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Design and modeling of Free Piston Linear Alternator

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Abstract – *This paper deals with design, analysis and modeling of free piston linear alternator. In the modern world, free piston engines have been under extensive research in past years. It is not successful in modern application. These papers deals with development of free piston engine, in recent paper there are less effort is obtained on free piston engines. The aim of this project with is to provide electricity generation and to give high efficiency. It works on principle of electromagnetic induction and this paper gives helpful information for development of free piston engine*

***Key Words*: Solenoid valve, alternator, ultrasonic sensor, double acting pneumatic cylinder, charging circuit, compressor.**

1. INTRODUCTION

This case study is concerned with design of free piston engines and it is a renewable source of electricity generation with the help of compressed air. In engines, piston used for reciprocating motion is used for power stroke only. In this project with the help of free pistons reciprocating motion are used for electricity generation. The word free piston describes that there is no crankshaft attached to connecting rod.

The aim of this project is to generate electricity from friction produced between piston and cylinder movement. For these, our team has mounted magnet on connecting rod and copper wire has been wounded on cylinder. With the help of ultrasonic sensor the piston's motion is controlled and magnet cuts the flux of copper wire with electromagnetic induction principle and electricity is produced. We can also store extra electricity into battery by using charging circuit. Free piston linear engines can also be used in modern applications where large size of double acting pneumatic cylinder is in operation.

2. LITERATURE REVIEW

1. Investigation of the starting process of free-piston engine generator by mechanical resonance by Boru Jia1, Zhengxing Zuo2, Huihua Feng3, Guohong Tian4, A.P. Roskilly5.

As an alternative to conventional engines, free-piston engine generator (FPEG) is a promising power generation system due to its simplicity and high thermal efficiency. One crucial technical challenge in the FPEG operation is the initial process of overcoming the compression force to achieve a certain speed which allows a stable and continuous operation, i.e. starting process. This paper proposes a novel method to start the engine by mechanical resonance. A closed-loop control model was developed and implemented in a prototype FPEG which was driven by a linear machine with a constant driving force. Both numerical and experimental investigation was carried out. The results show that once the linear motor force have overcome the initial friction force, both the in-cylinder peak pressure and the amplitude of the piston motion would increase gradually by resonance and quickly achieve the target for ignition. With a fixed motor force of 110N, within 0.8 second, the maximum in-cylinder pressure can achieve 12 bars, the compression ratio can reach 9:1, and the engine is ready for ignition. The results demonstrated that it is feasible to start the FPEG by mechanical resonance in a constant motor force in the direction of the natural bouncing motion.

2. Disturbance analysis of a free-piston engine generator using a validated fast-response numerical model by Rikard Mikalsen1, Boru Jia2, Andrew Small bone Huihua Feng3, Zhengxing Zuo4, Anthony Paul Roskilly5.

In this paper, a fast-response numerical model was used to investigate potential disturbances to a free piston engine generator (FPEG), i.e. engine cycle-to-cycle variations, misfire and immediate electric load change. During the engine operation, there could be one disturbance taking place or several disturbances take place simultaneously. By identifying different types of system disturbance with specific occurring times, the influence on the system was characterized. It was found that a step change of electric load would induce a corresponding top dead centre (TDC) step change. Low variations on piston TDC are observed when cycle-to-cycle variations take place. When unsuccessful ignition occurs, the engine will stop after one oscillation cycle. Reducing the electric load after misfire would cause more oscillation cycles and require a restart of the engine. Technically feasible control variables were identified and coupled with a PI feedback controller design to minimize the impact of each kind of disturbance, a design which could be used in future FPE control system designs. The controller performance was seen to be satisfactory for the electric load step change, and the piston TDC was controlled to back to the set point in 0.5 s.

3. Dual loop Control of Free Piston Engine Generator by Xun Gong1, Kevin Zaseck2, Ilya Kolmanovsky3, Hong Chen4.

The precise control of piston motion is the key to guaranteeing reliable free piston engine generator (FPEG) operation. This paper presents a dual-loop controller to

manage piston motion in a free piston engine. In this paper, the piston motion dynamics are represented by a discrete-time model system which derived by energy balance while the air flow dynamics are represented by a mean value model. The outer-loop adjusts the fuel quantity and load change rate by a model predictive control (MPC) that tracks clearance height set-points. The desired cylinder air flow is calculated using the desired fuel amount from MPC assuming stoichiometric air-to-fuel ratio. A nonlinear inner loop controller is designed to regulate the throttle to meet the air flow demand. The design of the inner loop controller is based on the Triple Step method. In simulation, the proposed controller successfully tracks the target piston clearance height and satisfies the constraints during an instantaneous electrical load change while maintaining a stoichiometric air-fuel ratio.

4. Experimental study of the operation characteristics of an air-driven free piston linear expander by Yaodong Wang1, Lin Chen2, Boru Jia3, Anthony Paul Roskilly4.

Free-piston engine is a kind of linear internal combustion engine, and shows advantages on simple mechanical structure, low frictional losses, high thermal efficiency and operational flexibility. In this research, an experimental test rig of a dual-piston air-driven free-piston linear expander (FPLE) is established using the FPE concept. A linear generator is used to convert the mechanical work of the pistons into electricity during the expansion process. The piston dynamics, the output voltage of the generator, and the expander operation frequency, as well as the system energy conversion efficiency are identified. It is observed that the piston displacement profile is similar with a sinusoidal wave. The piston is found to run at relative high speed during the middle stroke, and peak velocity is usually achieved when the piston approaches the middle stroke. The output voltage of the generator is sensitive with the piston velocity. With higher driven pressure, the expander frequency is higher. The energy conversion efficiency increases with higher driven pressure and can reach up to 55% with a driven pressure of 3.75 bar. This research presents a fundamental analysis of a FPLE prototype, which can be used as guidance for the future design of this FPLE type.

5. Experimental study on free piston linear generator (FPLG) used for waste heat recovery of vehicle engine Yaming Tian1, Hongguang Zhang2, Gaosheng Li3, Xiaochen Hou4, Fei Yu5, Fubin Yang6, Yuxin Yang7, Yi Liu8.

In this study, a novel free piston expander coupling with a linear generator prototype is presented to recover exhaust waste heat efficiently from vehicle engine. The free piston linear generator (FPLG) can be used in a small-scale organic Rankine cycle (ORC) system and can directly convert the thermodynamic energy of working fluid into electricity. The effects of intake pressure, operation frequency as well as external load resistance on operation characteristics and output performance are discussed. The results show that the piston displacement profile is similar to a sinusoidal wave. The piston is found to run at relative high speed during the middle stroke, and peak velocity is usually achieved when the piston approaches the middle stroke. The output voltage of the generator is sensitive with the piston velocity.

3. OBECTIVE

The objective of free piston linear alternator is to provide the electrical energy by using electromagnetic induction, which can be store in the battery by using charging circuit.

4. PROBLEM STATEMENT

As we know that the piston used in engine has reciprocating motion, and reciprocating motion in today engine are more helpful, in our project with help of piston reciprocating motion we can generate electricity.

5. METHODOLOGY

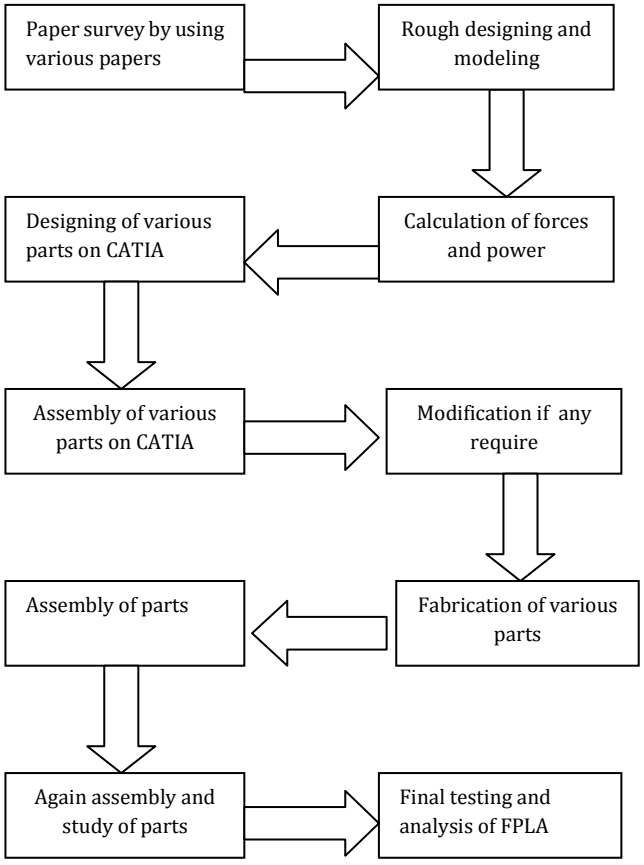

Chart -1: rough model

6. DESIGN OF (FPLG) BY CATIA MODEL

The designing of Free Piston Linear Alternator was done in CATIA. The various components part drawings are created separately and by using this parts assembly is created.

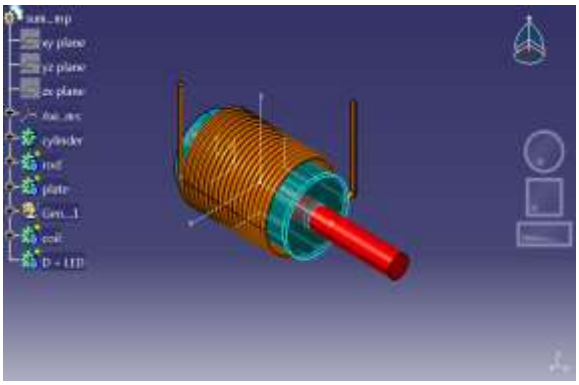

Fig -1: Model Design

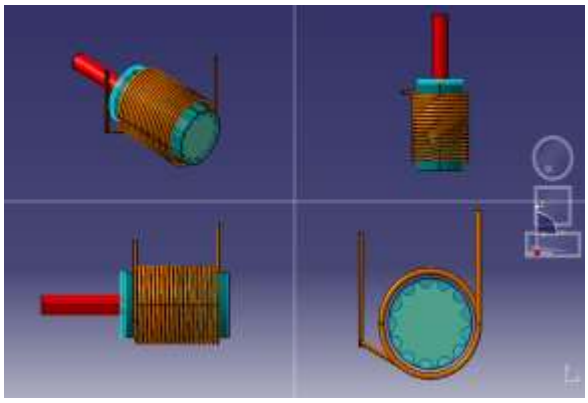

Fig -2: Model Design Views

7. EXPERIMENTAL SETUP

During this experimental study, it is found that the model is working as per principle of electromagnetic induction. when the compressed air first passes through 3/2 solenoid valve to inlet of double acting pneumatic cylinder and movement of piston is controlled by ultrasonic sensor which has aurdino program inbuilt in it and magnet cuts the flux of copper wire and electricity is generated successfully

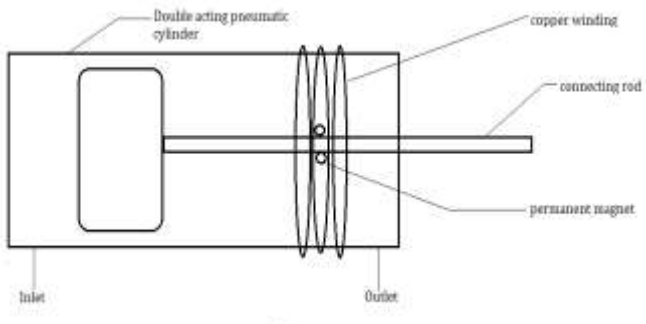

Fig -3: Free Piston Linear Alternator

8. TESTING

While running of free piston linear alternator we found it produce about 4v of electricity per stroke.

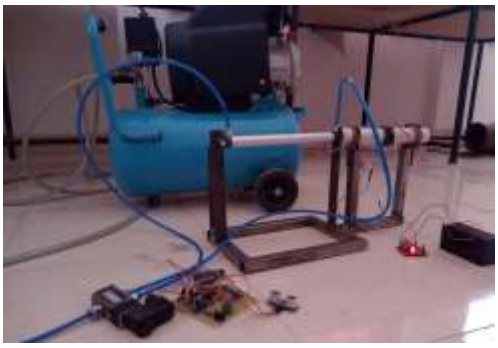

Fig4. Actual Model

9. CONCLUSION

Design and modeling free piston linear alternator has been successfully completed. It is concluded that free piston linear alternator is working properly under the specified working condition. From the testing and observed result we got electricity generated is 4V. It is also useful for charging of battery. Most of potential advantages of free piston engine depends on and appropriate control of system being reliable

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