MAK 3031- Internal Combustion Engines

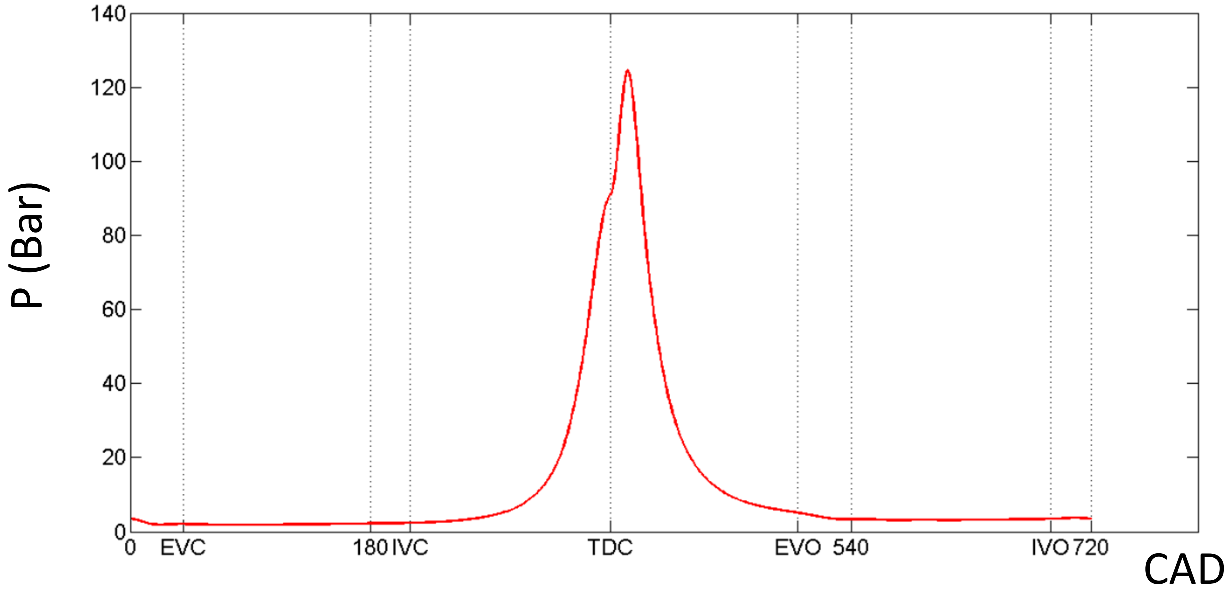
Asst. Prof. Dr. Levent YÜKSEK
Yıldız Technical University-Automotive Sub-Division
Internal Combustion Engine Laboratory

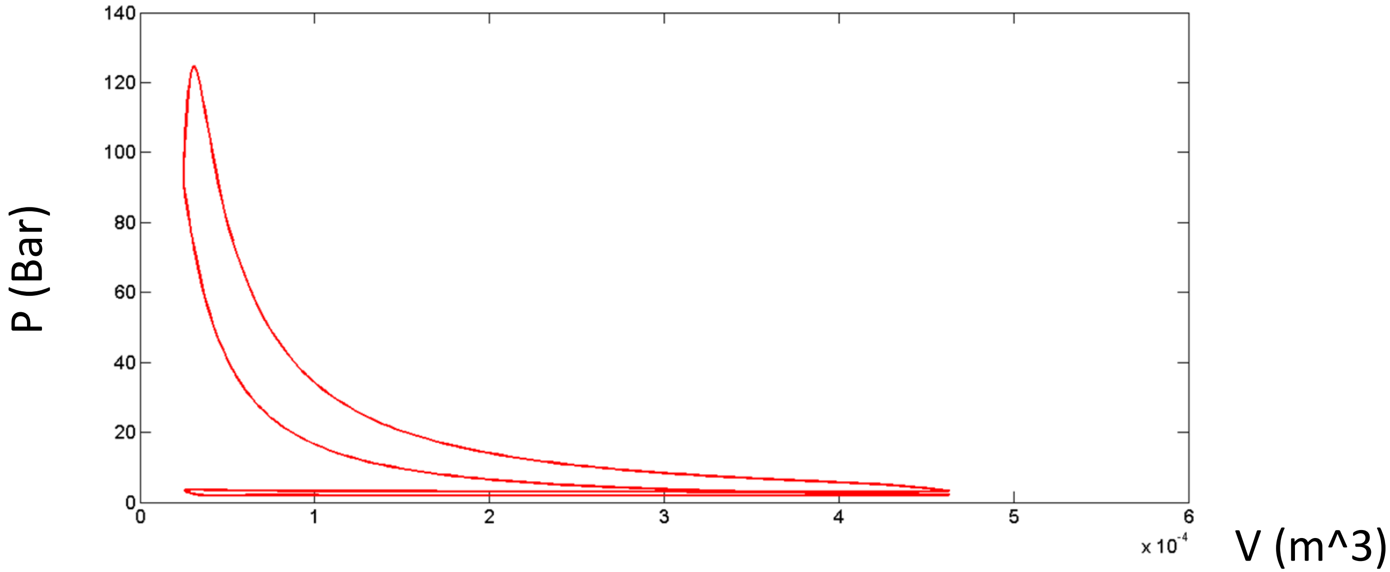
Week-8/ Actual engine cycle

The possible causes of the observed differences between the actual cycle and the fuel-air cycle include the following losses that are taken into account for the analysis of the actual cycle, and which are not considered in the analysis of the fuel-air cycle.

1. Leakage
2. Imperfect mixing of fuel and air
3. Progressive burning
4. Heat losses to the cylinder walls
5. Exhaust blowdown loss
6. Fluid friction
7. Gas exchange or pumping loss

Week-8/ Actual engine cycle

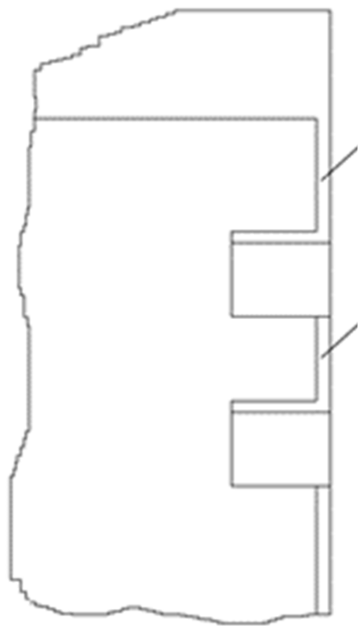




Week-8/ Actual engine cycle

Leakage

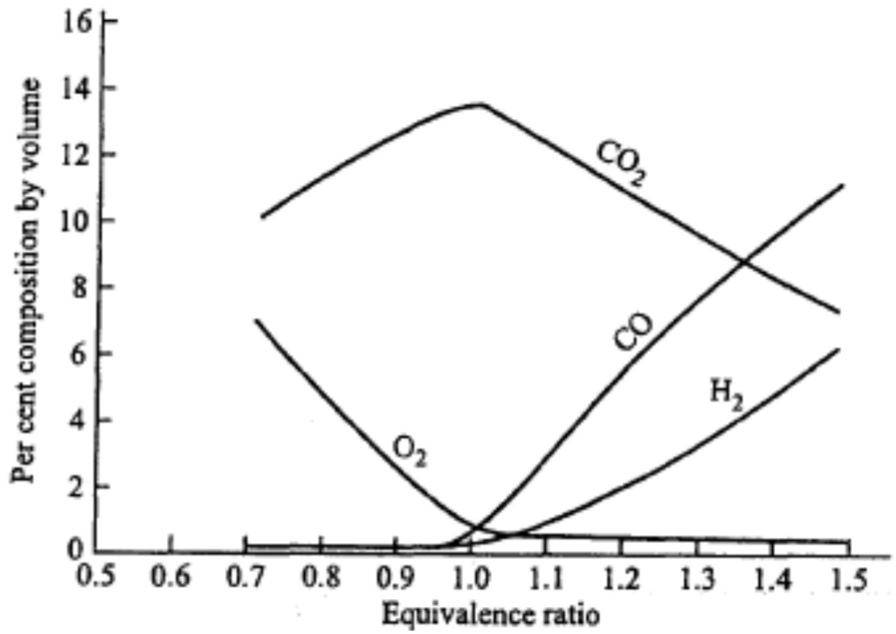
At higher piston speeds, leakage is usually insignificant in a well adjusted engine. However, at low piston speeds and high gas pressure, the gas flows into the regions between the piston, piston rings and cylinder walls and gets cooled by heat transfer through cylinder walls.



Week-8/ Actual engine cycle

Imperfect mixing of fuel and air:

In practice, it is not possible to obtain a perfect homogeneous mixture of fuel, air and residual gases in the cylinder before the ignition takes place, because of insufficient turbulence. In one part of the cylinder, there may be excess oxygen and in another part excess fuel may be present. The excess fuel may not find enough oxygen for complete combustion, which may result in the appearance of CO and unburned fuel in the exhaust. The efficiency of the engine will decrease because of the wastage of fuel. Figure shows the composition of exhaust gases of a typical gasoline engine at various equivalence ratios. The wastage of fuel can be reduced by using lean mixture. This will ensure the complete utilization of fuel, thus providing maximum economy.



Week-8/ Actual engine cycle

Even if the unburned fuel and oxygen combine later during the expansion stroke, resulting in no loss of fuel in the exhaust, still there will be a loss in efficiency, since the sensible energy present with the combustion of this part of fuel is not utilized at top dead center and hence does not contribute to the pressure rise at that point.

Week-8/ Actual engine cycle

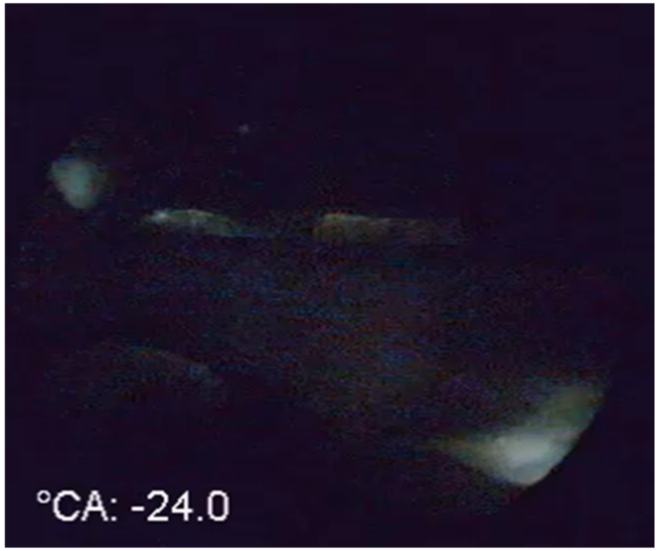
Progressive Burning:

In the analysis of constant volume fuel-air cycle it is assumed that the ignition takes place at top dead centre and combustion is instantaneous. In an actual SI engine, combustion starts at a certain point and continues by moving the flame front. Combustion is complete when the flame front has passed through the entire charge. It takes some time in doing so. The time required for this varies with the fuel composition, the combustion chamber shape and size including the number and position of the ignition point and engine operating conditions. Different amounts of charge burn at different times even if the piston is nearly stationery during combustion. The spark ignites a very small portion of the charge immediately adjacent to it. The flame then spreads progressively throughout the mixture. This phenomenon of burning is called progressive burning.

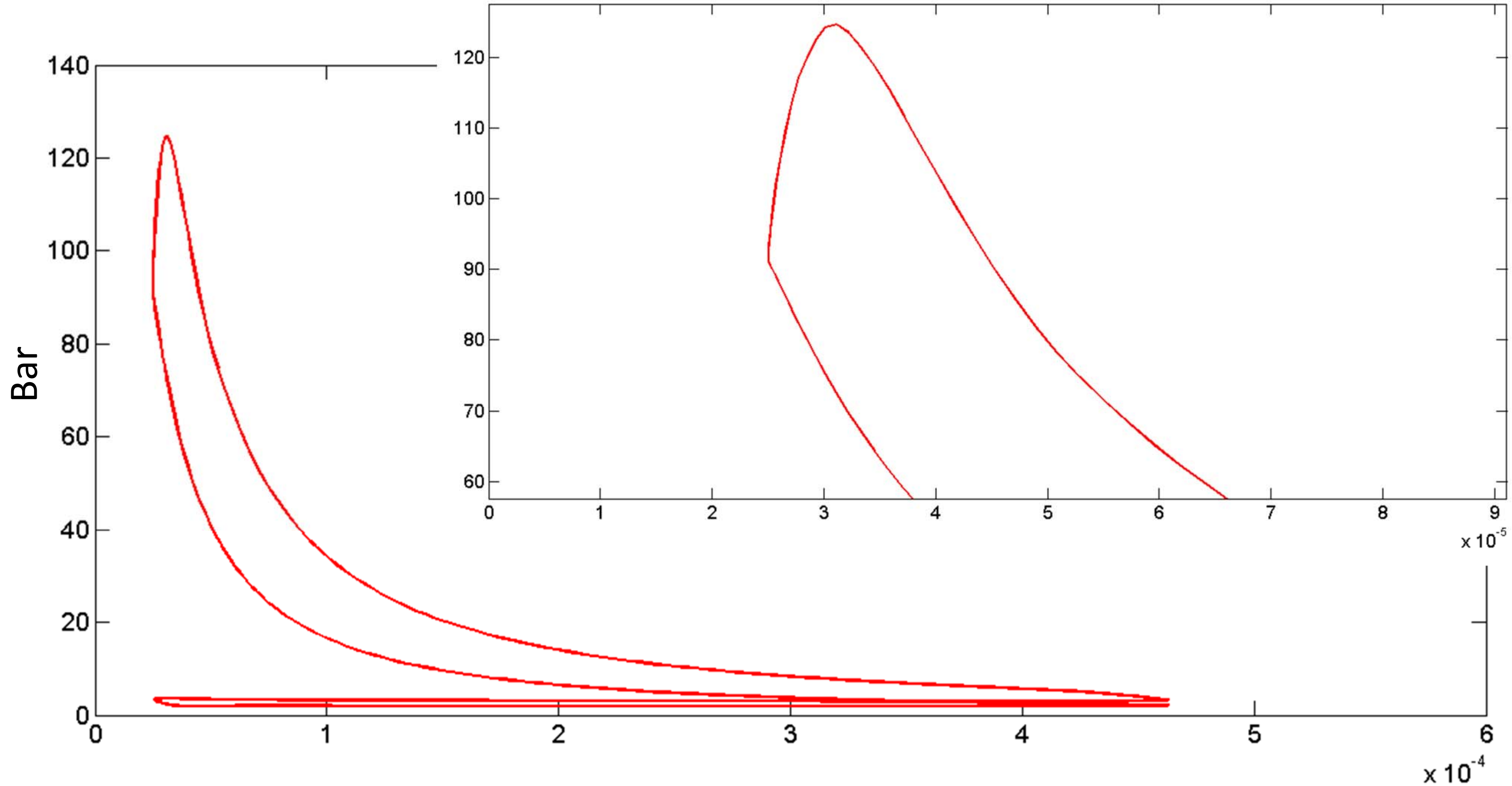
The crankshaft normally rotates through 40° or more between the time the spark is produced and the time the charge is completely burned. The time in degree crank angle (DCA) depends upon the flame speed and the distance between the position of spark plug and the farthest side of combustion chamber. The flame travel distance can be reduced by locating the spark plug at the centre of the cylinder head or by using more than one spark plug. A hemispherical combustion chamber often uses two spark plugs mounted on the cylinder head on opposite sides to reduce the flame travel distance. The motion of the flame front depends upon how fast the heat is transferred from the flame front to the unburned mixture just ahead of the flame front. Heat is generated by the chemical reaction at the flame front. As the crankshaft rotates, the piston moves and if the piston motion during combustion is taken into account the burning time losses are determined, which results in loss of work and efficiency. However, the burning time losses are quite large, if: (a) The fuel/air ratio is made too lean, or too rich.
(b) The throttle is partially closed, reducing the intake pressure.
(c) The point of ignition is not properly set.

Week-8/ Actual engine cycle

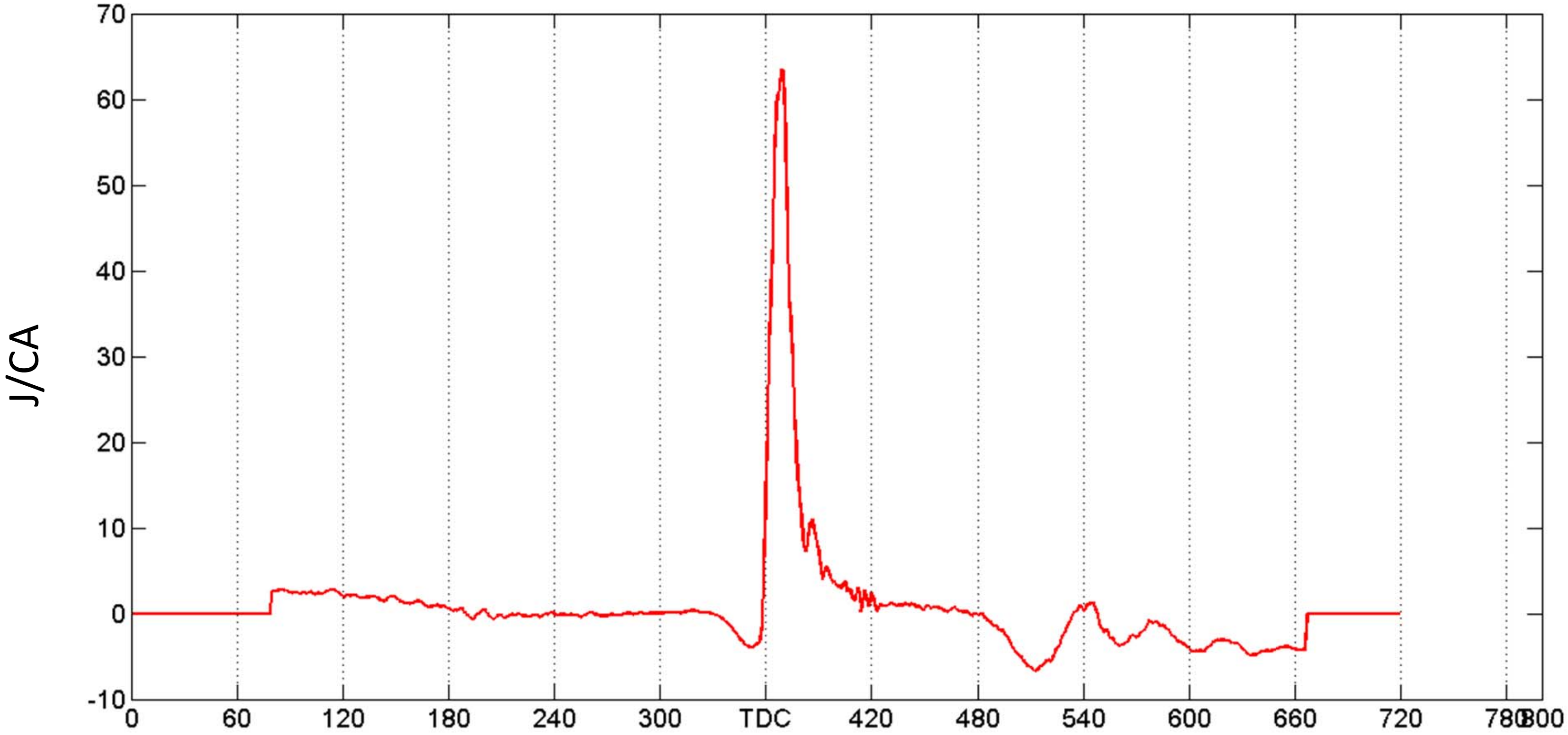
Week-8/ Actual engine cycle



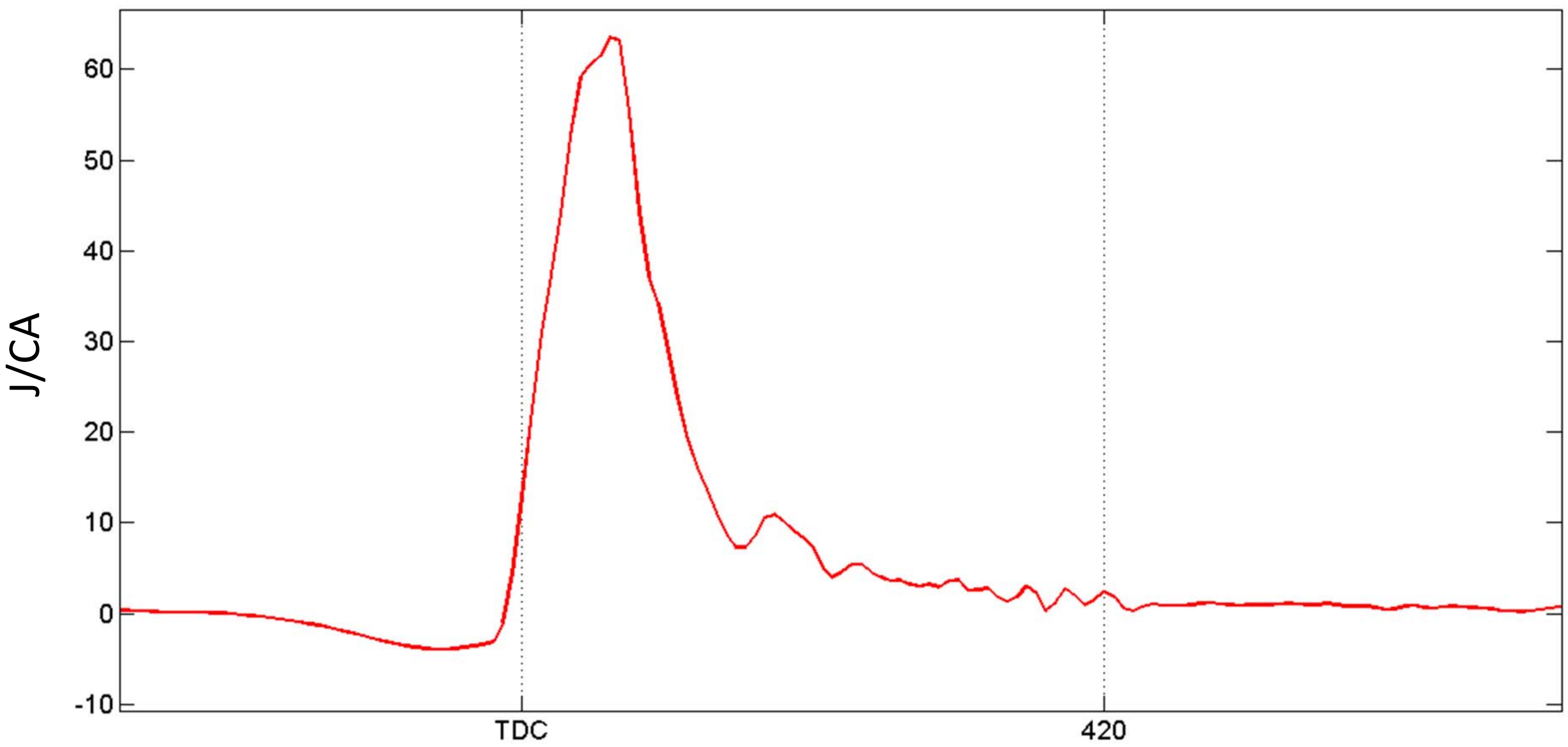
Week-8/ Actual engine cycle



Week-8/ Actual engine cycle

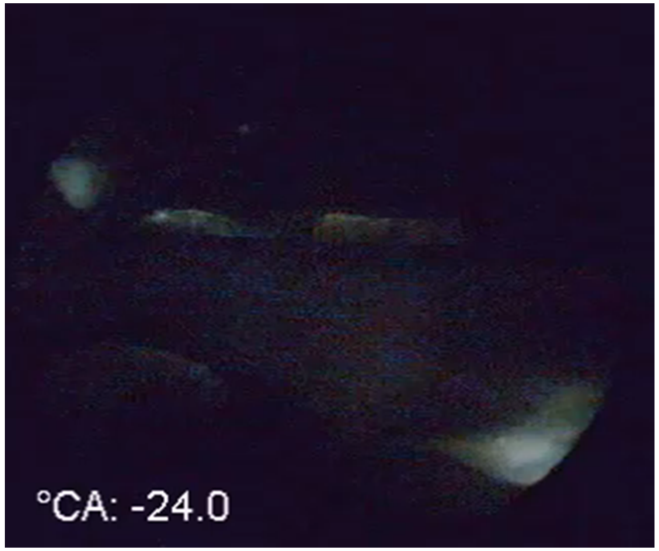


Week-8/ Actual engine cycle

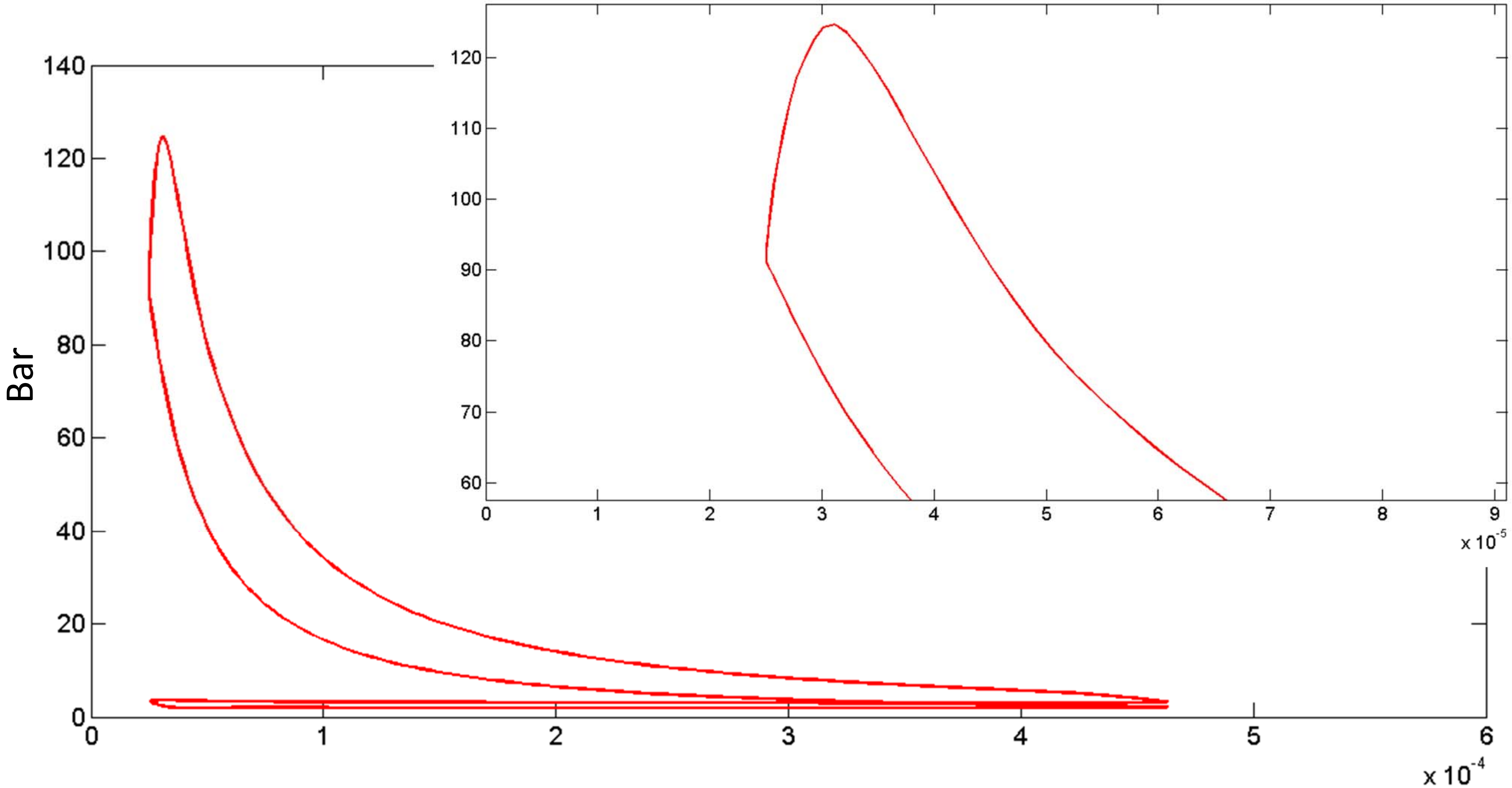


Week-8/ Actual engine cycle

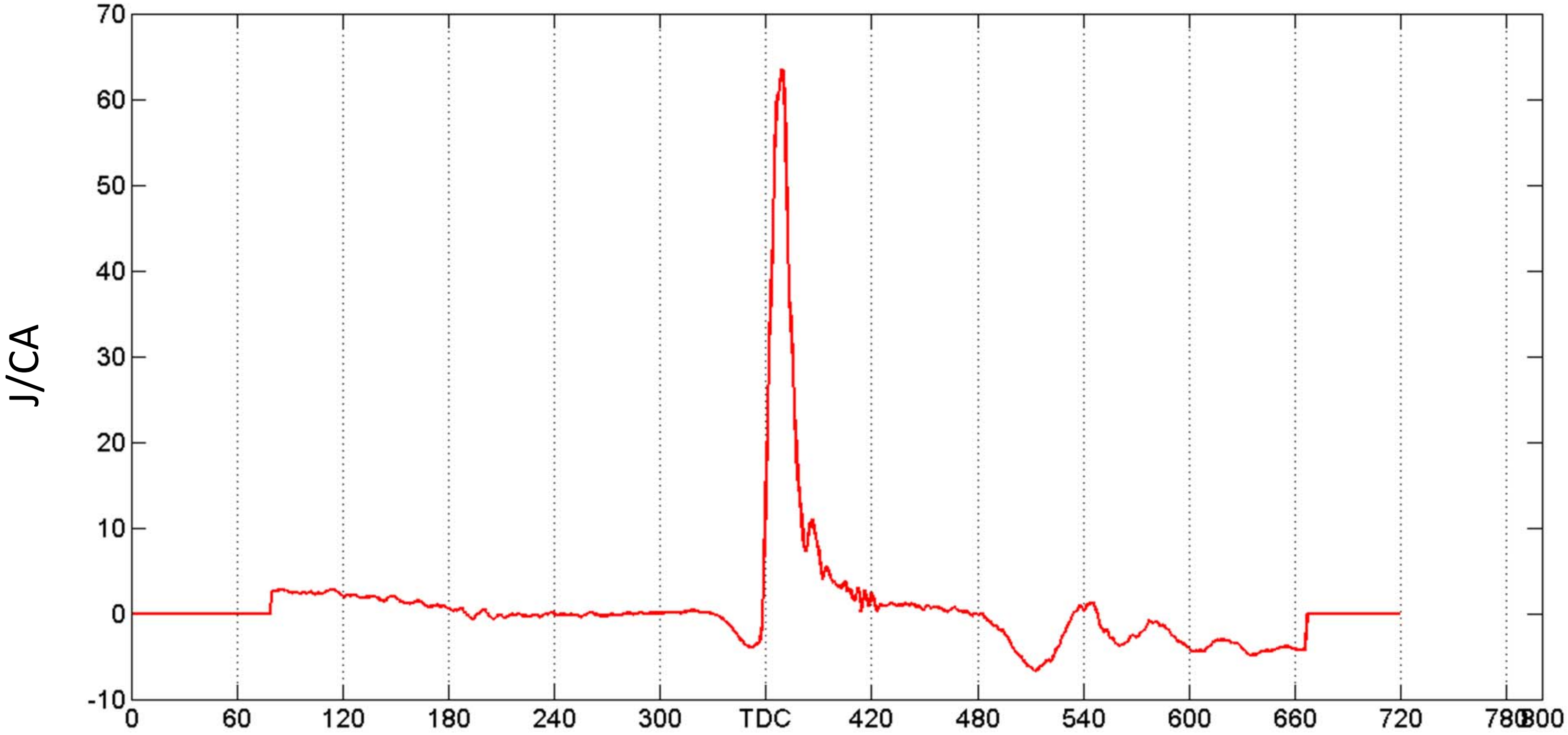
Week-8/ Actual engine cycle



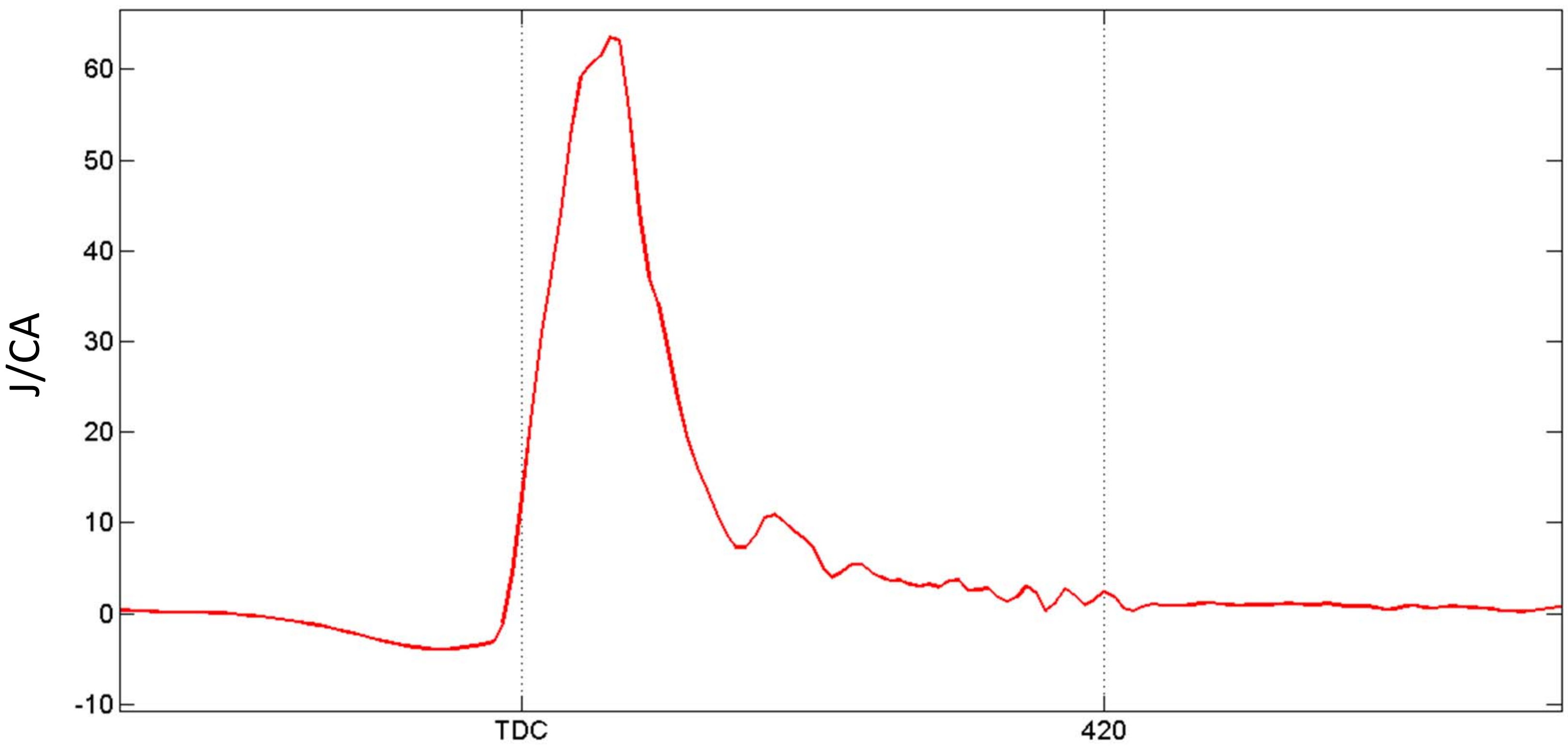
Week-8/ Actual engine cycle



Week-8/ Actual engine cycle



Week-8/ Actual engine cycle



Week-8/ Actual engine cycle

Heat Losses to the Cylinder Walls

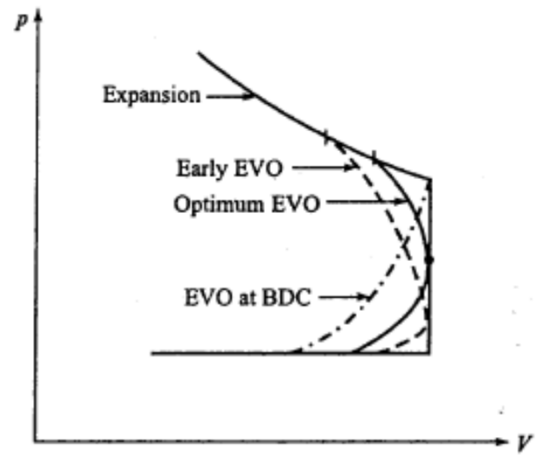
Heat transfer in combustion engines discriminate the actual cycle from the air-standard cycles. During whole intake stroke and initial stages of compression stroke heat transfer is directed to the in-cylinder gases due to lower in-cylinder temperature. During this stage, actual specific heats ratio is higher than adiabatic ideal. When charge temperature rises, heat transfer direction change vice-versa almost to the end of the cycle. Specific heats ratio is lower than ideal assumption and hence thermal efficiency of the actual cycle is lower.

Combustion heat transfers to the cooling medium and/or lubricating oil by several pathways. Main and the most important mechanism is heat transfer to the water jacket and/or cooling fins. Heat convection from the gases to the cylinder wall followed by the heat conduction in metal. Finally heat transfers via cooling medium to the atmosphere. Second mechanism is the heat transfer through the piston to cylinder liners or lubricating oil.

Week-8/ Actual engine cycle

Exhaust Blowdown Loss

The pressure at the end of the expansion stroke is much higher than the atmospheric pressure. If the exhaust valve is opened at bottom dead centre, the piston would have to do a large amount of work in order to expel the high pressure exhaust gases during the exhaust stroke. If the exhaust valve is opened too early, part of the expansion work is lost. The best position is to open the exhaust valve 40° to 70° before BDC. In this case too, some expansion work is lost but the work spent by the piston during the exhaust stroke is reduced. The net result will be the gain in some work. The early opening of the exhaust valve releases the pressure of the gas before the piston reaches BDC. This process is called *exhaust blowdown.* With proper designing and timing of the exhaust valve opening, the blowdown loss is not much.

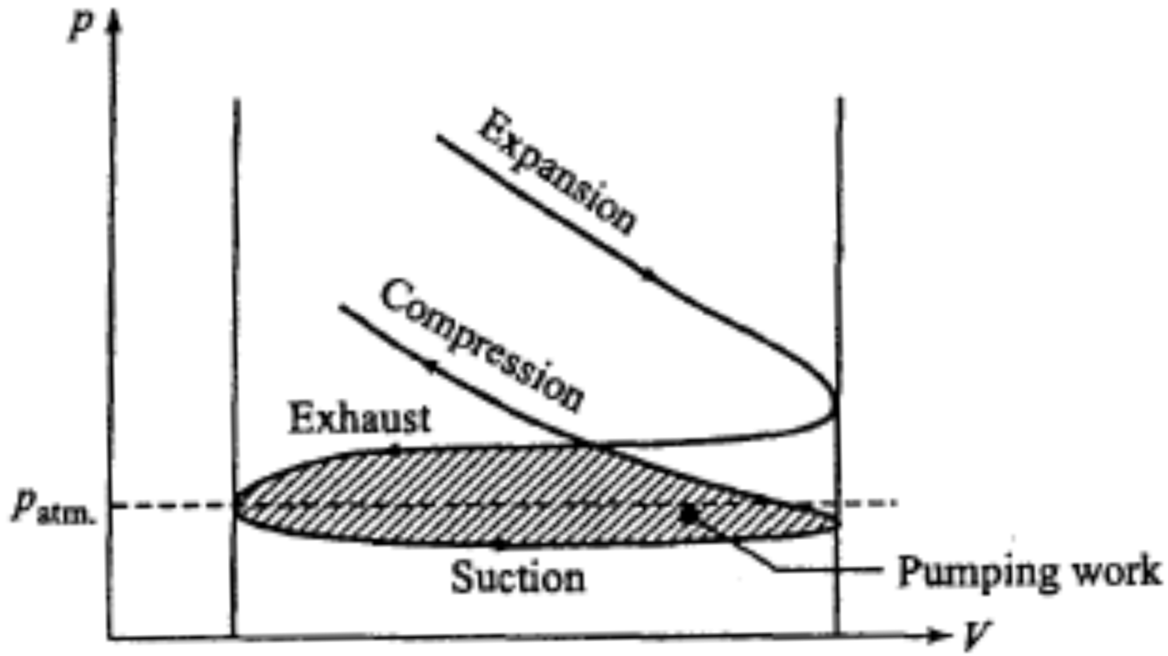


Week-8/ Actual engine cycle

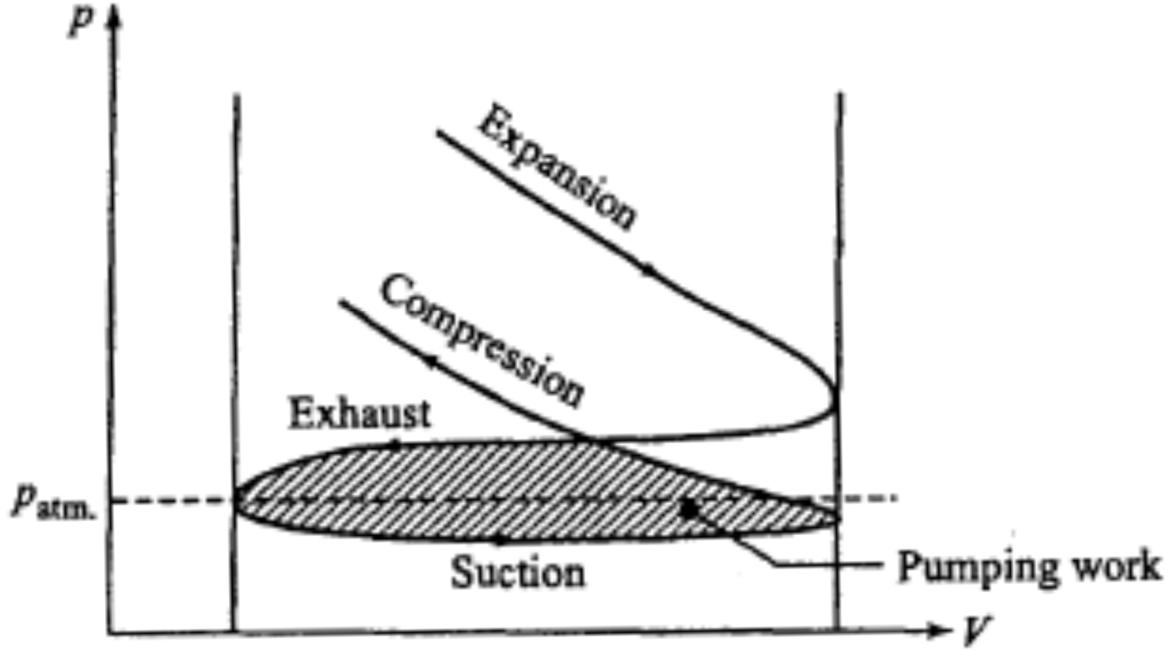
Gas Exchange or Pumping Loss

The purpose of the gas exchange process is to admit the fresh charge during the intake stroke and remove the burned gases at the end of the expansion stroke. During the induction process, pressure losses occur as the charge passes through the air filter, the carburettor and the intake manifold. There is additional pressure drop across the inlet valve. The drop in pressure along the intake system also depends on the engine speed. The pressure during the intake stroke is below atmospheric. The exhaust system consists of an exhaust manifold, an exhaust pipe, and often a catalytic converter for emission control, and a muffler or silencer. The burned cylinder gases get expelled because of the pressure difference between the cylinder and the exhaust system. The pressure during the exhaust stroke is much higher than the atmospheric. Figure shows the gas exchange processes in a conventional SI engine. The difference of the work done in expelling the exhaust gases and the work done by the fresh charge during the suction stroke is called the pumping work and the loop formed is called the pumping loop. The area of the pumping loop indicates negative work and it represents pumping losses. The pumping loss increases at part throttle because throttling reduces the suction pressure. The pumping loss also increases with speed.

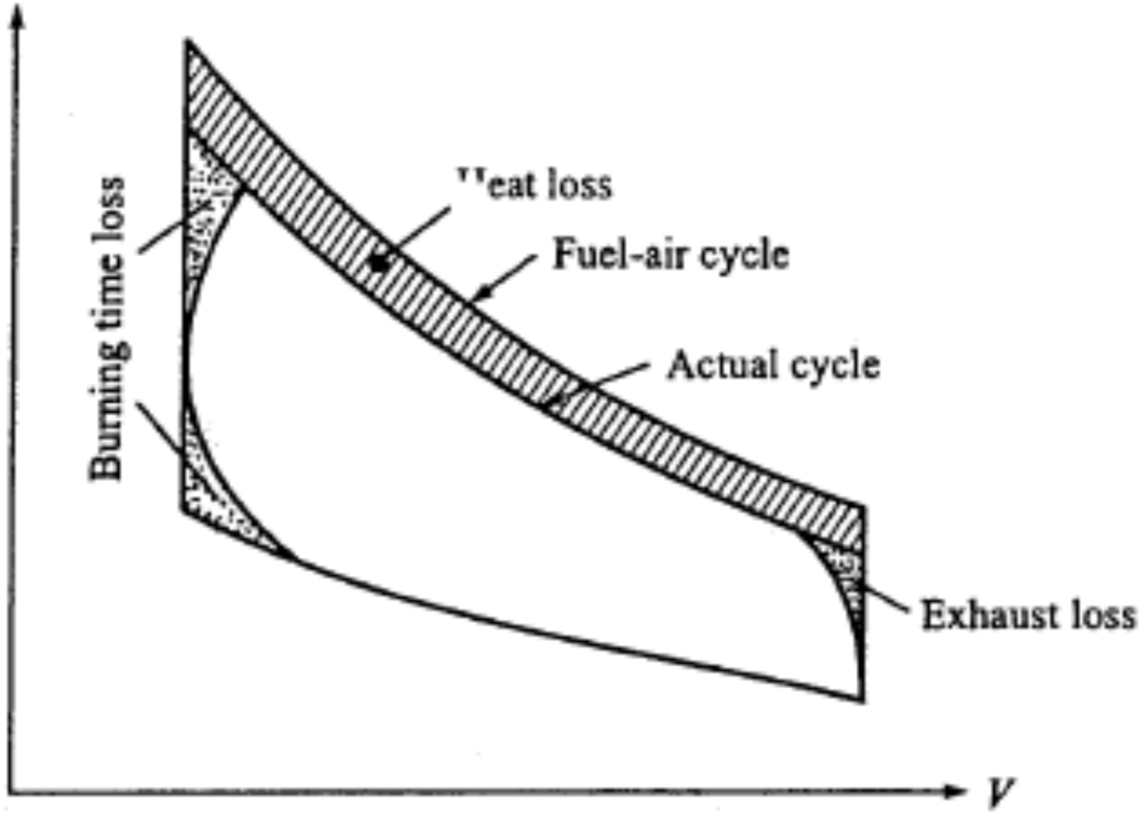
Week-8/ Actual engine cycle



Week-8/ Actual engine cycle



Week-8/ Actual engine cycle



Week-8/ Actual engine cycle

Item	At load	
	Full load (%)	Half load (%)
Air-standard cycle efficiency, η_a	56.5	56.5
(i) Losses due to variation of specific heat and chemical equilibrium	13.0	13.0
(ii) Loss due to progressive burning	4.0	4.0
(iii) Loss due to burning time	3.0	3.0
(iv) Heat loss	4.0	5.0
(v) Exhaust blowdown loss	0.5	0.5
(vi) Pumping loss	0.5	1.5
(vii) Frictional losses	3.0	6.0