Journal of Advanced Mechanical Sciences (JAMS)
ISSN: 2583-3790 (Online)
"J. Adv. Mech. Sci., vol. 1, no. 2, pp. 36-40, April 2022"

Studies on Performance and Optimization Analysis in Otto Cycle- A Review

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Article received: 02/03/2022, Article Revised: 22/04/2022, Article Accepted: 26/04/2022
Doi:10.5281/zenodo.6490955

Abstract

Air standard Otto cycle is an ideal thermodynamic cycle employed in spark ignition engines. Since some assumptions are made, it deviates from the real air fuel cycles. There have been lots of researches and studies to help advance the Otto cycle and enhance its performance by considering different parameters. Here we try to discuss and give an overview related to the effects of several parameters like variable specific heat, heat loss from cylinder walls, regeneration with polytropic expansion, etc. on the working of an Otto cycle. In addition, a summary is provided in accordance to the performance analysis and optimization of Otto cycle.
Keywords: *Quantum Otto cycle, Endo reversible Otto cycle, Bose Otto cycle, Variable specific heat.*

1. INTRODUCTION

In the eighteenth century, steam engines as an external combustion engine were developed to ease the load on human beings. But due to its high operating and capital cost and large size, people looked for its alternatives. One such possible alternative was to substitute steam with air which allowed internal combustion to take place in the cylinder. Thereafter, Nicolaus Otto came up with such an engine in 1876. It had large practical applications in daily lives of human beings which attracted researchers for its performance analysis. The design and thermodynamic analysis of IC engines is generally done on the basis of air standard power cycles by researchers. But in actual conditions, the results deviate from the standard thermodynamic analysis as irreversibility and entropy generation are not included in the ideal cycle. However, the errors obtained are not that high. In ideal cycles, air is taken as the working fluid having non varying specific heats but variable specific heat is a significant factor which affects performance of the Otto cycle. There are no heat losses in an ideal cycle but in actual, heat deprivation does occur from the cylinder walls and because of friction in pistons. IC engines have wide range of applications like generation of power, agriculture, transportation, etc. and hence act as an extensive source of pollution. Adiabatic and polytrophic expansion can be utilized in a regenerative Otto cycle to reduce the NOx emissions. The performance and optimization analysis of a real cycle can be done using finite thermodynamic analysis which provides realistic results. New parameters like internal irreversibility and rate of exergy destruction can be defined to find optimal operating conditions of different objective and ecological functions. Effect of engine parameters can also be taken into account. At lower temperatures or high density, the working fluid deviates from the ideal gas behavior and obeys laws of quantum mechanics. Hence, the impact of quantum behaviors of the working fluid must be studied. Numerical methods can also be employed to find out optimal conditions for different parameters like efficiency and power output.

2. EARLIER STUDY OF OTTO CYCLES

Chen et al. [1] takes into account the irreversibility arising due to the non-isentropic processes in the cycle like expansion and compression and loss of heat from the walls of the cylinder. He found that expansion efficiency had a larger impact on the efficiency and power output and at an optimal value of compression ration they have a maximum value. The power output along with efficiency decreases with decrease in expansion and compression efficiency. Further, expressions of their dependence on parameters like working substance temperature, compression ratio and so on are derived. Chen et al. [2] scrutinized the out-turn of heat transfer from the engine walls on air standard Otto cycle with the help of a constant. He attained the relationship between the maximum power output and efficiency. Furthermore, Ge et al. [3] used finite-time thermodynamic modelling to analyze the functioning of the cycle due to frictional losses as a linear function of velocity of the piston. Also, the non-linear relationship linking specific heat and temperature of the operational fluid was taken into account. It is found from studies that inconstant specific heat of the active fluids, deprivation of heat from cylinder walls and friction plays a salient role in estimating the functioning of an Otto cycle. Lin et al. [4] looked into the functioning of an Otto cycle by limiting the maximum cycle temperature and found the effects of inconstant specific heat of operational fluid and friction and loss of heat as percentage of energy of the fuel. At peak power output, the efficiency surges with temperature. Abu-Nada et al. [5] studied the outcomes of inconstant specific heat on different engine parameters. The outlet temperature of the gas had notable effects. Variable specific heat had no effect on efficiency at low engine speeds and on brake means effective pressure. Higher engine speeds and F/A ratio produced higher thermal efficiency.

Chicurel [6] proposed an Otto cycle engine with some modifications to enhance the fuel economy. The suction and compression of air fuel mixture takes place in a separate compressor than the expansion unit and supercharging is included. The heat from exhaust gases is utilized by employing a regenerator. The power output is determined by the speed ratio of the transmission which drives the compressor. This leads to lower pumping and rubbing friction, lower compression work and F/A ratios for idling and low load operations. Garcia et al. [7] probed the outcome of a regenerative Otto cycle with Polytropic expansion as opposed to that of a traditional cycle with adiabatic expansion and regeneration. For a given range of pressure and temperature of combustion, the proposed cycle exceeded Carnot efficiency. CO2 and NOx emissions were reduced drastically. Wu et al. [8] improved the output response of an end reversible Otto cycle considering its mean effective pressure and power. Here, the heat addition and removal cycles are irreversible processes. The compression ratio is an increasing function of the apex temperature of the cycle. Higher thermal efficiency was found to be obtained by optimization of the network output. For a temperature limit, the optimum case has the same thermal efficiency as that of the cycle under consideration. Kodal et al. [9] analyzed the working of an irreversible Otto cycle considering new parameters like EPLOS and PLOS to compare different operating conditions and optimization functions. The effects of different parameters of engine like coefficient of friction, volumetric efficiency, maximum temperature, engine speed, etc. on the total performance are assessed. High power loss is found in maximum operating conditions but losses due to internal irreversibilities are less in the optimizing conditions.

Entransy analysis and entropy generation concepts were applied on a nano scaled irreversible Otto cycle by Ahmadi et al. [10] using Maxwell Boltzmann gas as the operational fluid. The efficiencies of expansion and compression process and the maximum and minimum temperatures were taken as decision parameters. Multi-objective optimization algorithms were applied to maximize or minimize the dimensionless ecological function. Eldhigidy [11] looked into the ideal outlet temperature of a solar collector to maximize the output work of an ideal regenerative cycle. Such heat engines can be employed in rural areas for running refrigeration units or irrigation purposes. He found that high thermal efficiency and power output can be achieved at lower compression ratios. Convection and radiation heat losses are reduced by using spectral selectivity and special coverings. Nie et al [12] established a nano scaled Otto cycle with friction loss and irreversibilities. Mechanical Casimir and quantum boundary effects of gases as working substance was considered for calculation of power output and efficiency using finite thermodynamic modelling. Ratios of efficiency and work output were used to analyze the outcome. Power output and efficiency were found to be independent of ratio of surface areas of both isochoric processes and dimensionless thermal wavelength. Numerical calculation was used to determine important optimal parameters. Quantum boundary effects are more significant in degenerate quantum gas system. Wang et al. [13] explored the outcome of heat transfer between the working fluid and engine walls and quantum degeneracy on the working of an Otto cycle with ideal fermi gas. Efficiency and power output become maximum at model values of the compression ratio. At higher temperatures, Fermi Otto Cycle realizes to be a traditional Otto cycle. Optimization conditions for different parameters like efficiency and compression ratio at weak and strong gas degeneracy were obtained. Wu et al. [14] investigated the outturn of quantum declension on the working of Otto cycle. Ideal Bose gas is taken as the active fluid and hence the name Bose otto cycle. Variation of the efficiency and power output ratios with temperature ratio is studied. At higher temperatures, their value becomes equal to unity. Cullen et al. [15] investigated the use of Stirling cycle in an Otto cycle as a waste heat recovery device. At a given fuel consumption rate, this resulted in the increase of brake power output. It was found that the combined cycle was able to create 30% more power as compared to that of an Otto cycle.

3. CONCLUSION

As a result, from the literature review discussed above the different areas that will be covered in this study are as follows:

- The ramifications of loss of heat from the cylinder walls, friction loss due to progress of piston and internal irreversibility on the operation of an orthodox Otto cycle were considered.
- The engine parameters are affected significantly by working substances with inconstant specific heats.
- Split cycle engines lead to reduced brake specific fuel consumption. Regeneration in an Otto cycle having expansion governed by polytrophic process helps to realize thermal efficiency higher than Carnot efficiency and reduced NOx emissions.

- Entropy generation and entransy concepts are also employed for performance evaluation.
- At very low temperatures, the quantum degeneracy of the operational fluid plays a predominant role in the efficient working of the cycle.

Acknowledgement/Funding Acknowledgement

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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