Theoretical Study Of Some Combustion Parameters On Performance Of Internal Combustion Engines.

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الملخص :

أجريت دراسة تأثير بعض المتغيرات الخاصة بالوقود على كفاءة محرك احتراق داخلي، حيث تم دراسة كفاءة احتراق الوقود ونسبة خلط الهواء إلى الوقود وكذلك نسبة الحرارة النوعية على قدرة وكفاءة المحرك. تم حساب تأثير هذه المتغيرات على الأداء والقدرة الناتجة لمحرك أوتو لعدة نسب انضغاط مختلفة.

Abstract:

A study of gas cycles as the models of internal combustion engines is useful for illustrating some of the important parameters influencing engine performance. In this paper the effect of combustion efficiency, specific heat ratio, and equivalence ratio on the variation on performance with compression ratio for Otto engine. By using Excel program the characteristic curves of the power output and thermal efficiency versus compression ratio are obtained.

The results show that the power output, the thermal efficiency, the optimal compression ratio corresponding to maximum power output point, the optimal compression ratio corresponding to maximum thermal efficiency point. The performance characteristic curves of the cycle are presented. Moreover, the effect of combustion efficiency, specific heat ratio, and equivalence ratio on the cycle performance were analyzed. The results show that the effect of combustion efficiency, specific heat ratio, and equivalence ratio on the cycle performance are significant. The results of this investigation are of importance when considering the designs of actual Otto engines.

1. Introduction:

A heat engine is a machine which converts heat energy into mechanical energy. The combustion of fuel such as coal, petrol, diesel generates heat. This heat is supplied to a working substance at high temperature. By the expansion of this substance in suitable machines, heat energy is converted into useful work. Heat engines can be further divided into two types:

- External combustion .
- Internal combustion .

External combustion type in which the working fluid is entirely separated from the fuel- air mixture (ECE), and the internal combustion (ICE) type, in which the working fluid consists of the products of combustion of the fuel- air mixture itself.

Chemical energy of the fuel is first converted to thermal energy by means of combustion or oxidation with air inside the engine. This thermal energy raises the temperature and pressure of the gases within the engine and the high-pressure gas then expands against the mechanical mechanisms of the engine. This expansion is converted by the mechanical linkages of the engine to a rotating crankshaft, which is the output of the engine. The crankshaft, in turn, is connected to a transmission and/or power train to transmit the rotating mechanical energy to the desired final use. For engines this will often be the propulsion of a vehicle (i.e., automobile, truck, locomotive, marine vessel, or airplane).

Most internal combustion engines are reciprocating engine shaving pistons that reciprocate back and forth in cylinders internally within the engine.

The objective of this study is to examine of the some of the dominant effective parameters in combustion on performance of air standard Otto cycle.

2. Air-standard Otto cycle:

The Otto cycle is the ideal cycle for spark ignition, reciprocating engines. The thermodynamic analysis of four-stork cycle can be simplified if the air standard assumptions are used. The Otto cycle consists of four internally reversible processes as shown in figure (1).

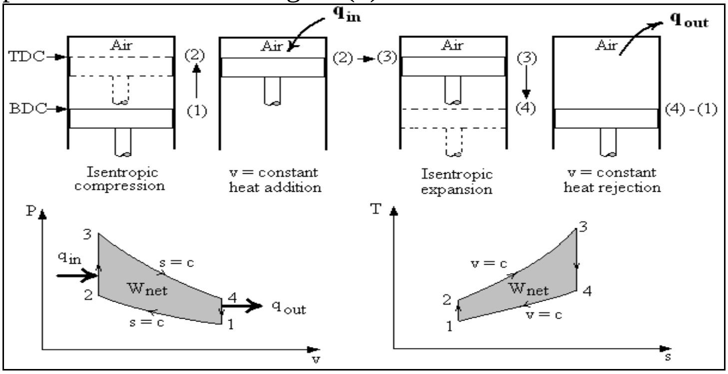

Figure (1) Otto cycle and P-v, T-s diagrams

The Otto cycle is executed in a closed system and the change of kinetic and potential energies are disregarded. The energy balance for any of the processes is expressed in a unit mass basis as,

- Process 1→2, isentropic compression

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1} \rightarrow (1)$$

$$r = \frac{V_1}{V_2} \rightarrow (2)$$

Where: T is the temperature (°K).
k is the specific heat ratio.
V is the volume (m3).
R is the compression ratio.

$$\therefore \frac{T_2}{T_1} = r^{(k-1)} \rightarrow (3)$$

- Process 2→3, constant volume heat addition,

$$V_2 = V_3,$$

$$Q_{in} = \dot{m}_t . c_v (T_3 - T_2) \rightarrow (4)$$

Where: Q_{in} is the inlet energy (W).

$\dot{m}_t$ is the total mass flow rate (kg/sec).

c_v is the specific heat volume (kJ/kg.°K).

When the total energy of the fuel is utilized, the maximum cycle temperature reaches undesirably high levels with regard to structural integrity. Hence, engine designer intend to restrict the maximum cycle temperature, the total energy of the fuel per second input into the engine can be given by :

$$Q_{fuel} = \eta_c . \dot{m}_f . Q_{LHV} \quad \rightarrow (5)$$

Where: η_c is combustion efficiency.

$\dot{m}_f$ is fuel mass flow rate (kg/sec).

Q_{LHV} is lower heating value of fuel (kJ/kg).

Assumed to be the heat add to working fluid:

$$Q_{fuel} = Q_{in} \quad \rightarrow (6)$$

The relation between $\dot{m}_f$ and $\dot{m}_t$ is defined as :

$$\dot{m}_t = \dot{m}_f \left(1 + \frac{(m_a / m_f)_s}{\emptyset} \right) \rightarrow (7)$$

The relation between combustion efficiency and equivalence ratio is :

$$\eta_c = \eta_{c,max} \left(-1.6082 + \frac{4.6509}{\emptyset} - \frac{2.0764}{\emptyset^2} \right) \rightarrow (8)$$

Where: $\emptyset$ is equivalence ratio.

$\frac{m_a}{m_f}$ is the air fuel ratio.

And the subscript (S) denotes stoichiometric conditions.

- Process 3→4, isentropic expansion,

$$\dot{m}_t = \dot{m}_f \left(1 + \frac{(m_a/m_f)_s}{\emptyset}\right) \rightarrow (7)$$

$$r = \frac{V_1}{V_2} = \frac{V_4}{V_3} \rightarrow (10)$$

$$\therefore \frac{T_3}{T_4} = r^{(k-1)} \rightarrow \quad (11)$$

- Process 4→1, constant volume heat rejection, ,

$$V_4 = V_1$$

$$Q_{out} = \dot{m}_t c_v (T_4 - T_1) \rightarrow (12)$$

Where: Q_{out} is outlet energy (W).

Otto cycle net work done or power is,

$$P_{otto} = Q_{in} - Q_{out} \rightarrow \quad (13)$$

Where: P_{otto} is power of Otto cycle (W).

The thermal efficiency of Otto cycle is,

$$\eta_{th,Otto} = \frac{P_{otto}}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}} = 1 - \frac{Q_{out}}{Q_{in}} \rightarrow (14)$$

$$\therefore \eta_{th,Otto} = 1 - \frac{T_4 - T_1}{T_3 - T_2} \rightarrow (15)$$

3.Constants and parameters used in the study:

The values of the constant and the parameters used in this study are summarized in table [1].

Table (1) constants and parameters used in the study [3], [7]

$\dot{m}_f$	0.001 kg/sec
R	0.287 kJ/kg .k
Q_{LHV}	45000 kJ/kg
$(m_a/m_f)_s$	14.5
T_1	300 K
r	1 – 100
η_c	80 - 100%
K	1.4 , 1.3 , 1.2
$\emptyset$	1, 0.6 ,1.3

4. Results and discussions :

The thermal efficiency and the power output of the Otto cycle are dependent on the combustion efficiency, specific heat ratio and equivalence ratio. In order to illustrate the effect of these parameters, the relations between the power output and the compression ratio and between the thermal efficiency and the compression ratio of the cycles are presented in following figures.

4.1 Effects of the combustion efficiency on the cycle performance :

The effect of the combustion efficiency on combustion temperature is as shown in figure (2), as is evident in the figure, the combustion temperature increases with increasing combustion efficiency.

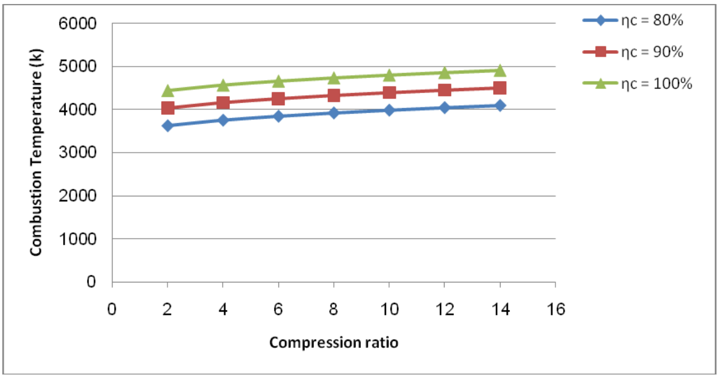

Figure (2) Effect of combustion efficiency on the variation of the combustion temperature with compression ratio.

Figures (3) and (4), show the effects of the combustion efficiency on the power output and the thermal efficiency of the cycle without heat resistance and friction losses. From figures (3), it can be seen that the combustion efficiency plays an important role on the power output of the Otto engine. They reflect the performance characteristics of an Otto cycle engine.

The variation of the power output with respect to the compression ratio and the combustion efficiency are indicated in figure (3). It can be concluded that, through the compression ratio range, the power output increase with the increasing combustion efficiency.

Therefore, it can be resulted that the effect of combustion efficiency on the power output of the cycle is related to compression ratio. It should be noted that the increase of the value of maximum power output with increasing combustion efficiency is due to the increase in the ratio of the heat added to the heat rejected.

In this case, when combustion efficiency increases by about 20%, the power output increase 20%.

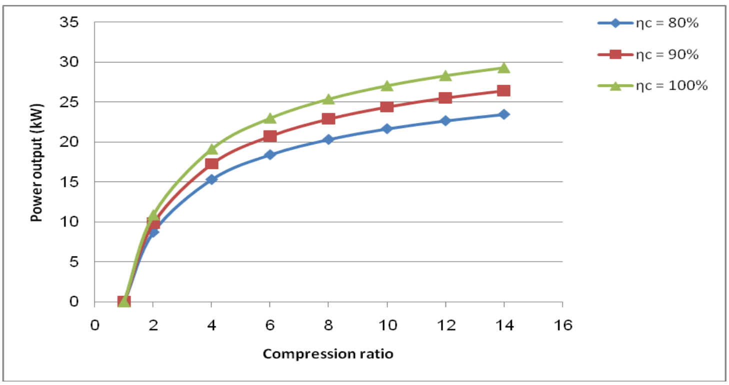

Figure (3) Effect of combustion efficiency on the variation of the power output with compression ratio.

Figure (4) shows the effect of combustion efficiency on thermal efficiency with respect to the compression ratio. It can be seen that the thermal efficiency increase with increasing compression ratio. The thermal efficiency is equal at all different combustion efficiency.

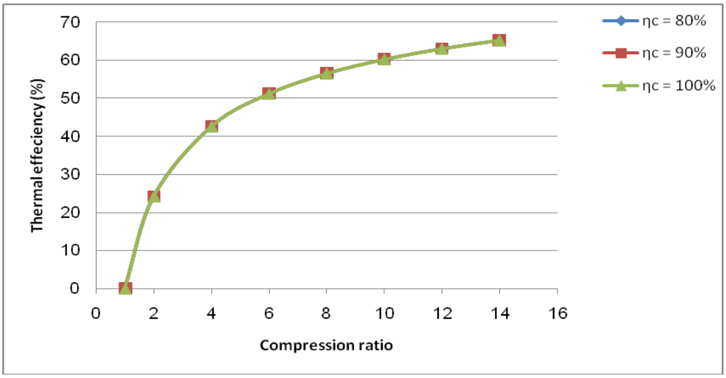

Figure (4) Effect of combustion efficiency on the variation of the thermal efficiency with compression ratio.

4-2 Effects of the specific heat ratio on the cycle performance :

The effect of the specific heat ratio on combustion temperature is as shown in figure (5), as is evident in figure, the combustion temperature increases with increasing specific heat ratio.

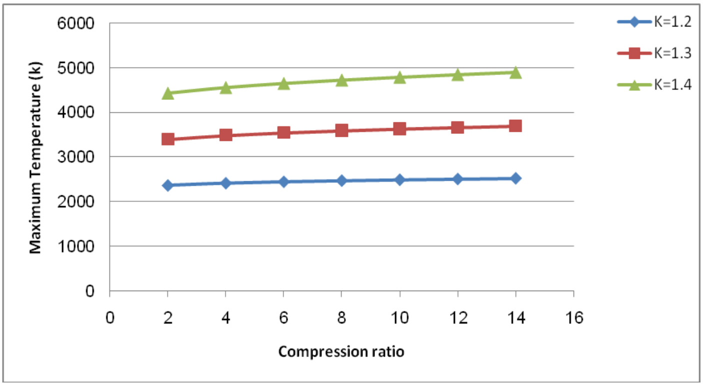

Figure (5) Effect of specific heat ratio on the variation of the combustion temperature with compression ratio.

Figures (6) and (7), show the effects of the specific heat ratio on the cycle performance without heat resistance and friction losses. From these figures, it can be found that the specific heat ratio plays an important role on the performance of the Otto engine. It is clearly seen that the effects of specific heat ratio on the performance of the cycle is related to compression ratio. They reflect the performance characteristics of an Otto cycle engine.

It can be concluded that, through the compression ratio range, the power output and thermal efficiency increase with the increasing specific heat ratio. This can be attributed to the fact that the difference between heat added and heat rejected increase with the increasing specific heat ratio. From these figures, it can be resulted that the power output and the thermal efficiency increase about 46.8% and 46.5% when specific heat ratio increases 14%.

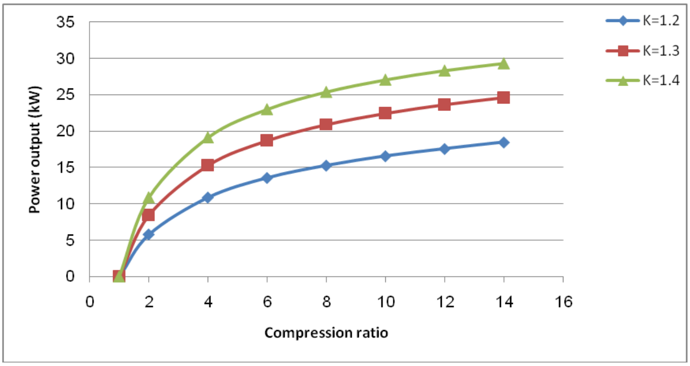

Figure (6) Effect of specific heat ratio on the variation of the power output with compression ratio.

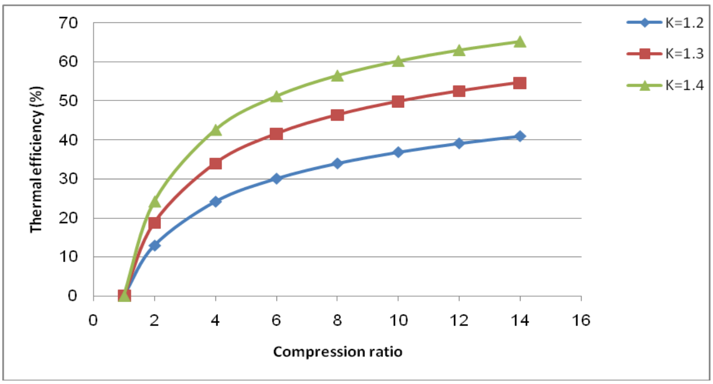

Figure (7) Effect of specific heat ratio on the variation of the thermal efficiency with compression ratio.

4-3 Effects of the equivalence ratio on the cycle performance :

The effect of the equivalence ratio on combustion temperature is as shown in figure (8), as is evident in figure, the combustion temperature increases with increasing equivalence ratio.

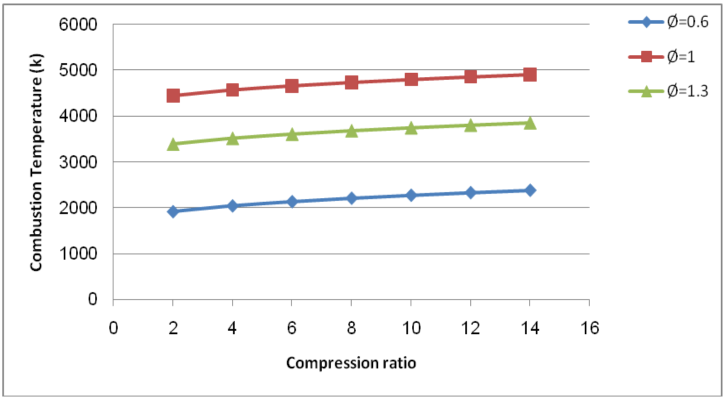

Figure (8) Effect of equivalence ratio on the variation of the combustion temperature with compression ratio.

Figures (9) and (10), show the effect of the equivalence ratio on the cycle performance without heat resistance and friction losses. From these figures, it can be found that the equivalence ratio plays an important role on the performance of the Otto engine. It is clearly seen that the effects of equivalence ratio on the performance of the cycle is related to compression ratio. They reflect the performance characteristics of an Otto cycle engine.

The power output and thermal efficiency increase with the increasing compression ratio. Figure (9) and figure (10) show that the power output and the thermal efficiency increase with increasing equivalence ratio up to about Ø=1 where they reach their peak value. This can be attributed to the fact that the ratio of the heat added by the working fluid increase with increasing equivalence ratio. With further increase in equivalence ratio, the

power output and the thermal efficiency start to decline as the equivalence ratio increases. It can be attributed to the decrease in the ratio of the heat added by the working fluid to the heat rejected by the working fluid. The calculations shows that for any same compression ratio, the smallest power output and the smallest thermal efficiency are for Ø=0.6 and the largest power output and the largest thermal efficiency are for Ø=1 when the equivalence ratio increases from Ø=0.6 to Ø=1.3.

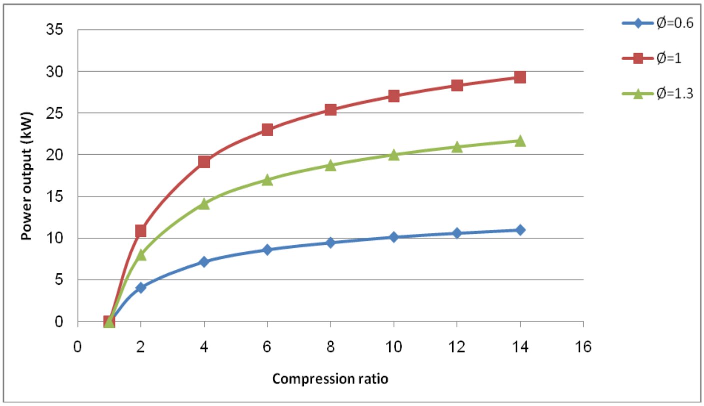

Figure (9) Effect of equivalence ratio on the variation of the power output with compression ratio.

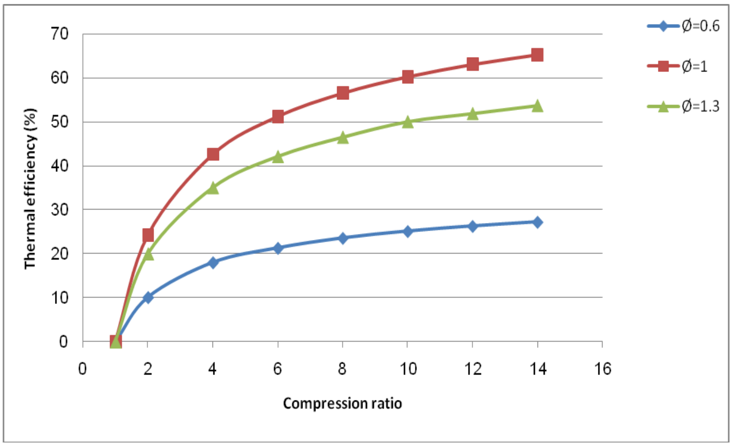

Figure (10) Effect of equivalence ratio on the variation of the thermal efficiency with compression ratio.

5.Conclusion :

This paper shows the outcome of an assessment study the effect of combustion efficiency, specific heat ratio and equivalence ratio on power output and thermal efficiency of an Otto engine cycle.

The general conclusions drawn from the results of this work are as follows:-

- Throughout the compression ratio range, the power output increase with increasing combustion efficiency, specific heat ratio, and equivalence ratio.
- Throughout the compression ratio range, the thermal efficiency increase with the increasing specific heat ratio and equivalence ratio.
- The thermal efficiency is equal at all different combustion efficiency.
- The power output and the thermal efficiency increase with increasing equivalence ratio up to about Ø =1 where they reach their peak value, and with further increase in equivalence ratio, the power output and the thermal efficiency start to decline as the equivalence ratio increases.

The results of this investigation are of importance when considering the design of actual Otto engines.

6. REFRENCS :

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