International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
www.ijiemr.org

A STUDY OF FREE PISTON ENGINE TEST RIG DEVELOPMENT

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ABSTRACT

The global effort to battle climate change and improve air quality has resulted in stricter emission limits and regulations being implemented by governments and regulatory agencies across the globe. Manufacturers of automobiles are feeling the heat to create cleaner, more efficient technology in order to meet these standards. A revolutionary free piston engine with multi-fuel capabilities offers a way to potentially achieve these strict standards while also reducing emissions significantly. Sustainable transportation is a global priority, thus new technologies must be created to lessen our reliance on fossil fuels and lessen our negative effects on the environment. Transitioning to a greener transportation system is simplified by using a free piston engine that can run on multiple fuels, which is in line with the larger aims of decarbonisation and sustainability. New ideas like the free piston engine have been made possible by vast improvements in engine design, materials, and control systems. In a free piston engine, precise and efficient combustion control is made possible by the integration of modern electronics, sensors, and control algorithms. Because of these developments, the potential for multi-fuel use and high thermal efficiency can be realized, prompting the need for much more study in this field.

KEYWORDS: Free Piston, Engine Test, Development, thermal efficiency, combustion control

INTRODUCTION

The design of a free-piston engine, like the design of any engine, starts with an idea. The desired amount of power is determined in tandem with the engine. The basic design of the engine was based on a combination of a two-stroke combustion engine, linear alternator, and gas spring as rebound devices developed at the German Aerospace Center's Institute of Vehicle Concepts. As can be seen in Figure 1, the piston assembly is controlled and reset by an adjustable gas spring.The engine's linear load is located between the combustion and rebound chambers.

The engine would operate on a spark ignition cycle with a single piston and two cylinders. By using the combustion chamber and the rebound devices as gas spring paired with wound spring system for the engine cylinder, a single piston type arrangement can maximize power output while realizing a compact design. Furthermore, the piston motion control is made possible by this conceptual design.

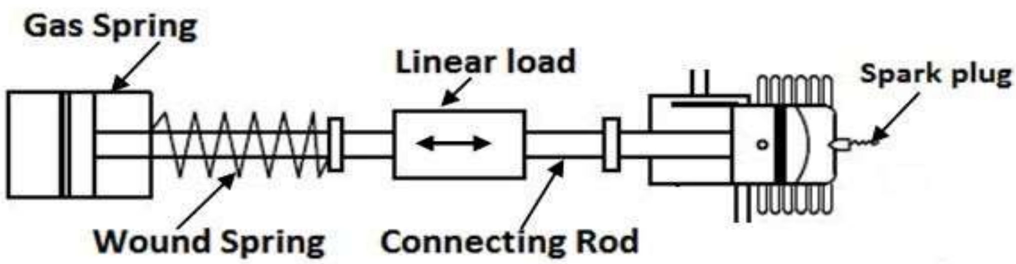

Figure 1 Free piston engine with spring mechanism

In this configuration, the gas spring functions as a linear motor to achieve the desired stroke and cyclic speed during start-up, misfire, and throughout normal operation. To achieve the necessary oscillatory motion of the slider assembly, the linear force can be managed by a control valve strategy that brakes or accelerates the connecting rod.

Due to the low compression ratio required for beginning, Spark Ignition combustion was chosen over Compression Ignition and Homogenous Charge Compression Ignition. Since SI combustion permits the use of lower compression pressure and intake air temperature, this may be necessary during prototype testing to prevent damaging, violent combustion and excessive vibration. Importantly, the ignition point marks the beginning of combustion in SI, so the combustion profile may be accurately predicted.

ENGINE MODIFICATIONS

In the first of an internal combustion engine's three phases of energy conversion, chemical energy is transformed into the kinetic energy of the gas molecules in the cylinder through the combustion process. The heat and pressure of the cylinder charge are converted from the kinetic energy as a whole. The mechanical motion of the piston is generated by the pressure exerted on it within the cylinder.

The crankshaft and flywheel of an internal combustion engine convert this translational motion into rotating kinetic energy. However, in a free-piston engine, a linear load device like a linear generator, hydraulic pump, or pneumatic actuator can directly transform this linear motion into productive labor. The stated power from an engine is generated by combustion pressure, while the braking power is the actual power that may be drawn from the crankshaft. Losses from friction between the additional rotating parts and the linearly moving piston caused by side thrust cause the brake power to be less than what is indicated. As shown in Figure 2, the main components of an internal combustion engine are a cylinder, piston, and connecting rod, and the side thrust is generated by the effect of the crank-slider mechanism converting the linear motion of the piston into a rotational motion.

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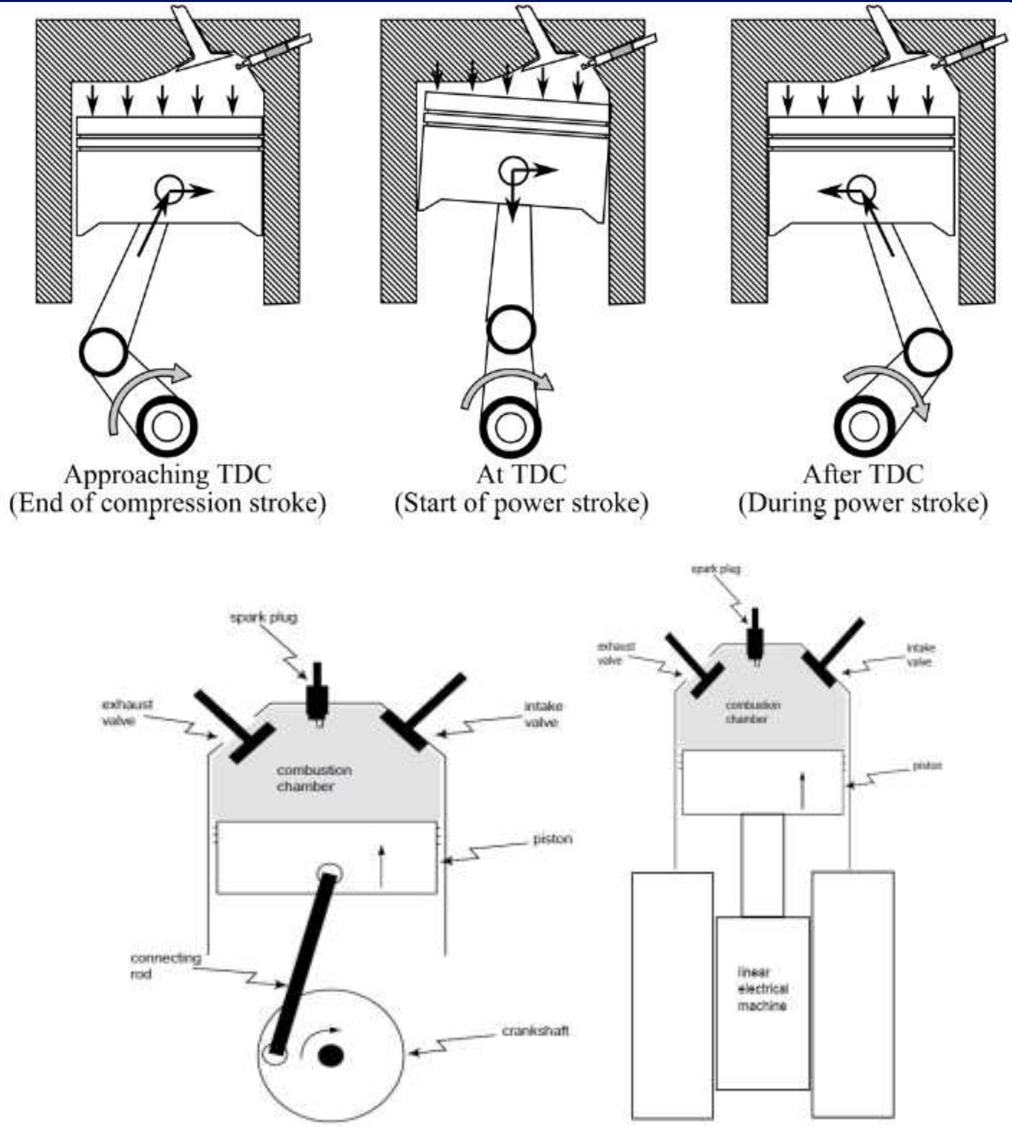

(Courtesy: Gupta 2006)

Figure 2- Side thrust in a Crankshaft Engine due to crank-slider mechanism

Gupta (2006) has determined that side thrust, piston impulse, and combustion pressure pushing on the piston are the three primary causes of such friction. The ability to quantify the amount of side thrust-related friction on the power cylinder while driving is a necessary but not sufficient condition. About 40-55% of the total frictional forces in a crankshaft engine come from side thrust friction.

A low power-to-weight ratio is essential, as is an engine that is solely focused on creating power and not rotational torque. The engine's cylinder unit was adapted from a production TVS 50 motor. As can be seen in Figure 3, the original engine underwent the necessary adjustments, and new components were built to better serve the needs of the free piston engine.

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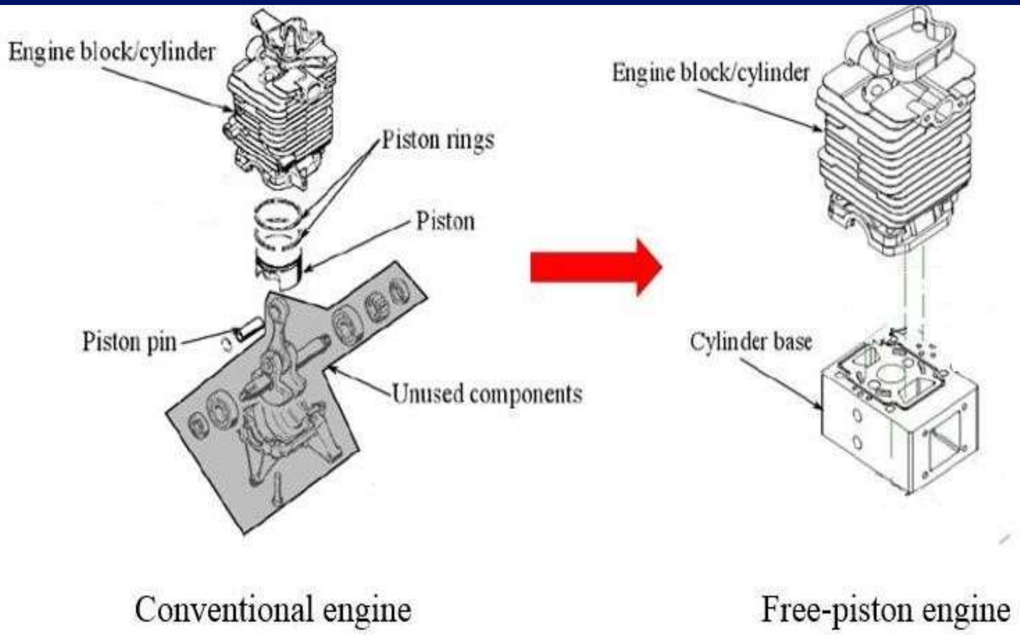

Figure 3 Engine components for Free Piston Engine prototype design

Firstly, the structure of spring system of FPE is described and components are built. The working principle of this device is introduced. Secondly, on the basis of the characteristics of the piston motion, and a starting strategy is proposed to engine. Finally, the brake load unit is implemented to the engine to obtain reliable results. A set of parallel gas and wound springs functions as a rebounding device to push the piston back from BDC to TDC. It is assembled to the end of combustion chamber to decrease the heat transfer rate from the combustion chamber. This single-cylinder FPE with gas spring coupled wound spring system is a compact device which is easier controlled to overcome the combustion fluctuation and made to achieve stable operation. The final prototype specifications as shown in It begins with a description and construction of the parts that make up the FPE spring system. Its basic operating principle is described. Second, a starting strategy for the engine is provided based on the features of the piston motion. The engine is then equipped with a brake load device for consistent results. To return the piston from BDC to TDC, a system of parallel gas and wrapped springs acts as a rebounding device. It is attached to the end of the combustion chamber to slow the pace at which heat escapes. The combustion fluctuation may be more easily managed with this tiny single-cylinder FPE that uses a gas spring coupled wrapped spring system.

SPRING SYSTEM FOR REBOUND DEVICE

1. Wound Spring

The load is connected to the connecting rod in the middle of the piston, and combustion takes place at one end. When the piston is driven in only one direction, it must be returned by a rebound device. A gas spring or a wrapped spring might serve as the return mechanism. The single power piston and rebound spring mechanism are at the heart of the free-piston engine.

Combustion forces the piston downward, and the springs store that energy until they return the piston and compress it again.

A connecting rod joins the engine's piston to the latter's wound spring and gas spring. For compression, the spring system must be robust enough to store and transfer enough energy between strokes. A single free piston with a return spring is used in the engine design. Over time, the compression of the engine's spring system caused by the force of combustion occurs naturally.

2. Gas spring

The gas spring is a hydro pneumatic adjustment element that features a pressure tube, a piston rod, and piston, all of which are connected via suitable connection fittings. It is stuffed with compressed air, which exerts a uniform force over the piston's cross section. This causes a pressure to develop along the extending axis. By carefully choosing the filling pressure, this extension force can be precisely defined within physical bounds.

3. Numerical Investigation for Scavenging

The scavenging performance of the two free piston engine determines how effective the engine is. The engine's scavenging performance is simulated using Computational Fluid Dynamics (CFD). Many commercial software codes are now available to examine the in-cylinder flow pattern, and CFD has developed as a potent and alternative tool for simulation of internal combustion engine processes. Many design criteria have their origins in the results of CFD codes, which are employed extensively to arrive at preliminary and indicative solutions. The key benefit of CFD research is that it can accurately forecast the spatial and temporal values of fluid characteristics over the whole domain of interest of the engine. Therefore, CFD research provides a useful alternative to costly experiments.

CONCLUSION

The transportation industry has a significant role in the generation of greenhouse gas emissions and the exacerbation of air pollution. Traditional engines, particularly those that depend on fossil fuels, release detrimental pollutants such carbon dioxide (CO_2), nitrogen oxides (NO_x), and particulate matter (PM). Through the use of several fuel sources and the optimization of combustion processes, a free piston engine has the potential to effectively decrease emissions, therefore offering a means to mitigate the negative environmental impacts often associated with transportation. The exclusive reliance on a singular kind of fuel imposes constraints on the flexibility and adaptability of traditional engines. The ability to use many types of fuel, including both traditional options like gasoline and diesel, as well as alternative sources like natural gas, biofuels, and hydrogen, is referred to as multi-fuel capabilities. The engine's adaptability allows it to accommodate many fuel sources, therefore decreasing dependence on fossil fuels and encouraging the use of renewable and low-carbon alternatives. Governments and regulatory entities throughout the globe are enacting more rigorous emission rules and regulations in order to address climate change and enhance air quality. Automobile manufacturers are under significant pressure to cultivate cleaner and more efficient technology in order to adhere to these regulatory requirements. The implementation of a revolutionary free piston engine that has the ability to use several fuels presents a feasible resolution to address these rigorous criteria, concurrently presenting the possibility of significant reductions in emissions. The attainment of sustainable transportation is a matter of utmost importance on a worldwide scale, requiring the advancement of inventive technologies that diminish dependence on fossil fuels and mitigate adverse effects on the environment. The use of a free piston engine that can operate with several fuels is in line with the overarching objectives of decarbonization and sustainability, facilitating a more seamless shift towards a more environmentally friendly transportation system. The development of engine design, materials, and control systems has led to notable progress, hence enabling the exploration of innovative ideas such as the free piston engine. The use of sophisticated electronic systems, sensors, and control algorithms facilitates the achievement of accurate and effective regulation of combustion processes inside a free piston engine. The aforementioned technological breakthroughs have rendered the achievement of multi-fuel usage and high thermal efficiency a viable prospect, hence necessitating more research and development endeavors in this domain.

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