ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 5, Special Issue 1, February 2024

Case Study of Internal Combustion Engine Design and Simulation for Future High Speed LMV

Tarun Kumar Yadav[1], Gaurav Khare[2], Hemant Jain[3], Dr. Veeresh Fuskele[4]
[1,2,3]Assistant Professor, Babulal Tarabai Institute of Research and Technology, Sagar
[4]Professor, Babulal Tarabai Institute of Research and Technology, Sagar

Abstract: The article aims to evaluate the performance of the Internal Combustion (IC) Engine under the consideration of RPM variation for light motor vehicles (LMV). This paper presents various applications and the overview of the types of strokes in the IC engines. Then finally the impact of the RPM variation on the velocity, displacement of the piston and the PV curve of the IC engine operation for the single cylinder operation is considered in this paper. The evaluation is carried out corresponding to the different Crancks angles. This paper has preseted simulation case study using the MATLAB based code. The constant gamma and variable gamma constant considered for the simulation of the pressure and volume analysis. The variation of the Gamma is evaluated for the combustion, compression and the expansion cycle and the variation in temperature is monitored. Over all paper preseted the concluding impact of RPM variant on IC engine design.

Keywords: **Internal Combustion Engine, LMV, Stroke, RPM, Gamma, Applications PV curve, Piston Velocity, Piston Displacement,, Fuel Efficiency.**

I. INTRODUCTION

All across the world, internal combustion (IC) engines is frequently employed in a variety of applications. Small utility leisure, agricultural, construction, light-duty cars, heavy-duty vehicles, maritime, and electric energy production are all applications for IC engines. As an illustration, it is projected that by 2035, there will be more than 2 billion automobiles and the engines that power them worldwide. These are extraordinary numbers for a device of this complexity. Application areas of the IC engines are vast but frequent ones are shown in Figure 1.

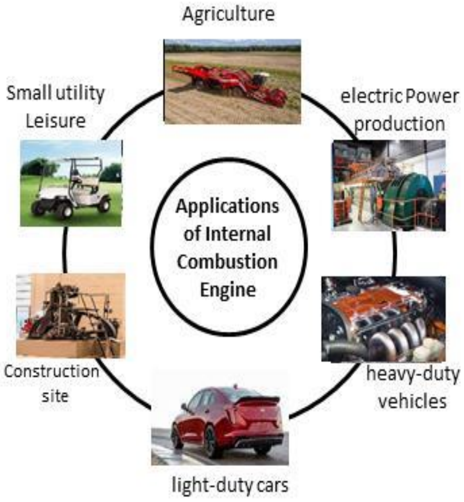

Fig. 1 Applications of IC engines

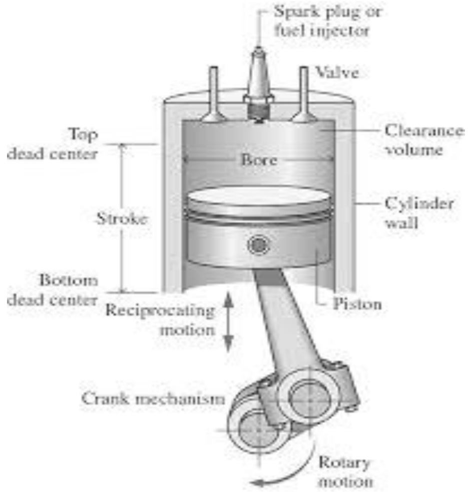

Fig. 2 various parts of the Internal Combustion Engine

The various basic elements of the IC engine design are shown in the Figure 2. The 4-stroke engine is a relatively efficient engine. It can convert up to 35% of the energy in the fuel into power. However, it is also a relatively complex engine. It has more moving parts than a 2-stroke engine, which makes it more expensive to manufacture and maintain. The 4-stroke engine is also a cleaner engine than a 2-stroke engine. It produces fewer emissions, which is why it is more commonly used in cars and trucks.

II. TYPES OF ENGINE STROKES

A 4- A gasoline or diesel engine known as a stroke engine generates power by going through four strokes, or cycles. There are four strokes:

Intake stroke: As the engine's piston descends in the cylinder, in order a void is created, drawing air and fuel into the engine:

Compression stroke: The combination of air and fuel is compressed as the piston rises in the combustion chamber.

Power stroke: The air and fuel combination is ignited by the spark from the plug, which causes it to erupt and push the combustion chamber downward.

Exhaust stroke: The gases that leave the engine are forced out of the cylinder when the piston's pressure rises. Engines with four strokes come in a variety of designs. Whichever is the application, a 4-stroke engine's architecture can change. A mower's cylinder will be built differently than a car engine, for instance.

The kind of fuel an engine utilises also has an impact on how it is built. A diesel engine won't be built similarly to a

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 5, Special Issue 1, February 2024

petrol engine. A well-established technology is the 4-stroke engine. It has been in use for more than a century and continues to be the most popular type of engine with internal combustion. The 4-stroke engine's architecture can still be improved in a variety of ways, though.

Here are some suggestions for enhancing the 4-stroke engine's style:

Minimise friction: The 4-stroke engine's biggest cause of inefficiency is friction. Here are several strategies for lowering friction, including the use of coverings and low-friction components.

Increase combust productivity: By utilising more cutting-edge technology, such as the use of direct injection and adjustable valve timing, the process of combustion in the engine with four strokes can be improved.

Reduce emissions: By employing less polluting fuels and more effective burning technology, pollution from 4-stroke engines can be decreased.

Although the four-stroke engine is an established technology, here are still lots of opportunities to enhance its design. The 4-stroke motor will get even more effective and greener as these enhancements are implemented.

A. Intake Stroke Significance

In the case of a four-stroke engine, the stroke that starts the engine is the primary stroke. When the piston descends in the cylinder, a vacuum is created and an amalgam of air and gasoline is drawn into the engine. The next steps involve compressing, lighting, and exhausting the air-fuel combination during the compression stage, power, and exhaust strokes. Although it is the initial stage of burning, the induction stroke is important. What will ultimately be burned and used for powering the engine is the combination of fuel and air that is pulled into the combustion chamber. The engine will run more efficiently depending on the intake pulse.

The effectiveness of the stroke used for intake can be impacted by a few different factors. The entrance manifold's design is the first. The component of the engine's combustion chamber that sends the combination of air and fuel to the cylinders is the intake funnel. The distribution of the air-fuel combination inside the combustion chamber will be improved with a designed effectively entrance tract.

The overall shape of the gates is an additional factor that may have an impact on the effectiveness of the intake stroke. The components of the motor that regulate the passage of both fuel and air from the inside to the outside of the cylinder are called valves. The combination of air and fuel will be pulled into the combustion chamber quietly and efficiently if the openings are attractive. The state of the engine can also have an impact on how effectively the intake stroke works. The ability of the engine to pull in the mixture of air and fuel will be reduced if it is unclean or worn. In order to keep the engine in good shape and maximise the effectiveness of the induction stroke, it is crucial to frequently repair the motor.

B. Compression Stroke Significance

The subsequent stroke in an engine with four cylinders is the one for compression. The combination of air and fuel that was pulled in throughout the intake process is compressed at this point by the piston rising in the cylinder. The air-fuel mixture now has a higher pressure and humidity, which improves the likelihood that it, will ignite whenever the ignition source fires. The stroke that causes compression is important since it helps the engine run more efficiently. The pressurised air-fuel combination grows increasingly combustible.

This can increase fuel efficiency because less fuel is required to provide the same quantity of power. The total volume of the chamber while the crankshaft is at the bottom pf the stroke's length divided by the amount of space of the chamber while the mercury is at the very top of the stroke is known as the percentage of compression. The amount of compression of the air-fuel combination increases with the proportion of compression. Higher compression ratios might, however, also increase the engine's susceptibility to knocking, an unregulated explosion that can harm the engine's components.

A few factors can have an impact on the length of the stroke of compression. One piston's construction is the first. To lessen the chance of the air-fuel combination adhering to the piston, it should be smooth. A strong seal around the piston is also necessary to keep air from seeping past it. The overall shape of the cylinder is another element that may have an impact on the length of the stroke of compression. The cylinder ought to be flawless and devoid of any flaws that could lead to a combination of air and fuel leaking past the stroke of the piston.

To guarantee that the combination of air and fuel has been compressed to the right level, the cylinder must be of the proper size. The state of the engine might also have an impact on the length of the compression stroke. The combination of air and fuel will not be compressed as effectively if the combustion system is filthy or worn. To keep the engine is good shape and maximise the effectiveness of the stroke that produces compression, it is crucial to frequently repair its condition.

B. Improvements

Here are some suggestions for enhancing the performance of the four strokes:

Use a good air filter because a dirty one can hinder airflow entering the engine's combustion chamber, which can harm the effectiveness of the entrance stroke. Use high-performance entrance manifolds to enhance air flow into the engine's combustion chamber, which will also increase the effectiveness of the entrance cycle.

To verify that the gates are open and shut correctly, they must be modified to the required height. This will facilitate the effective and smooth entry of the mixture of air and fuel into the cylinder's combustion chamber. In order to increase the effectiveness of the stroke used for intake, the engine should be cleaned because a dirty engine might hinder the flow of fuel and air. To get rid of any possible dirt or debris, the engine needs to be cleaned frequently.

You may increase the 4 stroke's effectiveness and make your engine run with greater ease and effectiveness by using these recommendations.

III. RELATED WORK

There have been lot of research carried out for IC engine design in past. This section review some of relevant works referred in the paper. According to Alsuwian et al. [1], process plant technology may be employed to reduce severe production losses caused by irregular unplanned equipment tripping. In their study, they suggested a sort of IC engine hybrid fault-tolerant control system that combines an active fault-tolerant management system and an inactive fault-tolerant control framework. The active component was created using the fault identification and separation unit based on genetic algorithms. If any sensor fails, this genetic algorithm transmits anticipated values to the engine control system. S. Studener et al. [2] created a conceptual air intake model for a four-stroke IC engine based on the fundamentals of mass conservation and energy conservation. The whole valve activation is taken into account: The opening angles of the intake and exhaust valves, as well as the adjustable valve lift, are considered plant inputs that can be changed to boost air intake rate and, thus, engine production. The model must be validated for a formal relationship to be made between the angle of the crank resolved physical model and modern facilities mean value theories.

S. Studener et al. [2] developed a conceptual air intake model for a four-stroke IC engine based on mass and energy conservation principles. The entire valve activation is considered: The intake and exhaust valve opening angles, as well as the adjustable valve lift, are considered plant inputs that can be modified to increase air intake rate and, hence, engine production. For a formal relationship to be established between the angle of the crank resolved physical model and modern facilities mean value theories, the model must be validated. The emphasis of Charles Fayette Taylor et al [4] was on fuel efficiency. All of the statutory constraints on air pollution have resulted in advancements and modifications in engine construction and management, which have been incorporated into this revised edition of Taylor's classic treatise on internal combustion engines. The emphasis on complete tests of air ability, wear and tear, heat transfer, including the effects of cylinder size, as opposed to just descriptive examinations of real combustion cycles, has all been preserved.

Huang et al [5] uses an immediate motion similarity approach to develop a general formula for the non-constant drag of engines flywheel assembly. They established equations for dynamics of a multi-cylinder flywheel component considering nonlinear elements such as the torsional resonance of shaft sections with reciprocating components' non-constant inertia. They adopted eigenvector approach to study inherent resonance and mode configurations of a crank assembly. The integral approach is used to study the compelled vibration behavior of an engine's shaft assembly while handling non-constant inertia.

Chinujinim G Thomas et al [6] preseted the fuel based performance assessment of IC engines, including spark and ignition with compression motors. There studies looked at the efficiency of spark and compression-ignition and kind of fuel utilized in engine. Additionally, they found that engines with spark ignition are more affordable, quieter, and create more speed. Yet, the study advised using petrol with the injector to increase its speed and that they should be properly installed on the bench to prevent vibration and noise. Duque Amaya et al [8] created a mathematical model of the emissions from the Twingo D7F engine. Under pollutant emission conditions, the effects of adjustments in fuel/air equivalency ratio, compression ratio, combustion duration and spark advance, were evaluated.

Mahdisoozani et al [7] study engine vibrates throughout this energy conversion process due to a number of factors, which severely reduces the engine's efficiency and lifespan. The goal of the current study is to compile all recent efforts made to isolate and lessen engine vibration before it spreads to other car components like the drive shaft and chassis. The ICEs' history and the characteristics related to their vibration will be discussed in order to serve this objective. The paper's main body is broken into three sections: The vibration-based theory in ICE defect detection is first briefly summarized. The use of various techniques and engine upgrades to reduce vibration is then discussed.

Ge, Y.; Chen et al [8] work analyses the design of FTT optimization for ICE cycles from the four perspectives listed below: studies on the best operating characteristics of air standard irreversible (with only heat resistance being irreversible) and reversible the Immigration and Customs cycles, such as Otto, Diesel, who Atkinson's Brayton, Dual, Miller, It Medium, and omnipresent cycles with unchanged specific heats, parameter specific heats, and parameter specific ratios of the traditional and period working fluids (WFs); examines on the effectiveness limits of ICE cycles with inconsistent WF with a Newtonian and other thermal transfer laws; studies on the achievement simulation of ICE cycles; and investigations on the optimum piston motion (OPM) paths of ICE cycles, such as Otto and Diesel, also known as cycles with the Newtonian and other warmth transfer laws.

Abdullah Jamil et al Various engine layouts and combinations have been created in recent years in an effort to increase the thermal and fuel efficiency of internal combustion engines. The geometrical characteristics of combustion chambers and engine topologies and their impact on in-cylinder air/fuel combining turbulent conditions, and combustibility of fuel have grown more and more important due to the field's continual advancement. As a result, a critical evaluation of the present in-cylinder flow analysis methodologies, their use with various engine types and the study's findings is urgently required.

Pisnoy et al have proposed to design ignition and gas-exchange operations in the Wankel engine were simulated numerically using three-dimensional fluid mechanics and chemistry. This technique was created and approved. The placement of an additional plug in the operational room, in place of the two currently mounted plugs on the front face of the base engine, and the creation of a slot on the back side of the rotational recess were also investigated as methods of improving performance.

Balaji Mohan et al [13] used machine learning-based optimization framework for gasoline-powered applications is presented in this paper. A Super Learner method, a group of multiple base learners augmented by optimizations techniques, and a method of active learning are all included in this system. By employing an elitist-based evolutionary algorithm to optimize the hyper-parameters, the efficiency of the Super Learner model was increased. In this study, a smaller dataset pertaining to a heavy-duty petrol compression ignition engine of size 64 that was randomly selected from the existing dataset will be used to show the framework.

IV. PROPOSED SIMULATION METHODOLOGY

In this paper the simulation of the IC engine is carried out in MATLAB and to evaluate the impact of higher RPM requirement of design. It is required to calculate the piston velocity, and displacement. The variable RPM is considered for impact analysis in the work. The mass fraction of the consumed fuel as an estimate of crank angle is required, or the instance of the cycle simulation employed here. This is provided for this task by a Wiebe function.

$xb=1-\exp(-aym+1)$ (1)

When xb represents the mass percentage of fuel consumed, an as well as m are constants in nature, where the burn curve is chosen to be acceptable. According to Heywood, a = 5.0 and m = 2.0 for this job. Y stands for the non-dimensional advance variable in this equation.

$y=(\theta-\theta o) / \theta b$ (2)

Where θ is the immediate crank angle, θo is the ignition, and θb is the length of the combustion

Mean Speed of Piston (fpm)=(Stroke * 2 * RPM) / 12 (3)

It can be observed from the Figure 2 that during one crankshaft revolution, a piston's velocity fluctuates constantly as it travels from top dead centre (TDC) to bottom dead centre (BDC) and back to TDC.

It is observed that the velocity peak is increased with the increase initial RPM value. The RPM is varied to 1000, 1200 and 1500 range for the performance evaluation and simulation as shown in the Table 1.

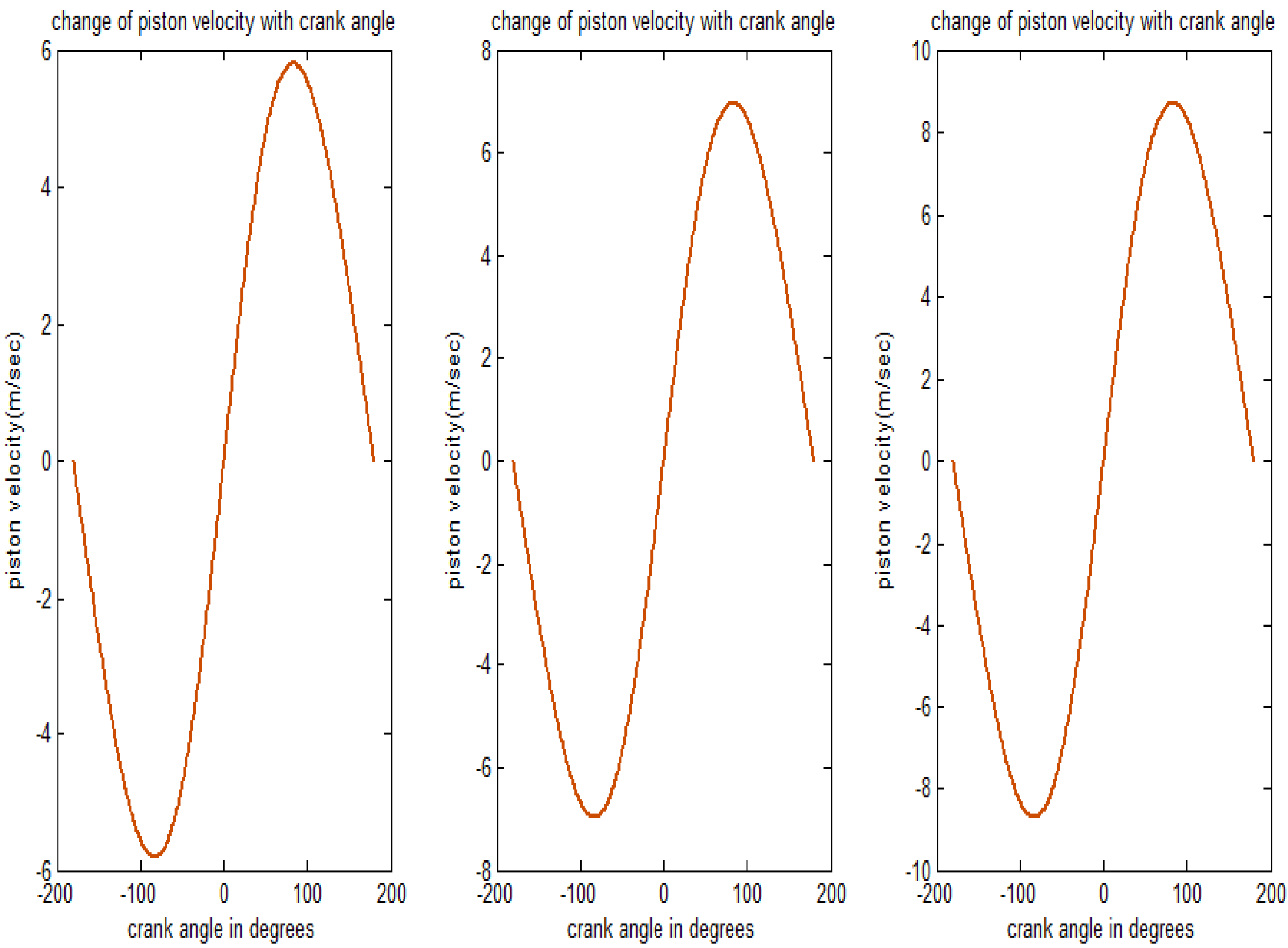

Fig.3. Impacts of the rpm variation on piston velocity a) for n=1000, b) for n=1200, c) for n=1500

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 5, Special Issue 1, February 2024

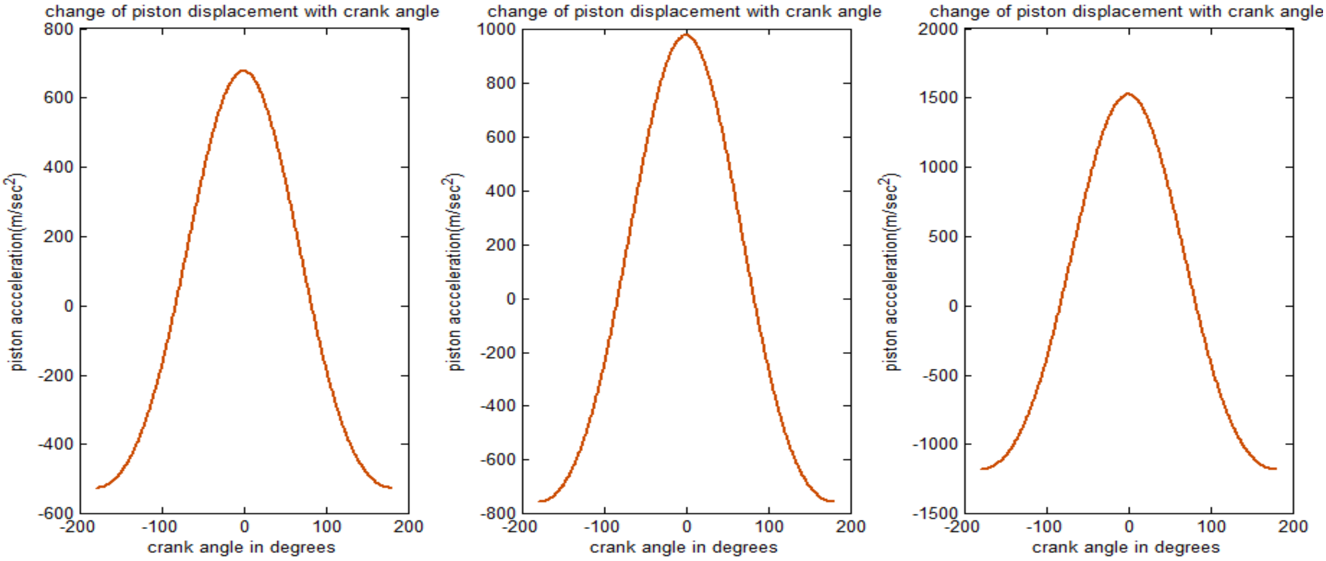

Fig.4.Impacts of the rpm variation on piston displacement for three cases as a) for n=1000, b) for n=1200, c) for n=1500

Table 1 Simulation parameters

Variable	Description
S=0.11	Length of stroke in meters
rd=S/2	Cylinder tedious
Lc=4*S	Rod connecting length
Tmax=3000	Maximum temperature in ^{o}K
D	Diameter = stroke
Gama=γ=1.4	Initial constant rage of *γ*
RPM= [1000 to1500]	Speed range
theta_deg=-180:1:180	Cranck angle range

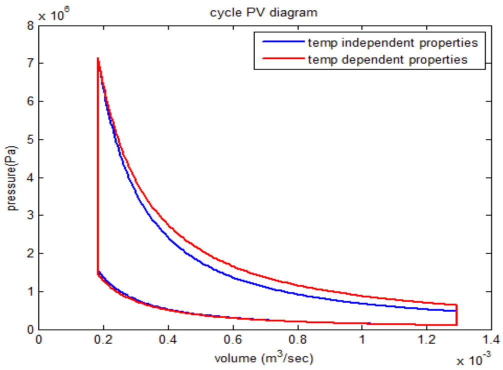

Fig.5. Cycle PV diagram corresponding to Higher RPM

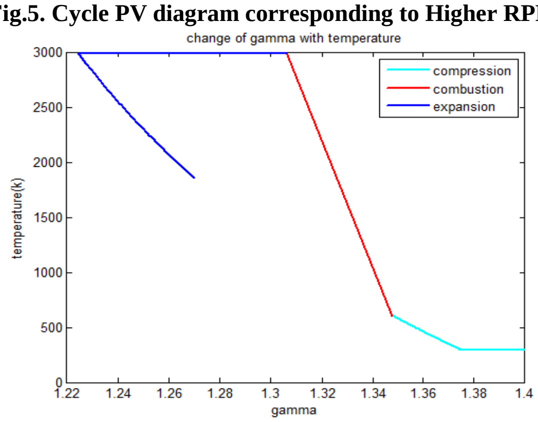

Fig.6.Gamma variations with temperature at higher RPM 1500

Similarly it can be concluded from the Figure 3 that displacement must be higher for the achieving the higher RPM or Speed of the vehicles. Piston Displacement=π (Radius x 2) x stroke x N cylinder It is concluded from the Figure 4 showing the PV plot for the IC engine for the higher RPM. It can be concluded that the pressure increases with RPM requirement. This might reduce the fuel efficiency of the system.

VI. CONCUSION

The article's main goal is to assess the internal combustion engine's (IC) performance while taking RPM variation into account. The paper provides an overview of the several types of strokes used in IC engines as well as diverse applications. Finally, this article considers the effects of RPM variation on the velocity, piston displacement, and PV curve of the IC engine operation for the single cylinder operation. According to the several Crancks angles, the evaluation is completed.

Using MATLAB-based code, this paper has a pre-set simulation case study. For the simulation of the pressure and volume analysis, the constant and variable gamma constants were taken into consideration. For the cycles of combustion, compression, and expansion, the variation of the Gamma

It has been noted that as beginning RPM increases, the velocity peak increases as well. We can infer that the

1, February 2024

pressure rises as the RPM requirement increases. The system's fuel efficiency may suffer as a result.

REFERENCES

[1]. Alsuwian, T.; Tayyeb, M.; Amin, A.A.; Qadir, M.B.; Almasabi, S.; Jalalah, M. Design of a Hybrid Fault-Tolerant Control System for Air–Fuel Ratio Control of Internal Combustion Engines Using Genetic Algorithm and Higher-Order Sliding Mode Control. Energies 2022, 15, 5666.

[2]. S. Studener, "Combustion Engine Air Intake Theoretical Modeling, Model-Verification & Application to Optimal Valve Actuation", IFAC Proceedings Volumes, Volume 45, Issue 2, 2012, Pages 171-176, ISBN 9783902823236.

[3]. Omar, M.; Baharum, A.; Hasan, Y.A. A Job-shop Scheduling Problem (JSSP) Using Genetic Algorithm (GA). In Proceedings of the 2nd IM TG T Regional Conference on Mathematics, Statistics and Applications Universiti Sains Malaysia, Penang, Malaysia, 13–15 June 2006.

[4]. Charles Fayette Taylor "The Internal-Combustion Engine in Theory and Practice". Volume I: Thermodynamics, Fluid Flow, Performance, Second Edition 1985.

[5]. Huang, Y., Yang, S., Zhang, F. et al. Non-linear torsional vibration characteristics of an internal combustion engine crankshaft assembly. Chin. J. Mech. Eng. 25, 797–808 (2012).

[6]. Chinujinim G Thomas "A Detailed Evaluation of Internal Combustion Automotive Engines". International Journal of Advanced Academic Research (Engineering) 2015.

[7]. Pritam Pain, Deep Dewan "Design And Specification Of Internal Combustion Engine. International Research Journal of Engineering and Technology (IRJET) Volume: 06 Issue: 09 | Sep 2019.

[8]. Duque Amaya, Andrés & Diaz, Adalberto Gabriel & Acosta, Diego. (2016). Control of emissions in an internal combustion engine: first approach for sustainable design. International Journal on Interactive Design and Manufacturing (IJIDeM).

[9]. Mahdisoozani, H.; Mohsenizadeh, M.; Bahiraei, M.; Kasaeian, A.; Daneshvar, A.; Goodarzi, M.; Safaei, M.R. Performance Enhancement of Internal Combustion Engines through Vibration Control: State of the Art and Challenges. Appl. Sci. 2019, 9, 406.

[10]. Ge, Y.; Chen, L.; Sun, F. Progress in Finite Time Thermodynamic Studies for Internal Combustion Engine Cycles. Entropy 2016, 18, 139.

[11]. Abdullah Jamil, Masri B. Baharom, A. Rashid A. Aziz, "IC engine in-cylinder cold-flow analysis – A critical review", Alexandria Engineering Journal, Volume 60, Issue 3, 2021, Pages 2921-2945.

[12]. Pisnoy, Shimon & Tartakovsky, Leonid. (2021). Numerical Investigation of the Combined Influence of Three-Plug Arrangement and Slot Positioning on Wankel engine Performance. Energies. 14.

[13]. Balaji Mohan, Jihad Badra, "An automated machine learning framework for piston engine optimization", Applications in Energy and Combustion Science, Volume 13, 2023, 100106.