

# Chapter Five

## *Results and Discussion*

## 5.1. INTRODUCTION

In this chapter we will display the results that obtained from the program for various parameters variability, such as effect of non-linear variable specific heats, effect of internal irreversibility, effect of heat losses and effect of friction losses. Also we will discuss these results and compare with similar results that obtained in previous studies.

## 5.2. THERMODYNAMIC MODEL INPUT DATA DETAILES

For this model we will assume the technical and thermodynamic engine specifications shown in table 5.1

**Table 5.1: The technical and thermodynamic engine specifications**

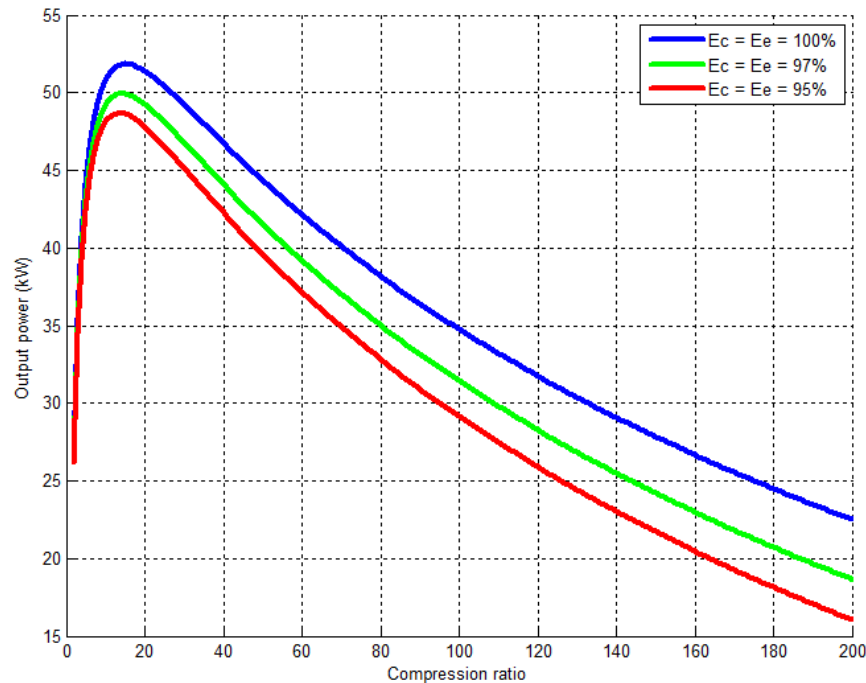
Engine type	4 stroke diesel engine
No. of cylinders ( $n$ )	4 cylinders
Bore ( $D$ )	91.1 mm
Stroke ( $L$ )	95 mm
Volumetric efficiency ( $\eta_v$ )	95%
Rotational speed ( $N$ )	1800 rev/min
Inlet air temperature ( $T_1$ )	300 K
Peak temperature ( $T_3$ )	2500 K
Inlet air density ( $\rho_a$ )	1.2 kg/m <sup>3</sup>
Compression ratio ( $r_v$ )	Vary from 1 to 200 with increment 1
Cut-off ratio ( $r_c$ )	Vary from 1.75 to 2.5 with increment 0.25
Heat leakage coefficient ( $B$ )	Vary from 0 kJ/kg.K to 0.4 kJ/kg.K with increment 0.2
Friction coefficient for global losses ( $\mu$ )	Vary from 0 N.s/m to 20 N.s/m with increment 10
Compression efficiency ( $\eta_c$ )	Three values: 0.95, 0.97 and 1.00
Expansion efficiency ( $\eta_e$ )	Three values: 0.95, 0.97 and 1.00
Gas constant for air ( $R$ )	0.287 kJ/kg.K

Depending on the data above, we will perform model calculations and presenting results according to the effect of each parameters mentioned above as shown in the following points.

### 5.3. EFFECT OF INTERNAL IRREVERSIBILITY

In this section we will discuss the effect of internal irreversibility of the engine performance parameters at fixed cut-off ratio and fixed ambient temperature, also without the presence of friction loss and heat loss,

Show in Fig. 5.1 the relation between the compression ratio ( $r_v$ ) and net output power ( $P$ ) for 3 different values of compression and expansion efficiencies.



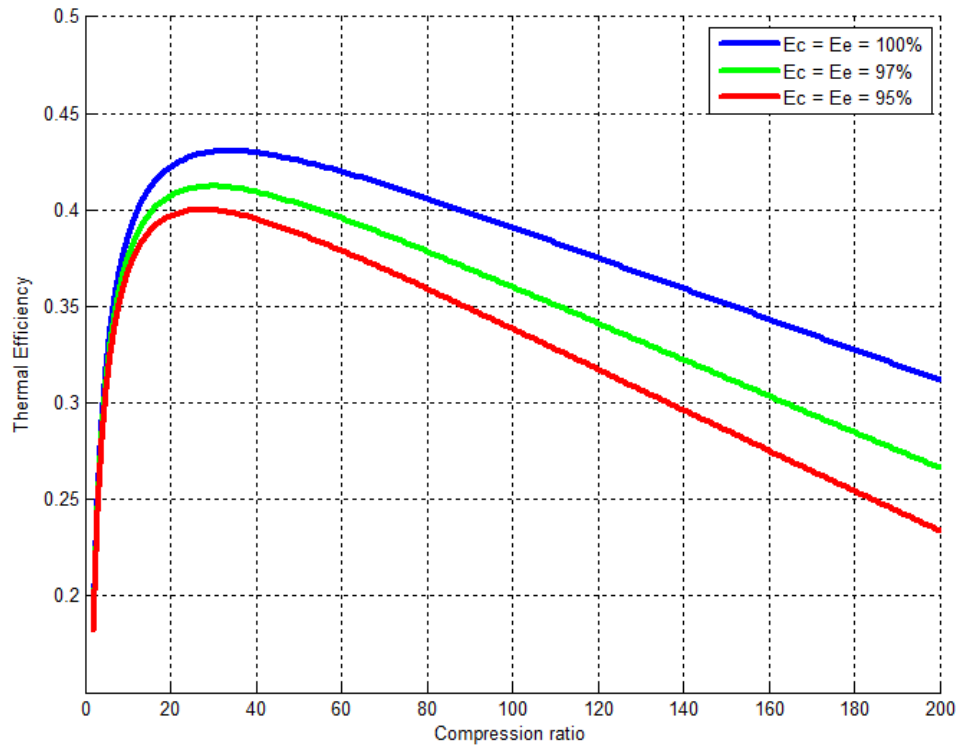
**Fig. 5.1: Effect of internal irreversibility on output power ( $P$ )**

From fig. 5.1 it's clear that when both of compression and expansion efficiencies increase, the output power values corresponding to higher efficiencies becomes greater than that values corresponding to lower efficiencies for all values of compression ratio.

The output power corresponding to the compression values approximately from 1 to 15 increases rapidly for all values of both of compression and expansion efficiencies, after that the output power

corresponding to the remaining values of compression ratio decreasing sharply for all values of both of compression and expansion efficiencies.

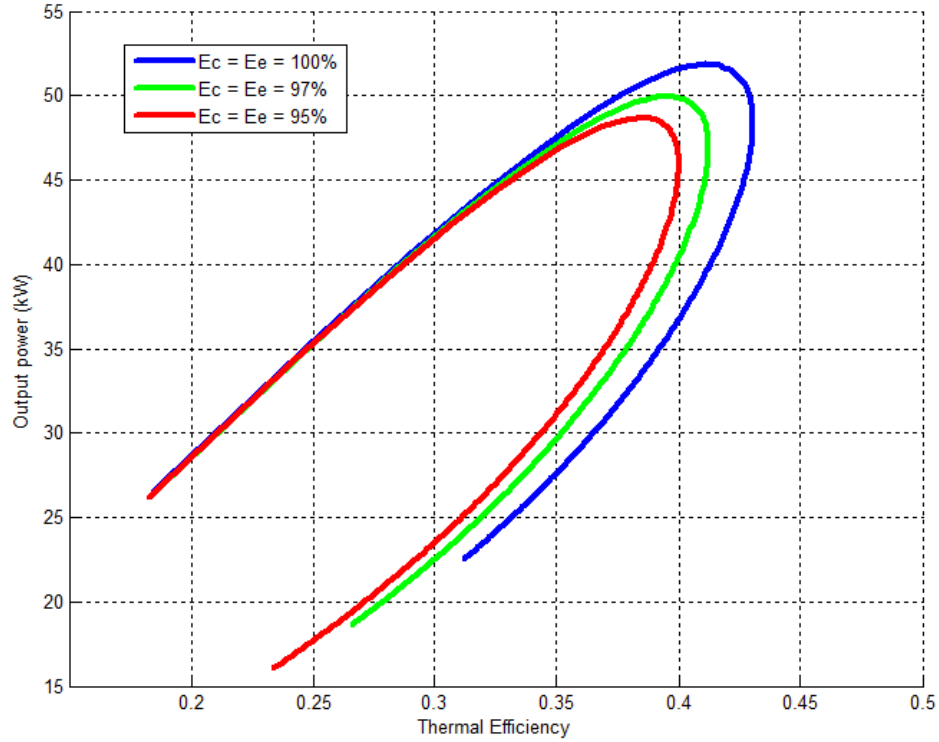
Show in Fig. 5.2 the relation between the compression ratio ( $r_v$ ) and thermal efficiency ( $\eta_{th}$ ) for 3 different values of compression and expansion efficiencies.



**Fig. 5.2: Effect of internal irreversibility on thermal efficiency ( $\eta_{th}$ )**

From fig. 5.2 it's clear that the effect of both of compression and expansion efficiencies on thermal efficiency is similar to that effect on output power, but for the thermal efficiency values corresponding to the compression values above 35 approximately decreasing slightly.

Show in Fig. 5.3 the relation between thermal efficiency ( $\eta_{th}$ ) and net output power ( $P$ ) for 3 different values of compression and expansion efficiencies.



**Fig. 5.3: Thermal efficiency ( $\eta_{th}$ ) versus output power ( $P$ ) with respect of internal irreversibility effect**

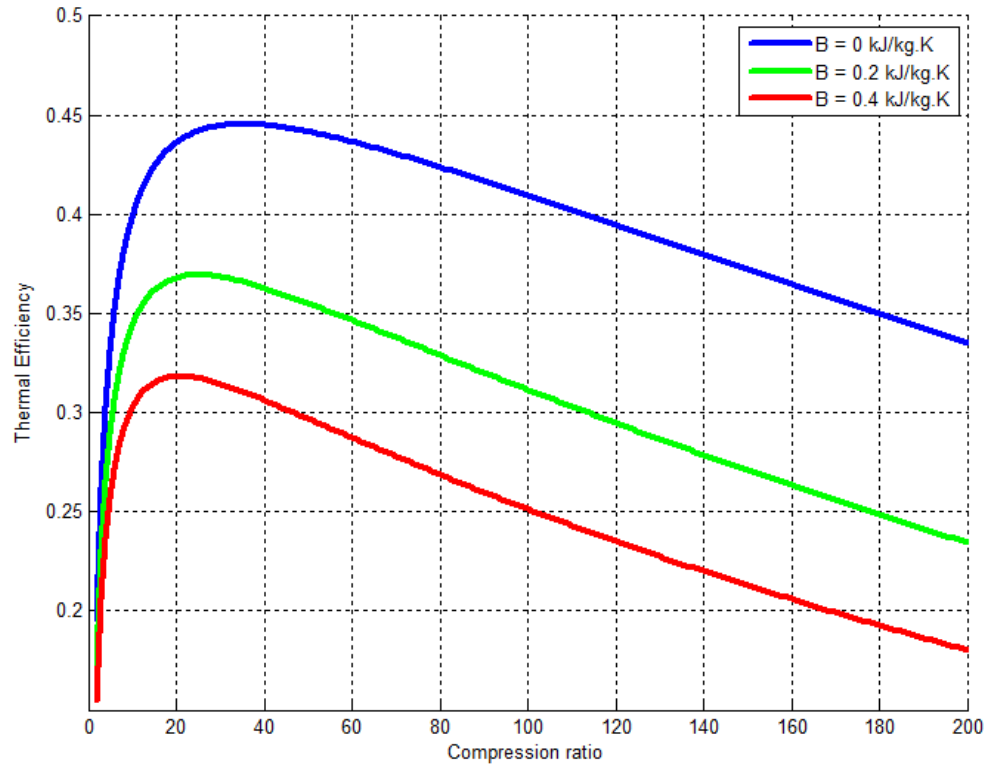
From fig. 5.3 it's clear that the effect of both of compression and expansion efficiencies on net output power versus thermal efficiency characteristic is decreasing both of them when the both of efficiencies is decrease, also at a specific point on any curve we found peak output power is not identical with maximum thermal efficiency; but we found the value of thermal efficiency corresponding to peak output power less than maximum power.

## 5.4. EFFECT OF HEAT LOSS

In this section we will discuss the effect of heat loss on the engine performance parameters also at fixed cut-off ratio and fixed ambient temperature, but without the presence of friction loss, and assumed reversible compression and expansion processes (i.e. compression and

expansion efficiencies are equal 100%). Heat loss is effect only on the amount of heat addition, thus the heat loss effect in the thermal efficiency.

Show in Fig. 5.4 the relation between the compression ratio ( $r_v$ ) and thermal efficiency ( $\eta_{th}$ ) for 3 different values of heat leakage coefficient.



**Fig. 5.4: Effect of heat loss on thermal efficiency ( $\eta_{th}$ )**

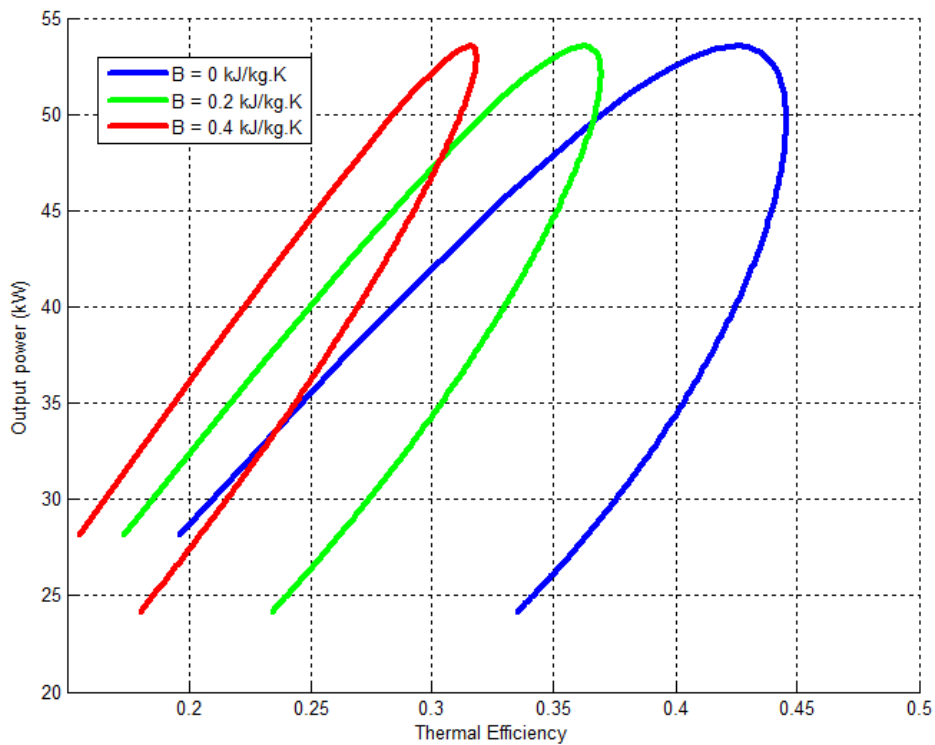
From fig. 5.4 it's clear that when the coefficient of heat leakage decreases, the amount of heat addition values corresponding to lower heat leakage coefficient becomes greater than that values corresponding to higher heat leakage coefficient for all values of compression ratio, with taking into account that the values of output power are not change. Thus the effect of heat leakage coefficient on the thermal efficiency it will be similar to that effect on the amount of heat addition.

The thermal efficiency corresponding to the compression values approximately from 1 to 37 increases rapidly for all values of heat leakage

coefficient, after that the thermal efficiency corresponding to the remaining values of compression ratio decreasing slightly for all values of heat leakage coefficient.

Also in specific value of compression ratio, the difference between the value of thermal efficiency corresponding to heat leakage coefficient and the value of thermal efficiency corresponding to another heat leakage coefficient is a significant difference.

Show in Fig. 5.5 the relation between thermal efficiency ( $\eta_{th}$ ) and net output power ( $P$ ) for 3 different values of heat leakage coefficient.



**Fig. 5.5: Thermal efficiency ( $\eta_{th}$ ) versus output power ( $P$ ) with respect of heat loss effect**

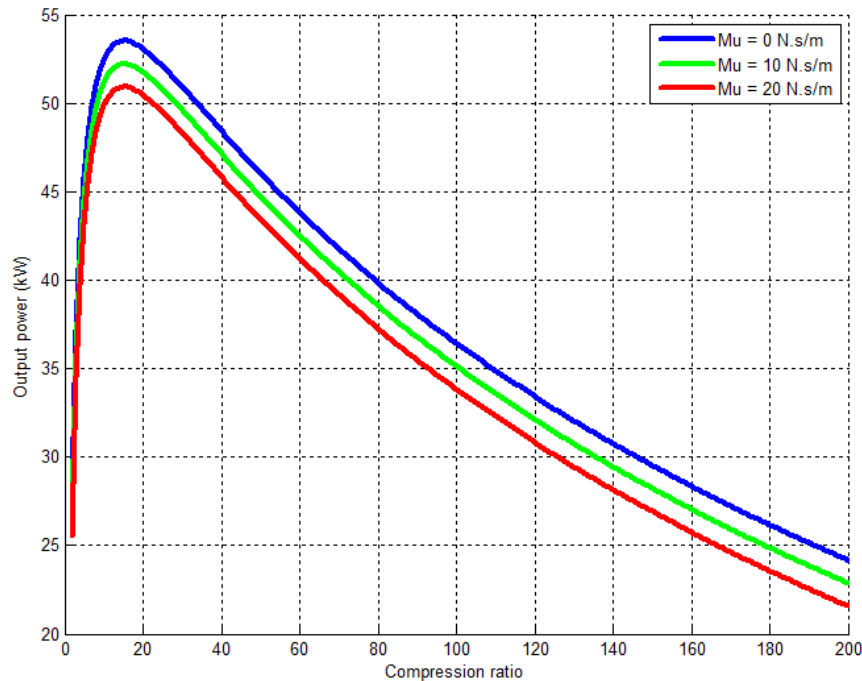
From fig. 5.3 it's clear that the effect of heat leakage coefficient on net output power versus thermal efficiency characteristic is decreasing the thermal efficiency only when the heat leakage coefficient is increase,

because the heat leakage coefficient effect just on the amount of heat addition and has no effect on the output power.

## 5.5. EFFECT OF FRICTION LOSS

In this section we will discuss the effect of friction loss on the engine performance parameters also at fixed cut-off ratio and fixed ambient temperature, but without the presence of heat loss, and assumed reversible compression and expansion processes (i.e. compression and expansion efficiencies are equal 100%). Friction loss actually effect on the net output power and heat transfer from or to engine. But can be assume that it affects only on the net output power because it effect on the amount of heat transfer is very small and can be neglected.

Show in Fig. 5.6 the relation between the compression ratio ( $r_v$ ) and net output power ( $P$ ) for 3 different values of friction coefficients.



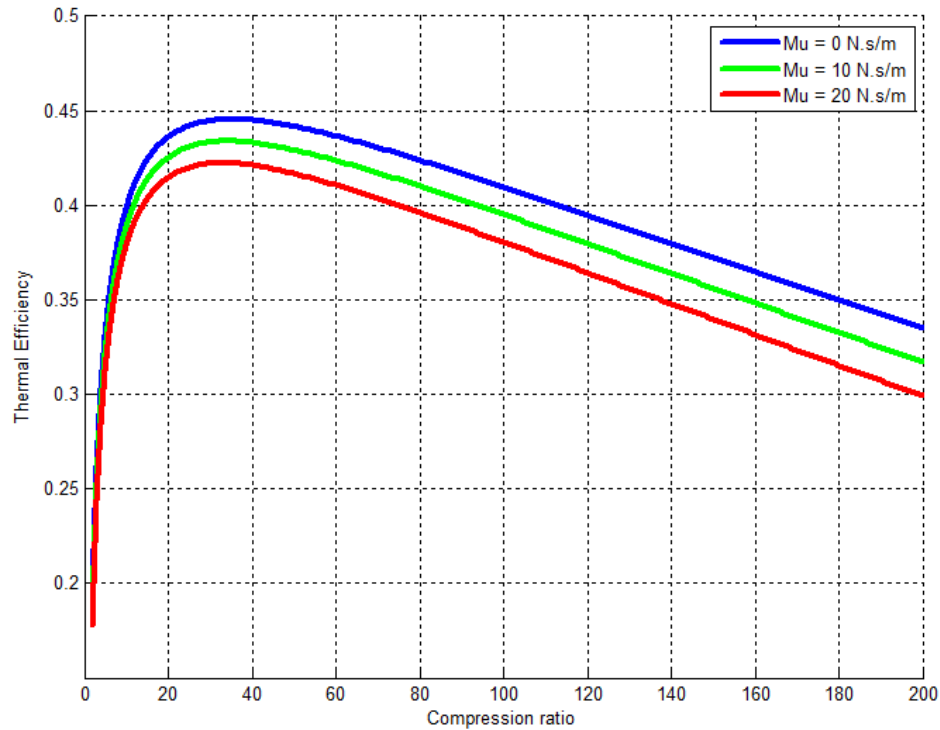
**Fig. 5.6: Effect of friction loss on output power ( $P$ )**



From fig. 5.6 it's clear that when the coefficient of friction increases, the output power decrease, but the amount of decreasing in the output power is not large.

The output power corresponding to the compression values approximately from 1 to 17 increases rapidly for all values of friction coefficients, after that the output power corresponding to the remaining values of compression ratio decreasing sharply for all values of friction coefficients.

Show in Fig. 5.7 the relation between the compression ratio ( $r_v$ ) and thermal efficiency ( $\eta_{th}$ ) for 3 different values of friction coefficient.



**Fig. 5.7: Effect of friction loss on thermal efficiency ( $\eta_{th}$ )**

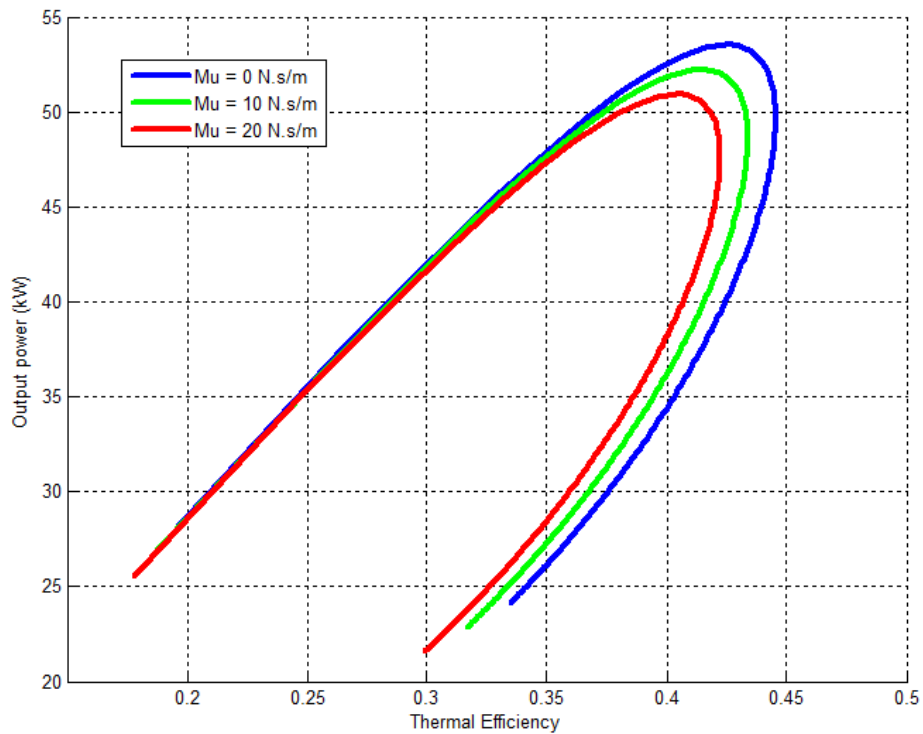
From fig. 5.7 it's clear that when the coefficient of friction increases, the output power values decrease for all values of compression ratio as mentioned previously, with taking into account that the amounts of heat

addition are not change. Thus the effect of friction coefficient on the thermal efficiency it will be similar to that effect on the output power.

The thermal efficiency corresponding to the compression values approximately from 1 to 32 increases rapidly for all values of friction coefficient, after that the thermal efficiency corresponding to the remaining values of compression ratio decreasing slightly for all values of heat leakage coefficient.

Also in specific value of compression ratio, the difference between the value of thermal efficiency corresponding to friction coefficient and the value of thermal efficiency corresponding to another friction coefficient is a relatively small difference.

Show in Fig. 5.8 the relation between thermal efficiency ( $\eta_{th}$ ) and net output power ( $P$ ) for 3 different values of friction coefficient.



**Fig. 5.8: Thermal efficiency ( $\eta_{th}$ ) versus output power ( $P$ ) with respect of friction loss effect**

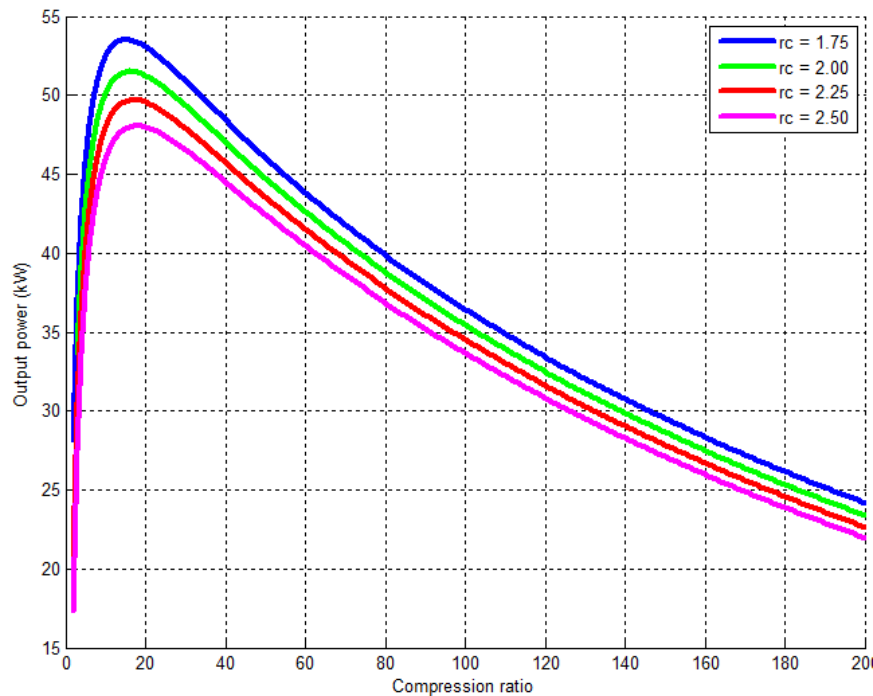
From fig. 5.8 it's clear that the effect of friction coefficient on net output power versus thermal efficiency characteristic is decreasing both of them when the friction coefficient is decrease.

The effect of friction coefficient variation is quite similar to that effect caused by the both of compression and expansion efficiency as mentioned previously.

## 5.6. EFFECT OF CUT-OFF RATIO

In this section we will discuss the effect of cut-off ratio variation on the engine performance parameters at fixed ambient temperature, but without the presence of heat loss and friction loss, in addition to the assumption of reversible compression and expansion processes (i.e. compression and expansion efficiencies are equal 100%).

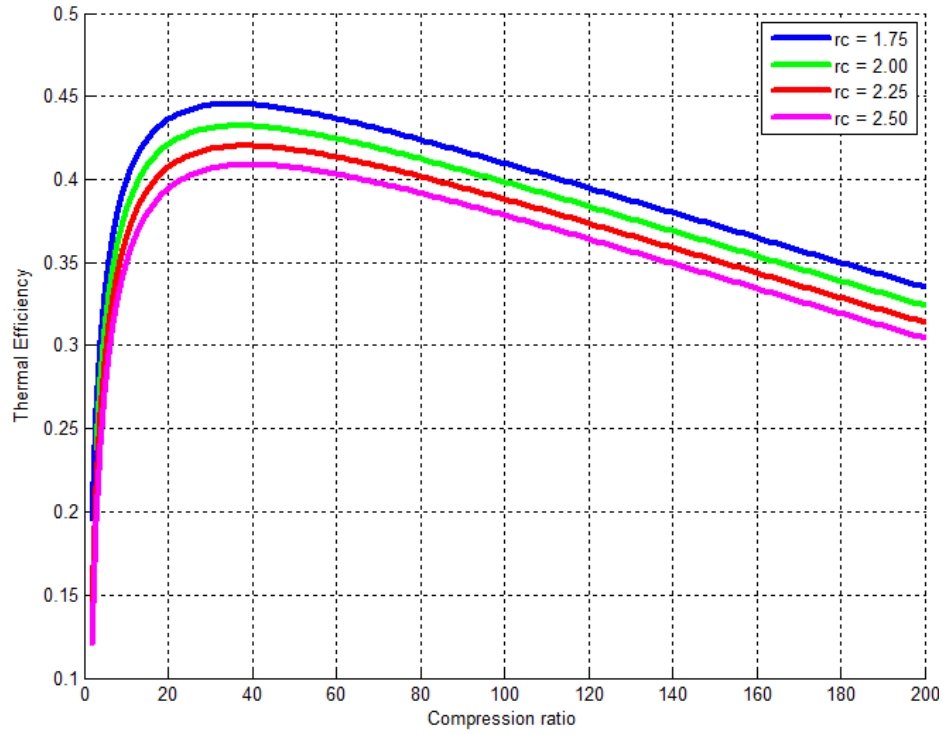
Show in Fig. 5.9 the relation between the compression ratio ( $r_v$ ) and net output power ( $P$ ) for 4 different values of cut-off ratio.



**Fig. 5.9: Effect of cut-off ratio variation on output power ( $P$ )**

From fig. 5.9 it's clear that when the cut-off ratio increases, the output power decrease, but the amount of decreasing in the output power is not large, this is quite similar to that effect on the output power caused by the variation of friction coefficient.

Show in Fig. 5.10 the relation between the compression ratio ( $r_v$ ) and thermal efficiency ( $\eta_{th}$ ) for 4 different values of cut-off ratio.



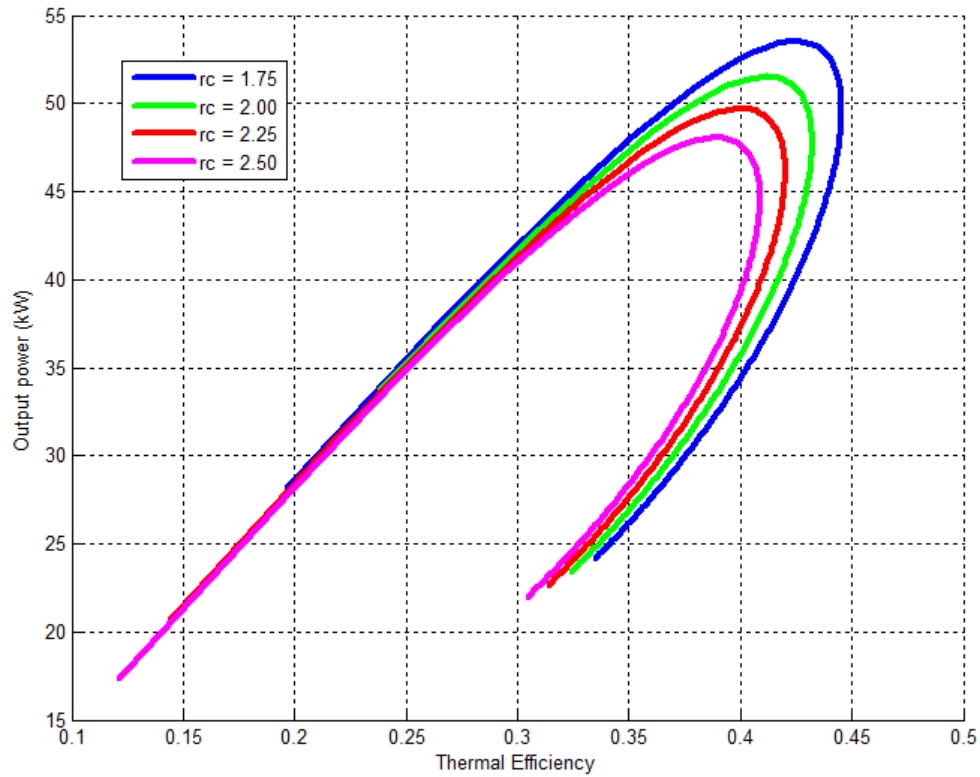
**Fig. 5.10: Effect of cut-off ratio variation on thermal efficiency ( $\eta_{th}$ )**

From fig. 5.10 it's clear that when the cut-off ratio increases, the thermal efficiency values decrease for all values of compression ratio, this corresponds with the thermal efficiency for diesel cycle given below:

$$\eta_{th} = 1 - \frac{1}{r_v^{\gamma-1}} \left[ \frac{r_c^\gamma - 1}{\gamma(r_c - 1)} \right] \quad \dots \dots (5 - 1)$$

From the above equation, we find that when the cut-off ratio increases, the thermal efficiency will be decrease. But the amount of decreasing in the output power is not large.

Show in Fig. 5.11 the relation between thermal efficiency ( $\eta_{th}$ ) and net output power ( $P$ ) for 4 different values of cut-off ratio.



**Fig. 5.11: Thermal efficiency ( $\eta_{th}$ ) versus output power ( $P$ ) with respect of cut-off ratio effect**

From fig. 5.11 it's clear that the effect of cut-off ratio variation on net output power versus thermal efficiency characteristic is decreasing both of them when the cut-off ratio is decrease, such like to that effect caused by friction coefficient.