International Journal of Scientific Research & Engineering Trends
Volume 9, Issue 1, Jan-Feb-2023, ISSN (Online): 2395-566X

A Review on Design Optimisation and Structural Analysis Of Piston

M.Tech. Scholar Ajay Shrivas, Prof. Prakash Kumar Pandey
Department of Mechanical Engineering, VIT & S, Bhopal

Abstract- A piston seems to be a component of an engine. It is also the moving component housed within a cylinder & sealed using piston rings. A piston rod or connecting rod transfers force from expanding gas there in cylinder towards the crankshaft inside of an engine. As either a key component in an engine, the piston was subjected to cyclic gas pressure and inertial stresses during work, which can result in fatigue damage towards the piston, including such piston skirt wear, piston head or crown fractures, and so on. The largest stress develops on the upper end of a piston, according to the research, and stress concentration has been one of the primary causes of fatigue failure. A piston overheating seizure, on the other hand, can only happen if anything burns or scrapes off the oil coating that lies between the piston and the cylinder wall.

Keywords- Design, optimization, structural analysis, piston.

I. INTRODUCTION

Due to the general rising utilisation vehicles, automobile components seem to be in high demand these days. "The growing demand is attributable towards the components' greater performance and lower cost. To reduce the time it takes to release new goods, R&D and testing engineers must build crucial components as quickly as feasible. It needs a thorough grasp of emerging technology as well as rapid incorporation into product development. In reciprocating IC engines, a piston seems to be a component. That's also the moving part of a cylinder that's sealed by piston rings. With such an engine, the objective of a piston rod and/or connecting rod seems to be to transfer force from the expanding pressurized gas towards the crankshaft.

"The piston, as both a critical component of such an engine, were exposed to cyclic gas pressure or inertial pressures whereas at operation, which could also cause piston fatigue damage such as piston side wear, piston head/crown fractures, and so on. According to the data, the piston's upper end experiences the most stress, so stress concentration is one of the leading reasons of fatigue failure. FEA is frequently then used characterise the stress distribution on an internal combustion engine's piston. FEA is performed with the help of CAD and CAE software.

Its major goals are to explore and analyse the thermal and mechanical stress distribution of the piston throughout the combustion process in such an actual engine. The paper also explains how to use FEA to estimate the component's greater stress and critical area. The structural model of a piston is created utilizing CATIA software. Simulation and stress analysis were carried out using the ANSYS V14.5 programme.

II. PISTON

A piston seems to be a reciprocating component of thean engine that transfers chemical energy into mechanical energy following fuel combustion. A piston's job seems to be to transfer energy from the connecting rod towards the crankshaft. The piston ring is being used to seal both cylinder and piston together. It must have been able to function in low-friction environments, with high explosive forces, and at temperatures ranging from 2000°C to 2800°C.

The piston must be powerful yet light in weight to avoid inertia forces caused by reciprocating action.
A piston seems to be a disc or short cylinder that fits tightly into an engine cylinder and pushes up and down against a liquid or gas to generate motion inside of an internal combustion engine or to impart motion inside a pump. A piston can be found in reciprocating engines, reciprocating pumps, gas compressors, hydraulic cylinders, and pneumatic cylinders, among many other things. It really is the moving part that really is encased in some kind of a cylinder & sealed shut by piston rings. A purpose of a piston rod and/or connecting rod in such an engine is to transfer force from expanding cylinder towards the crankshaft.

The intake, compression, combustion, and exhaust processes take place just above piston inside the cylinder head of four-stroke vehicle engines (petrol and diesel engines), forcing the piston to rise or fall (or in and out in a flat engine). The crankshaft rotates because the pressure within in the cylinder. Its function is reversed in a pump, with force transferred from of the crankshaft towards the

piston to compress or discharge the fluid inside the cylinder. The piston can also operate as a valve in the some engines , covering or uncovering apertures in the cylinder.

III. PAST STUDIES

Engineers can use computer-aided engineering software to develop products and model them for residual pressure, structural reaction, thermal repercussions, pre-processing, and post-processing fatigue there at automobile component level. Both thermal flux and thermal temperature distribution were researched through studying many authors inside the field of thermal evaluation, and this examination can indeed be beneficial to those working in the area for steady state thermal assessment of pistons. The researcher's previous literature investigations are listed below:

Subbaiah, K. V. (2021) investigated Internal combustion engines (IC engines) were widely used nowadays across the world. Due to stringent pollution regulations, most engineers have already been looking towards improved engine architectures that emit the least amount of pollutants. A most essential design issues for the diesel-fueled CI engine are soot and NOx emissions. A right mixing of air and fuel content improves the performance of a combustion engine.The most common method for improving air–fuel mixing within a chamber cylinder is to modify the piston bowl shape. A few engineers have been working on different types of piston bowl shape and combustion chambers.

These really are intricate interactions formed in combustion chamber geometry of low-used diesel engines including such direct injection (DI) engines, and they cause late cycle mixing of spray-wall interactions. As a result of these interactions, the fuel efficiency of a piston bowl shape was changed, as was the emission behaviour. In just about any case, inaccurate cylinder measurements have an influence on the dependent mechanisms, as well as the resulting difficulties really aren't thoroughly investigated in relation to pistons and engines. Researchers used CFD to examine emissions in direct injection engines with varying piston bowl shape. In addition, i recommended future improvements to increase the performance of direct injection engines.

Subramani, N. (2021) The pressure and knocking phenomena were investigated. The butterworth bandpass filter was utilised to obtain the pressure readings, and the potential for knocking were determined utilizing peak-to-peak pressure values as well as the species concentration. One approach utilised to reduce the incidence of knocking inside the engine is cooled exhaust gas recirculation. Furthermore, the effects of premixed methanol and engine start-up (SOI) on knocking was investigated.

Viswanathan, V. K. (2021) The Hyperloop seems to be a high-speed land transportation idea that involves passengers moving in pods at transonic speeds inside a partly evacuated tube. It comprises of a low-pressure tube that travels the length with capsules moving at both low & fast speeds. When a high-speed system travels through with a low-pressure tube with such a limited diameter, like the Hyperloop does, it becomes an aerodynamically difficult challenge. The "piston effect" occurs when airflow becomes clogged in confined areas surrounding the pod, resulting in a high-pressure zone just at pod's front. There are very few papers that look at possible solutions for the piston effect. The aerodynamic performance of the a Hyperloop pod within a vacuum tube is investigated in this research utilising the Reynolds-Average Navier–Stokes (RANS) approach for three-dimensional computer analysis. Aerofoil-shaped fins also are added towards the aeroshell as both a possible technique to reduce the piston impact. These results reveal that adding fins to the pod reduces drag and eddy currents while also producing a positive lift.

Prasanna Raj Yadav, S. (2021) Did The largest stress acted here on upper region of both the piston, according to experimental research, and stress concentration also is the major cause of fatigue failure. The article explains how to increase the piston's ability to withstand significant structural and thermal loads while also reducing stress concentration in the piston's upper part.In same operating environment, an aluminium alloy piston can indeed be replaced with a carbon-carbon piston with minimal thermal stress. The thermal study of carbon-carbon composite material on a commercial vehicle diesel engine piston was investigated in this research, as well as the findings are compared to those of an aluminium alloy piston for maximum stress.

Y., & Zeng, S. (2021) The impact of squish on the piston bowl in such a single cylinder 4 S compression ignition engine fed by jojoba biodiesel on performance, emission, and combustion parameters seems to be the subject of this study. To optimise performance, emission, or combustion characteristics, the squish area as well as its related velocity were adjusted via modifying the piston bowl cross-section without affecting the piston bowl volume. For the typical piston, CFD (Computational Fluid Dynamics) is used to investigate the velocity or squish impacts.

The results were compared with those obtained with a modified piston inside the piston combustion chamber that has an octagonal bowl shape. Specific fuel consumption, brake thermal efficiency, and brake pressure vs. crank angle and heat release rate are one of the performance and emission aspects investigated. Emission characteristics such as carbon monoxide, HC (hydrocarbons), and NOx (nitrogen oxides) were also monitored at the exhaust pipe's tail end. One goal of this study would be to improve

combustion chamber geometries utilising an octagonal bowl combustion chamber and compare results to a typical hemispherical combustion chamber. The octagonal piston bowl has a considerable boost in braking thermal efficiency. When comparing the regular piston with octagonal bowl piston, there is a reduction in HC and CO.

Lin, M., & Hong, G. (2020)A two-dimensional axisymmetric CFD model is built to explore the operating mechanism of a beta-type free piston Stirling engine. Experiments are then used to verify the model's dependability. The model may be used to determine the periodic fluctuation of the temperature field and flow field in the expansion and compression chambers. The velocity of a gas parcel through a heat exchanger may be traced using a post-processing approach that converts the Euler method to the Lagrange method.According to the findings, each gas parcel in the oscillating flow has a unique thermodynamic process which differs from of the typical thermodynamic cycle. The p-v work of parcels grows even as temperature gradient of both the gas parcel rises and also the capacity to pump heat rises as the distance between both the appropriate gas parcel as well as the hot end decreases. In that the thermodynamic process of a gas parcel was comparable to that of a micro-generator, the regenerator is indeed the key functioning component of heat exchangers.

Yuan, C. (2020) Because of gas exchange, piston motion, the combustion of both the free piston linear engine (FPLE) are all intimately related, variations in gas exchange may easily cause an engine to operate unsteadily. The paper presents a simulation that examines the impact of combustion variation on an FPLE's gas exchange stability. For FPLE, a full-cycle zero-dimensional dynamic model and a geometric model were generated independently, while a piston motion profile and the geometric model are used to perform a linked three-dimensional combustion and gas exchange. Following that, the impact of combustion variation (such as ignition location and combustion time) on FPLE gas exchange stability is investigated & addressed.

It is established that variations in combustion have a major impact on piston motion and gas exchange starting conditions, leading in changes on gas exchange stability. FPLE may achieve a greater piston travel distance thanks to the delayed ignition and extended combustion duration, to provide a sufficient intake duration for the gas exchange process, leading to an increase throughout intake flow mass and fresh charge inside the cylinder, improving the scavenging effectiveness to 96.82 percent at the very most, and promoting the reduction of residual exhaust pressurized gas, and yet inevitably lowering the trapping effectiveness to 44.06 %.

IV.CONCLUSION

Since of their superior mechanical and thermal capabilities, lightweight constructions, environmental and other desirable qualities, Al–Si based alloys have been widely employed in automobile piston and other thermal applications, as per a survey of literature by various authors. However, basic Al-Si alloys are unsuitable for making automobile pistons and it may not meet the fundamental criteria of both the piston. It caused a variety of unwelcome stresses in components during the manufacturing process. Catalytic converter life can indeed be extended through regulating the temperature of the exhaust stream. Heat transmission with in exhaust system has a direct effect on the internal combustion engine's operations and discharge characteristics. Controlling the temperature inside the automobile exhaust system is crucial for improving an engine's performance.In order to quantify the temperature effect and heat transfer towards the engine piston crown, it was determined that even a space and temporal averaged combustion side boundary scenario is most advantageous and appropriate treatment approach within engineering approximations.

REFERENCES

[1] Varma, P. S. P., &Subbaiah, K. V. (2021). A review on thermal and CFD analysis of 3 different piston bowl geometry's. Materials Today: Proceedings, 37, 2341-2345.
[2] Gaikwad, P. U., Gnanamani, S., &Subramani, N. (2021). Experimental and numerical simulation of the piston engine fueled with alternative fuel blends: CFD approach. Aircraft Engineering and Aerospace Technology.
[3] Bose, A., & Viswanathan, V. K. (2021). Mitigating the Piston Effect in High-Speed Hyperloop Transportation: A Study on the Use of Aerofoils. Energies, 14(2), 464.
[4] Joel, C., Anand, S., Padmanabhan, S., &Prasanna Raj Yadav, S. (2021). Thermal analysis of carbon-carbon piston for commercial vehicle diesel engine using CAE tool. International Journal of Ambient Energy, 42(2), 163-167.
[5] Li, J., Yuan, C., He, Y., & Zeng, S. (2021). A multi process coupled gas exchange model of free piston power system for scavenging control applications. Applied Thermal Engineering, 194, 117101.
[6] Chi, C., Mou, J., Lin, M., & Hong, G. (2020). CFD simulation and investigation on the operating mechanism of a beta-type free piston Stirling engine. Applied Thermal Engineering, 166, 114751.
[7] Yuan, C., Jing, Y., & He, Y. (2020). Coupled dynamic effect of combustion variation on gas exchange stability of a free piston linear engine. Applied Thermal Engineering, 173, 115201.
[8] Zhang, Q., Xu, Z., Liu, S., & Liu, L. (2020). Effects of Injector Spray Angle on Performance of an

Opposed-Piston Free-Piston Engine. Energies, 13(14), 3735.

[9] Sankar, V., Thampi, B. G., &Panicker, M. R. (2020, December). Optimization of thermal barrier coatings in a single cylinder diesel engine using thermal analysis and genetic algorithm. In Journal of Physics: Conference Series (Vol. 1706, No. 1, p. 012192). IOP Publishing.

[10] Rahman, M. A., Chander, P. R., & Prasad, M. Modeling and Analysis of Piston using Various Piston Crown Geometries.