Thus decreasing engine power (torque) output at a fixed engine speed and throttle position. For the fuel conversion efficiency, as indicated previously by fuel-air cycle analysis, leaner fuel-air mixtures lead to higher efficiencies due to the "advantageous" ratio of stoichiometric (gamma values); however, this gain is offset in practice by the lower flame speed which accompanies lean mixtures. Decreased flame speed causes late burning which means that more of the combustion energy is sent out with the exhaust rather than contributing to the work output. When the fuel-air mixture becomes too lean, the combustion becomes incomplete (in spite of more-than-adequate availability of oxygen!) and the fuel conversion efficiency is decreased; also, under such conditions the unburned hydrocarbons and CO emissions would be increased.

* Intake manifold temperature: Intuitively, it may appear that increasing the intake manifold temperature could possibly increase the fuel conversion efficiency; however, this improvement (if any) is likely to be modest because most of the increased energy (due to increased temperature)
would be lost due to heat transfer to the cylinder walls or increased enthalpy of the exhaust gas. Only a small fraction might be translated into useful work. The intake temperature increase also leads to reduced intake charge density, thus decreasing the power output via volumetric efficiency. Higher intake temperatures also increase flame speeds thereby increasing combustion rates; however, the tendency to knock is also increased because the temperature of the unburned "end-gas" is higher. Higher intake temperatures may help in reducing unburned hydrocarbon (HC) emissions but the NO emissions might increase.

* Intake manifold pressure/throttle position

The intake manifold pressure in a naturally aspirated SI engine is altered by changing the throttle position. In a supercharged/turbocharged SI engine, intake manifold pressure (sometimes called Manifold Absolute Pressure or MAP) can be varied by adjusting the "boost". Increasing MAP in an SI engine at constant intake temperature, speed, etc., leads to increased charge density which translates into higher power. Higher in-cylinder pressures
may lead to greater amounts of mass trapped in the crevices, thereby increasing HC formation.

Throttle position is an important control variable in SI engines (both N/A and turbocharged). The engine load (power output) at any given speed is varied by changing throttle position (i.e., by increasing or decreasing the amount of fuel-air mixture admitted into the cylinder.

Note: In an SI engine, the equivalence ratio of engine operation is almost constant (0.2-1.1) over the entire engine operating range; when throttle position is changed, only the amount of fuel-air mixture and not its equivalence ratio is changed.

Wall temperature: Temperature of the cylinder walls changes with engine load/speed and cooling rate. Usually, higher engine loads are accompanied with higher cylinder wall temperatures due to greater heat transfer from the working fluid. End-gas temperatures are also increased with higher wall temperatures, hence, adequate cooling of “critical” hot spots in the combustion chamber is necessary. However, higher cylinder wall temperatures also increase the temperature of crevice gases. This can lead to two effects: reduced crevice mass trapped (due to lower density)
and greater (faster) oxidation of the trapped fuel-air mixture. Also, “quench distance” (ie) the approximate distance from the cylinder wall where the flame gets quenched is decreased with higher wall temperatures. Thus unburned HC emissions may decrease with higher wall temperatures.

Location and number of spark plugs per cylinder

Spark plug location is very important since it determines the “origin” of the flame during combustion. The location is greatly affected by several parameters; combustion chamber design, operating conditions (typical), the overall tendency to knock, to name a few. In order to reduce the possible occurrence of surface ignition or knock due to hot spots in the exhaust valve, the spark plug is usually placed closer to the exhaust valve so that the flame consumes the unburned mixture near the exhaust valve. The number of spark plugs per cylinder depends on the size of the combustion chamber and the engine speed. In high-speed engines where the timescales available for combustion are very short, two spark plugs may be used per cylinder to give rise to two flame fronts, thereby increasing the effective area of the flame and the combustion rates.
In-cylinder fluid motion: The fluid motion inside the cylinder has a direct influence on combustion, e.g., the nature of fluid motion near the spark plug electrodes affects the first two stages (spark ignition & early flame development) of SI engine combustion. In-cylinder fluid motion occurs over a range of "length scales" and "time scales" and is dependent on the intake fluid dynamics, combustion chamber design, and engine operating conditions. Tumble and swirl are the most important large-scale, organized (coherent) fluid motions. Both are dependent on the intake port design and combustion chamber shape and both represent the most general motion that can be induced at the scale of the cylinder; note however that other kinds of secondary motion (sometimes unknown!) may exist inside the cylinder. Typically, swirl is a more stable organized motion than tumble. Both swirl and tumble store energy, so, due to its increased stability, swirl continues to store energy for a longer time. During the compression process, the tumbling vortex is compressed into smaller volumes, hence it becomes unstable and breaks down into turbulence thereby releasing the energy it stored. Swirl does not break down as much as tumble and therefore does not directly "generate" a lot of turbulence. In most engines...