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Gas Turbine as Majors in Internal Combustion Engine

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***Abstract*— This paper discusses gas turbine used as a new or latest means of producing very large quantities of power in a self-contained and compact unit. Gas turbine serves as a means of producing very large quantities of power in a self-contained and compact unit. Gas turbine may have a further relationship with the oil engine that is why it is related to internal combustion engine. Majorly gas turbine is used in aviation and marine fields because they are independent and self-contained. Light weight and liquid cooling system are not required and it generously fit into the overall shape of the structure. Gas turbines are selected to power generation because of the mechanical efficiency and ability to meet rotational request in power generation to overcome power outrage.**

***Keywords*— Gas turbine in relation with internal combustion, source of rotational force in power generation**

INTRODUCTION

Gas turbine is versatile item of turbo machinery it can be used in several field of life for example power generation, aviation, marine field e.t.c. Various mechanical devices have been used to produce power for industry and society needs. Analysis on stream power plant shows that heat was added to the water and the water vapor expanded through a steam turbine, producing work. The thermal efficiency of a 500LMIN plant is about 40%. One case of the inefficiency is that an intermediate fluid, water is used to transfer the energy of the hot combustion gases to the steam turbine.

Gas turbine units overcome this by using the combustion gases directly in the turbine. A very important factor in gas-turbine selection is that gas turbine power plants are very compact and lightweight. The conventional steam power plant must occupy a far greater area and also much heavier.

Fig 1.1 Gas turbine

FUNDAMENTAL GAS TURBINE CYCLE

For a gas turbine to produce any work, in hot and low pressure. Therefore, the gases must first be compressed. If after the compression the fluid is expanded through the turbine, the power produced would be used equally by the compressor, provided that both the turbine and compressor functioned ideally. If heat is added to the fluid before it reached the turbine, raising the temperature then an increase in power output should be achieved.

Unfortunately this cannot occur, the turbine blades have a metallurgical thermal limit. If the gas enters continuously higher than the temperature, the combined thermal and material stresses on the blade will cause it to inefficiency and later fail.

Typically inlet temperatures of 1300k may be found on industrial turbines.

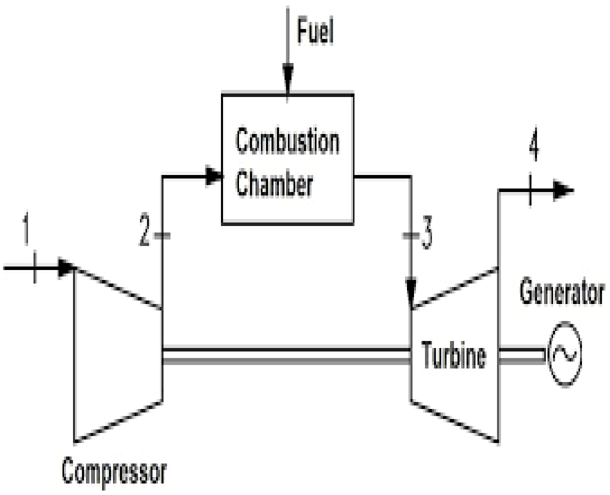

Fig 1.2 simple open gas turbine cycle

THE CYCLE ANALYSIS

The gas-turbine cycle may either be closed or open. The more common cycle is the open, in which atmospheric air is continuously drawn into the compressor, heat is added to the air by the combustion of fuel and the fluid expands through the turbine and exhausts to the atmosphere.

In the closed cycle, the heat must be added to the fluid in a nuclear power plant, and the fluid must be cooled after it leaves the turbine and before it enters the compressor.

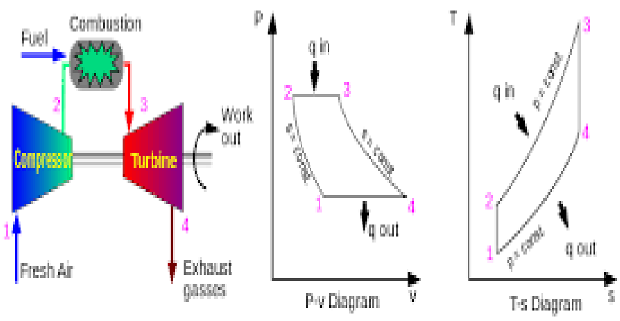

Fig 1.3 Brayton cycle

The air-standard Brayton cycle is the ideal closed system gas-turbine cycle. It is characteristized by constant pressure heat addition and heat rejection and is entropic compression and expansion processes.

Air is the working fluid and may be considered an ideal gas. The steady-flow constant pressure processed during which heat is transferred are no longer constant temperature processes and the ideal efficiency must therefore be appreciably less than the Carnot efficiency based upon the maximum and minimum temperature of the cycle.

Also, the negative compressor work, $C_p(T_1 - T_2)$ is an appreciable proportion of the positive expansion work $C_p(T_3 - T_4)$, so that the work ratio is considerably less than Rankine cycle and it is much more susceptible to irreversibility.

CALCULATIONS ON BARYTON CYCLE

The thermal efficiency η^{th} of the Brayton cycle may found as follows:

$$\eta^{th} = \frac{W_{net}}{Q_{in}} = \frac{EQ}{Q_{in}} = \frac{Q_1 - Q_2}{Q_1}$$

$$= 1 - \frac{Q_2}{Q_1}$$

$$Q_1 = m_{cp}(T_3 - T_2)$$

$$Q_2 = m_{cp}(T_4 - T_1)$$

$$\eta^{th} = 1 - \frac{T_4 - T_1}{T_3 - T_2} \qquad (1)$$

The pressure ratio, R_p is defined as:

$$r_p = \frac{p_2}{p_1}$$

And from isentropic expansion and compression processes, we find that

$$\frac{T_2}{T_1} = \frac{T_3}{T_4}$$

Therefore, $T_4 = \frac{T_3 T_1}{T_2}$ (2)

Substituting equation (2) into equation (1)

$$\eta^{th} = 1 - \frac{\frac{T_3 . T_1}{T_2} - \frac{T_1}{1}}{T_3 - T_2}$$

$$\eta^{th} = 1 - \frac{\frac{T_3.T_1 - T_1.T_2}{T_2}}{T_3 - T_2}$$

$$\eta^{th} = 1 - \frac{\frac{T_1(T_3 - T_2)}{T_2}}{T_3 - T_2}$$

$$\eta^{th} = \frac{1 - T_1(T_3 - T_2)}{T_2(T_3 - T_2)}$$

$$\eta^{th} = 1 - \frac{T_1}{T_2}$$

Relating the cycle temperature to the pressure ratio,

$$T_p = \frac{p_2}{p_1} = \frac{p_3}{p_4}$$

For isentropic compression and expansion,

$$\frac{T_2}{T_1} = \frac{P_2}{P_1} = r_p \frac{r-1}{n}$$

$$\frac{T_1}{T_2} = \frac{1}{r_p \frac{r-1}{n}}$$

$$\eta^{th} = 1 - \frac{1}{r_p \frac{r-1}{n}}$$

Thus, for the Brayton cycle the thermal efficiency is a function of the pressure ratio (r_p). The maximum temperature does have an effect on the optimum performance. If T_3 and T_1 are fixed, then there will be an optimum pressure ratio to produce a maximum amount of work, (W_{net}). The Variable temperature is T_2, the temperature of the fluid leaving the compressor.

W_{net}= (work output from Turbine) – (Work input to compressor):

Work output from turbine,

$$(h_3 - h_4) = C_p(T_3 - T_4)$$

Work input to compressor,

$$(h_2 - h_1) = C_p(T_2 - T_1)$$

$$W_{net} = C_p(T_3 - T_4) - C_p(T_2 - T_1)$$

But $T_4 = \frac{T_3.T_1}{T_2}$

$$W_{net} = C_p(T_3 - \frac{T_3.T_1}{T_2} - T_2 + T_1)$$

For W_{net} to be maximum the $\frac{dW_{net}}{dT_2} = 0$

$$dW_{net} = C_p(T_3 - \frac{T_3.T_1}{T_2} - T_2 + T_1)dT_2$$

$$C_p \frac{(T_3.T_1)}{(T_2)^2} - 1 = 0$$

$$\frac{T_3.T_1}{{T_2}^2} - 1 = 0$$

$$\frac{T_3.T_1}{{T_2}^2} = 1$$

$${T_2}^2 = T_3.T_1$$

$$T_2 = \sqrt{T_3.T_1}$$

Work ratio = $\frac{Net\ work}{Gross\ work}$

$$= \frac{C_p(T_3 - T_4) - C_p(T_2 - T_1)}{C_p(T_3 - T_4)}$$

$$= 1 - \frac{T_2 - T_1}{T_3 - T_4}$$

$$\frac{T_2}{T_1} = r_p^{\frac{r-1}{n}} = \frac{T_3}{T_4}$$

$$T_2 = T_1 {r_p}^{\frac{r-1}{r}}$$

$$T_4 = \frac{T_3}{{r_p}^{r-\frac{1}{r}}}$$

Hence, substituting

Work ratio = $\frac{{r_p}^{r-\frac{1}{r}} - 1}{T_3[1 - (\frac{1}{{r_p}^{r-1}})}$

RECOMMENDATION AND CONCLUSION

The use of gas turbine in smaller engine for power generation will be more efficient and cost less.

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