conventional gasoline-fueled engine, the diesel engine operates "unthrottled," meaning, the load is controlled via the amount of the fuel injected. This entirely eliminates the pumping losses required in conventional gasoline engines in order to bring the air in and sent the burned gases out of the combustion chamber, thereby controlling the engine load (or power). In addition, the diesel engine always operated as "overall lean" fuel/air ratio increasing the effective specific heat ratio during the expansion (or power) stroke over the gasoline spark-ignited engines. This, higher compression ratios, and essentially lack of the pumping work are primarily responsible for the higher overall efficiency of the diesel engines.


Air
Fuel
EGR
Characteristics of super charge
Characteristics of fuel (Cetane no. etc.)
Design of inlet port
Injection system
Characteristics of air motion
Swirl
Squash
Turbulence
Injection characteristics
Injection rate
Timing
Injection duration
Design of combustion chamber
Spray characteristics
Drop distribution
Penetration
Spray angle
Vaporizing characteristics
Fuel-air mixture
Characteristics of ignition delay
Ignition
Flame propagation
Combustion
Partially premixed combustion
Partially diffusive combustion
Diffusion of combustion products
Heat losses
Heat release rate
NO
Particulate
HC
CO
Exhaust emission