# PROJECT No. (1)
# (Otto Cycle Simulation)

## ⌘ OBJECTIVES

1. To have an idea about the basics of engine simulation.
2. To study the effect of various engine design conditions on its performance.

## ⌘ MODEL INPUT DATA REQUIRED

1. **Engine design parameters:** D, S, CRL, CR, RPM
2. **Fuel and air data :** CV, A/F, Cv, Cp, Ma
3. **Inlet conditions :** P1 and T1.

## ⌘ MAIN PROGRAM

### 1. Compression Stroke (1-2), ($0 \leq \theta \leq 180$)

- Start with calculation of V(θ) using equation No.(4) see next page.
- Then calculate $\mathbf{P(\theta) = P_1 * \left[\frac{V_1}{V(\theta)}\right]^{\gamma}}$
- Then finally calculate $\mathbf{T(\theta) = T_1 * \left[\frac{V_1}{V(\theta)}\right]^{\gamma - 1}}$

### 2. Combustion Stroke (2-3), (θ =180)

- Take the pressure ratio (P3/P2) = 4.5 – 5.0
- Calculate P3 which is P(180) after combustion.
- Then calculate T3.
- Then calculate Heat Input per Kg of air.

### 3. Expansion Stroke (3-4), ($180 \leq \theta \leq 360$)

- Start with calculation of V(θ) using equation No.(4).
- Then calculate $\mathbf{P(\theta) = P_3 * \left[\frac{V(\theta = 180)}{V(\theta)}\right]^{\gamma}}$
- Then finally calculate **T(θ) from T3**

### 4. Exhaust Stroke (4-1), (θ = 360)

Since this is a simplified model and for the sake of this project only, restore the final values to the initial values.

## ⌘ MAIN EQUATIONS USED

- $Vs = 0.25 * PI * D^2 * S$ (1)
- $V_{TDC} = V_2 = V(\theta = 0) = Vs * ( 1 / (CR-1))$ (2)
- $V_{BDC} = V_1 = V(\theta = 180) = Vs * ( CR / (CR-1))$ (3)

- $V(\theta) = Vs * \left[\left(\frac{CR}{CR-1}\right) - \left(\frac{1-\cos(\theta)}{2}\right) + \left(\frac{CRL}{S}\right) - \frac{1}{2} * \sqrt{\left(\frac{2*CRL}{S}\right)^2 - \sin^2(\theta)}\right]$ (4)
- $IMEP = WD / Vs$ (5)
- $IP = (IMEP * A * S * (N/n))$
- $IT = IP/2*PI*N$ (6)
- $WD = M_t * Cv * [(T_3 - T_2) - (T_4 - T_1)]$ (7)
- $\eta_{ith} = WD/Q_{add} = IP/M_f * CV$ (8)
- $ISFC = M_f / IP$

Where;

Vs = Stroke volume (m) D = Cylinder diameter (m) S = Stroke length (m)
CR = Compression Ratio CRL = Connecting Rod Length (m) $\theta$ = Crank Angle (rad)
WD = Net Work Done (kJ) IP = Indicated Power (kW) A = Cylinder Area ($m^2$)
IT = Indicated Torque (N-m) N = Engine Revolutions (RPM) n = 2 for 4-strokes
IMEP = Indicated Mean Effective Pressure (bar) $\eta_{ith}$ = Indicated Thermal Eff.
ISFC = Indicated Specific Fuel Consumption (Kg/kW-hr)

## PLOTS REQUIRED

- Pressure and temperature variations with crank angle.
- Pressure and temperature variations with cylinder volume.
- Effect of CR on engine performance parameters like (IMEP, ISFC, IP, WD & IT) taking 4 different values for CR (6,7,8 & 9).
- Effect of specific heat ratio ($\gamma$) on P-V and T-V diagrams.

This program can be done using any of the programming languages (C, FORTRAN, PASCAL, BASIC …etc) or worksheets (EXCELL ….etc).

Last date of submission of this project is **Tuesday 21st November 2002.**

To test the output of your program, use the following data :

D = 7.94 cm, S = 11.12 cm, CRL = 23.34 cm, N = 4000 rpm, CR = 6
CV = 42000 kJ/Kg, A/F = 14.6, Cv = 0.718 kJ/Kg-K, $P_1$ = 1.0135 bar, $T_1$ = 300 K

You should be able to get the following output :

P2 = 12.452 bar, T2 = 614.302 K, P3 = 88.468 bar, T3 = 4364.035 K, P4 = 7.2 bar&T4 = 2132.65K
IMEP = 24.98 (bar), WD = 1376.465 (kJ/Kg), IP = 45.88 (kW),
ISFC = 0.164 (kg/kW-h), $\eta_{ith}$ =0.5215

Once your model is verified, you can go for the engine performance study.