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The Practical Range of Expansion and Compression Ratios for an Atkinson Cycle Engine

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Abstract: The model and theoretical study on an internal combustion engine cycles are of great significance in enhancing the performance of the engine. The overall efficiency of the engine is an important output parameter which depends on a variety of factors under diverse conditions. Here in this paper a specific study is carried out on Atkinson engine. Some of the factors contributing to the performance of an Atkinson engine are its compression ratio, expansion ratio, calorific value of fuel and its ignition temperatures, ratio of specific heats of gas used etc… A special interest is given in this study to investigate and analyze how the efficiency parameters of the Atkinson engine vary its efficiency when the compression and expansion ratios are varied over an attainable practical range.

Keywords: Atkinson cycle, Performance parameters, compression ratio, expansion ratio, efficiency

I. INTRODUCTION

The Atkinson engine, named after James Atkinson (1846–1914) [1] is the most well-known of Atkinson's engines that is "Cycle 1887", patented in 1887 [2]. Atkinson cycle is an ideal cycle for Otto engine exhausting to a gas turbine [3] The Atkinson cycle engine plays a key role in the development of hybrid electronic vehicle (HEV) because of greater fuel economy than Otto cycle engine. [4] When a gas in a conventional four-stroke Otto engine is expanded, the exhaust gas pressure at valve opening is still three to five atmospheres and is bigger than the exhaust pressure. There is a loss in useful work that can be gained through power stroke because the exhaust valve decreases the pressure to atmosphere level. So, if we let the piston to expand to atmospheric pressure, the amount of work and thermal efficiency will be increased [5][6] Qin *et al.* [7] and Ge *et al.* [8] did a performance analysis of a general heat engine, including Atkinson cycle according to heat transfer loss and frictions losses and stated that Atkinson cycle is more efficient than Otto cycle [7,8].

II. STUDY OF ATKINSON CYCLE

The idealized Diesel cycles assumes an ideal gas and ignores combustion chemistry, exhaust and recharge procedures and simply follows four distinct processes. Air is assumed to behave as an ideal gas, and all processes are considered to be reversible.

1) 1→2: isentropic compression of the fluid
2) 2→3: reversible constant volume heating
3) 3→4: isentropic expansion
4) 4→1: reversible constant pressure cooling

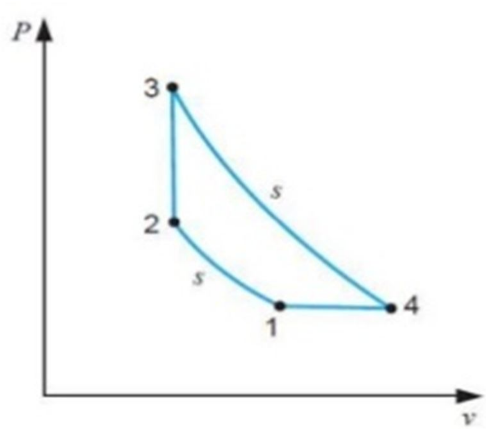

Figure 1

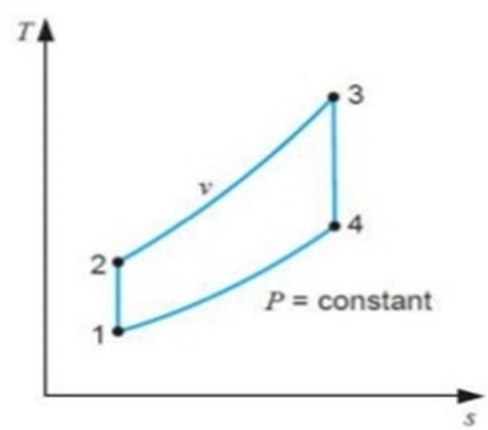

Figure 2

The compression ratio is the ratio between the volume of the cylinder and combustion chamber in an internal combustion engine at their maximum and minimum values. The expansion ratio is t ratio of the volume of a gas or vapor, such as steam in a thermal engine, after expansion to the volume before expansion began.. Atkinson wins over Otto engine in terms of efficiency because its expansion ratio is significantly larger than its compression ratio. It has a compression ratio of 8.00 to 1 and an expansion ratio of 10.0 to 1. The turbocharger provides air at 200. kPa and 40.0ºC when the intake valve closes. The air–fuel ratio is 15.0 to 1 and the fuel has a heating value of 43,300 kJ/kg [9] . the factors contributing to the performance of an Atkinson engine are its compression ratio, expansion ratio, calorific value of fuel and its ignition temperatures, ratio of specific heats of gas used etc… [10]

From figure 1,

Compression ratio, r = V_2/V_1

Expansion ratio, e= V_4/V_3

Efficiency,

$$\eta_{Atkinson} = 1 - \gamma\left(\frac{e-r}{e^{\gamma}-r^{\gamma}}\right)$$

Where k is ratio of specific heats, in this case for dry air k=1.4

The higher compression ratio results in higher in-cylinder pressure and higher heat release rate as well as lower ignition delay. The NO_x and CO_2 emissions increase because of higher compression ratio due to the higher pressure and temperature. The higher expansion ratio results in higher efficiency of Atkinson engine [11].

III. GRAPHICAL INSIGHT

The contour plots are drawn as shown in figure 2 taking expansion ratio on x-axis and compression ratio on y-axis and drawing z slices that is efficiency values as shown {0.1,0.2,0.3,0.4,0.5,0.5845}

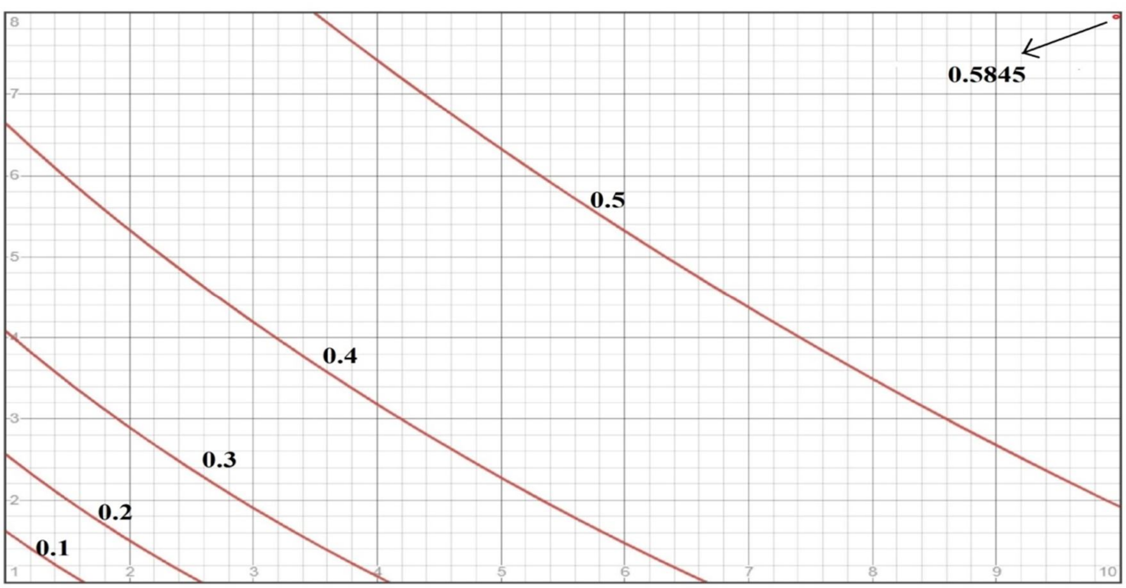

Figure 3

From the figure 3, from drawn graph the highest efficiency that can be obtained from these respective compressive and expansion ratios is around 58.45% but for that efficiency to be achieved high expansion ratios and high compression ratios are used which make cost of production high for high sustaining pressures and temperatures as well as release the pollutants in to the atmosphere.

IV. CONCLUSION

The compression and expansion ratios play crucial roles in determining the efficient and economical engines for production in practical usage. The practical range of efficiency is between 35% to 45% for which the compression ratio lies between 2.5 to 5 and expansion ratio lies between 5.5 to 8 and is economical and suitable. One can produce engines of high efficiency controlling the high pressures and high stresses but may not get commercial profit hence they can be sold as a job product only.

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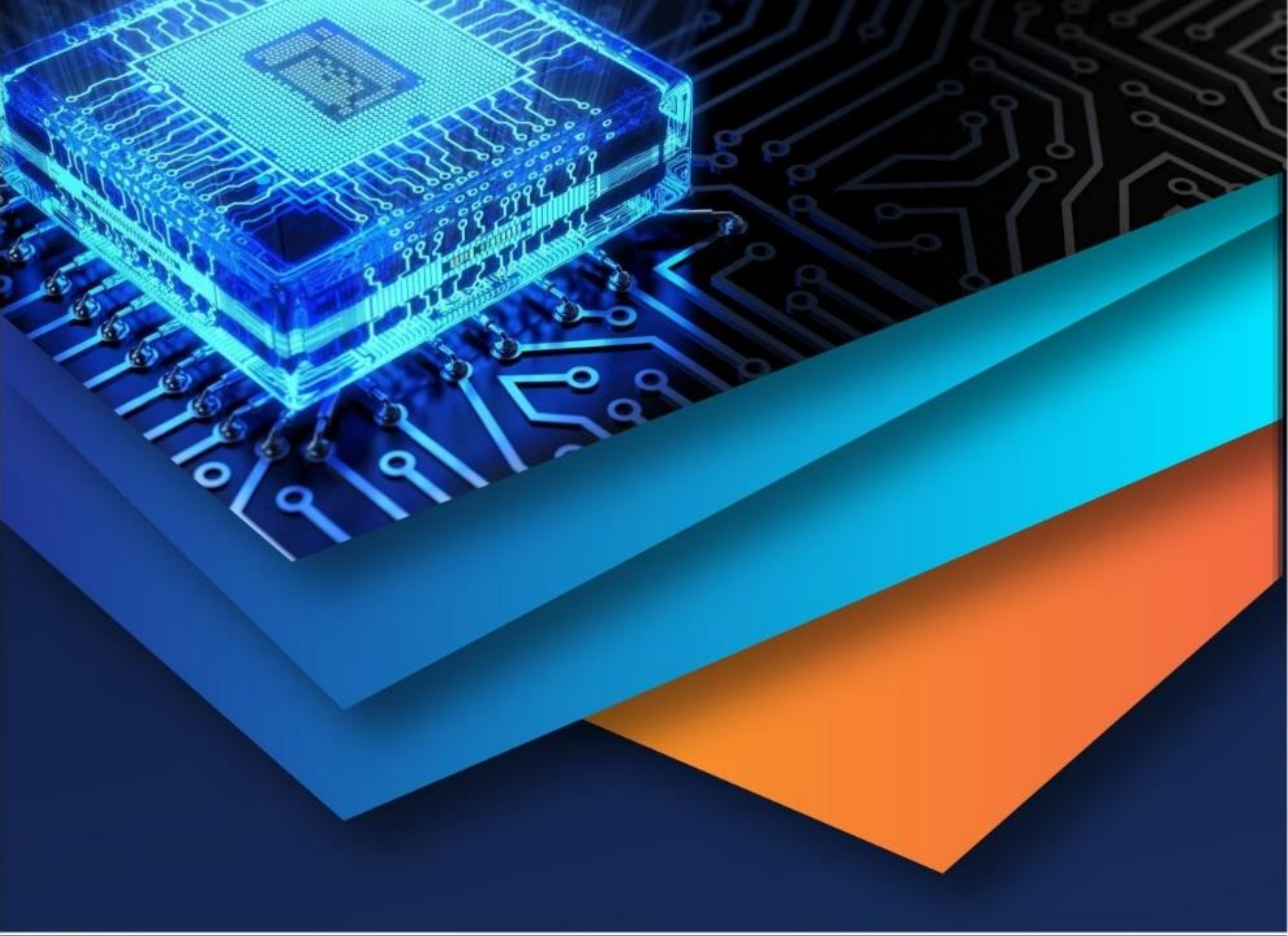

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