DESIGN AND ANALYSIS OF INTERNAL COMBUSTION COMPRESSED AIR HYDRID ENGINE (INCO)

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Abstract

This paper presents the outcome of innovative and creative research carried out regarding designing and analyzing a hybrid engine working by Compressed Air and gasoline. The conventional four strokes associated with IC Engines are being modified into six strokes. These tasks have been fulfilled by using UG NX-8, ANSYS CFD, SOLID EDGE-19 and MATLAB-2010.First four strokes of ***INCO*** *are executed by the combustion process. Last two strokes are executed by Compressed Air. During the intake of fifth stroke, intake valve is open and only Compressed air enters the combustion chamber. During the exhaust (sixth stroke), exhaust valve opens and Compressed air exits through it. Prototype constructed has emphatically shown that it is possible to modify the conventional cycle to* ***INCO*** *cycle for the purpose of realizing the need identified for this study. Preliminary investigation has revealed that the proposed* ***INCO*** *has an overall efficiency of 60-70% and thermal efficiency of 35-40%. Hybridization of the engine has reduced the emission of Nitrogen Oxides (NOx) by 13%. NOx is predominantly temperature dependent.*

KeyWords: *Internal Combustion, Compressed Air, Hybrid Engine.*

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1. INTRODUCTION

In the 21th century the world must face and solve two major problems. One is the rapid population growth rate in developing countries and the other is the increasing consumption of energy in both developing and developed countries. On one hand, developing countries have 80% of the world’s population and consume 20% of world’s energy resources. On the other hand, developed countries have 20% of the world’s population and consume 80% of the world’s energy resources. These aspects have led to the consideration of the Design and Analysis of INCO and very satisfactory results have been achieved.

Present work has considered the modification of 4 strokes of Otto cycle into 6 strokes. The last 2 strokes run by Compressed Air.

1.1 Literature work

Owing to the need identified and the innovative idea considered, literature review has been carried out. This has identified the Technology which is available or unavailable for the realization of the concept considered for the present work.

[1]George Marchettiet.al, 2005, were of the opinion that, one of the most difficult challenges in engine technology today is the need to increase engine thermal efficiency. In order to consider this, they proposed a Quasi turbine thermal management strategy in the development of high-efficiency engines for the 21st century. In the concept engine, high-octane fuels were preferred since higher engine efficiencies could be attained with these fuels. Higher efficiencies were reported in which compression pressure and rapidity of ignition were maximized.

[2] Sourabh Patak et.al, 2014, studied the latest trend in automotive industry to develop a light vehicle as it could help in better handling of vehicle and increase its efficiency. One of the method to reduce the harmful exhaust gases like CO2, SO2, is the use of Compressed Air to generate power to run an automobile. Due to the unique and environmental friendly property of Air, it was considered as one of the future fuels which will run automobiles.

[3] Mistry Manish et.al, 2012, reviewed the design and development of the single cylinder engine which could be run by Compressed Air. Their main objective was to run a single cylinder four stroke engine on Compressed Air with some modifications, the electrical energy required for compressing the Air was considered while computing the overall efficiency.

[4] VivekRautet.al, 2014, tried to implement a 6 stroke engine coupled to an electric motor in hybrid car. This was then numerically analyzed with existing hybrid cars. The parameters considered were efficiencies, fuel consumption. They analyzed and predicted fuel economy and opined that it improved considerably. The present investigation on INCO has proved emphatically that use of six stroke and hybrid energies and Co and Regeneration aspects which has brought in considerable energy efficiency (60%).

1.2 Definition of problem

Perusal of literature, market survey and feasibility study has led to the establishment of the need for carrying out this project and consequent objectives formulation. The objectives considered are mentioned below:

- To design and analyze the use of Compressed Air in improving innovatively the overall efficiency of Internal Combustion (IC) engines.
- To investigate the use of Compressed Air to run the engine and conduct Performance studies.

With respect to the objectives formulated, the problem which has been considered for the present study is defined as follows:

- Identification of suitable pressure for Compressed Air and using it along with Gasoline.
- Analyzing Co and Re generation characteristics of the use of Compressed Air and Gasoline
- Writing codes for the timing of Solenoid Valves operation for Compressed Air and Gasoline insertion. Carrying out performance tests using a lamp load for INCO.

2. CONCEPTS AND CONSTRAINTS

The proposed INCO concept has been physically realized. Use of Compressed Air and Gasoline are considered. This combined energies' synergetic effect has shown an overall efficiency 60% in comparison with fossil fuel powered conventional engines of the same indicated power of 3kW.
Another important aspect of the concept is that, Re-generation of pressure energy associated with the Compressed Air (4 Bars) and use of Gasoline which has resulted in 30% saving in the energy supplied to the engine.
Since the first four strokes were run by gasoline and the next two strokes by Compressed air ,timing of opening and closing of inlet and outlet Solenoid Valves and timing of the spark for gasoline combustion posed several problems. A Programmable Logic Controller (PLC) was used to eliminate these constrains.

3. PART DESCRIPTION

The following plates illustrate the parts used for INCO, which are created by NX 8.

Fig-1 is showing Programmable Logic Controller (PLC) interfaced with solenoid valves operating the inlet and outlet valves for compressed Air and inlet and Exhaust valves for Gasoline Assembly of Engine valve control system. The PLC's are programmed using a ladder circuit.

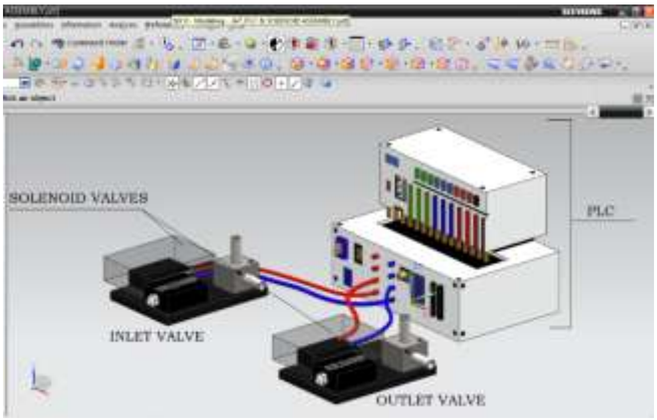

Fig-1: PLC and Solenoid valves modeled using NX 8

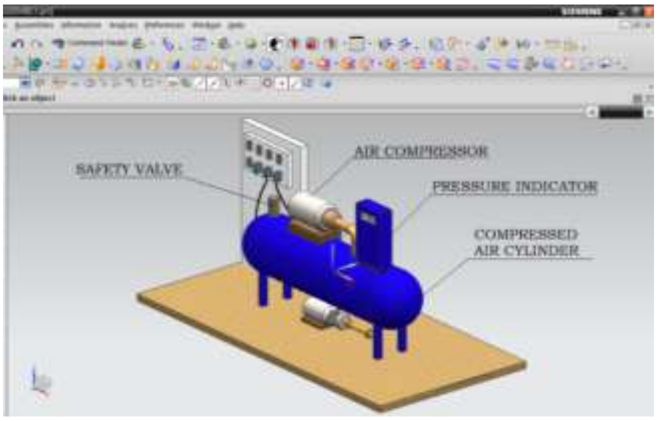

Fig -2: Compressor modeled using NX 8

Fig-2 depicts the Compressed Air unit and the cylinder where air is at 8 bars. Pressure gauge is used to sense and control the amount of pressure required for the INCO to run the last two strokes.

Fig -3: INCO Engine modeled using NX-8

Fig-3 shows the construction of INCO hybrid engine modeled using NX-8. It consists of crankshaft combined with flywheel as shown in the figure. The inlet and outlet valves are controlled by solenoids. It has a hemisphere type combustion chamber facilitating all six strokes.

3. WORKING PRINCIPLE

INCO engine is a hybrid version of conventional gasoline engine. First four strokes of the engine works exactly as same as the conventional engines. For the last two strokes

Air at 8 bar pressure (Compressed Air) enters the reciprocating engine through the Solenoid operated inlet valves and expands in the cylinder. This happens for 180 degrees rotation of the crank shaft. The expanding air exerts forces on crown of the piston, which makes the crankshaft to rotate. This is the working portion of the cycle. Some portion of the torque is stored in the flywheel (of mass 4 kg) coupled to the crankshaft. Further rotation of the crankshaft is by torque assistance energy stored in the flywheel. Subsequent rotation of 180 degrees of the crankshaft causes the expanded air to exit from the same exhaust manifold. The expansion and Compression repeats again for the next 360 degrees (for the next 5th and 6th stroke). During these rotations, the inlet and the outlet valves open and close twice each time 4 to 6 degrees before the dead centers.

4. FLUID ANALYSIS

INCO engine was subjected to the Fluid Analysis. Contours of Static and Dynamic Pressures and density are modeled and analyzed using ANSYS Fluent 15.0 software and are shown. All these values are well within the limits suggested by calculations with a deviation of about 15%.

In Fig-4, the green-yellow regions depict a static pressure distribution of 8 bar which was found to be accurate up to 96%.

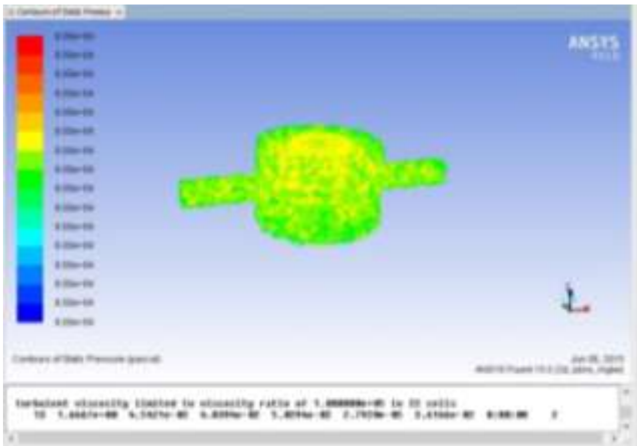

Fig-4: Showing Static Pressure (modeled using Ansys Fluent 15.0)

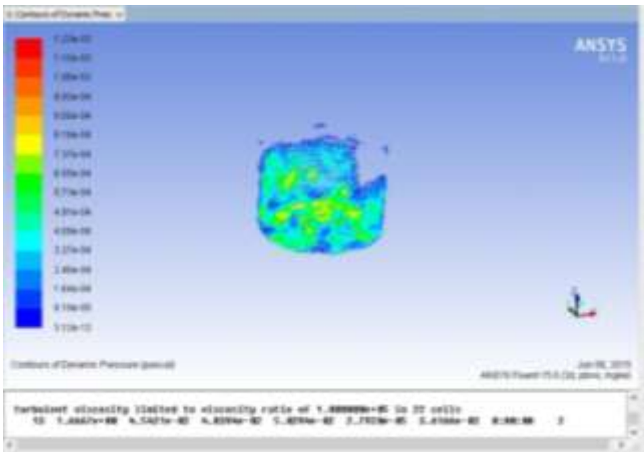

Fig-5: Showing Dynamic Pressure (modeled using Ansys Fluent 15.0)

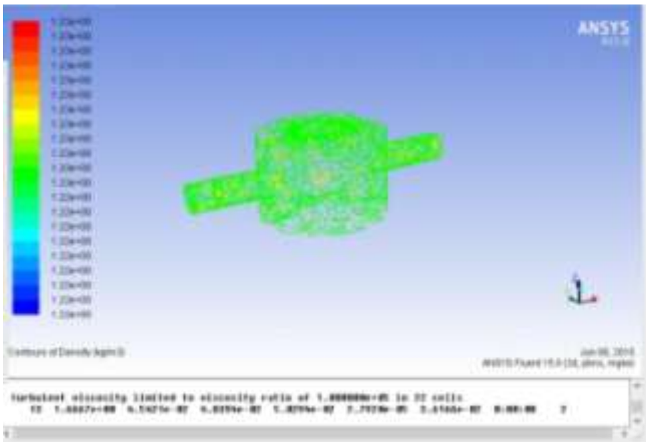

Fig-6: Showing Density of the fluid (modeled using Ansys Fluent 15.0)

5. FINITE ELEMENT ANALYSIS OF PISTON

Fig-7 and Fig-8 are showing Finite Element Analysis (FEA) using Ansys 15.0. Values of Equivalent Stress and Maximum Principal Elastic Strain were within the limits suggested by analytical calculations with a deviation of 5% to 6%.

Fig-7 is showing equivalent stress of piston in the INCO. The maximum deflection with respect to the applied load (a combination of gasoline combustion products and Compressed Air) is 1.9084 µm. These values are very small in comparison with the Young's Modulus of material which is 69 GPa.

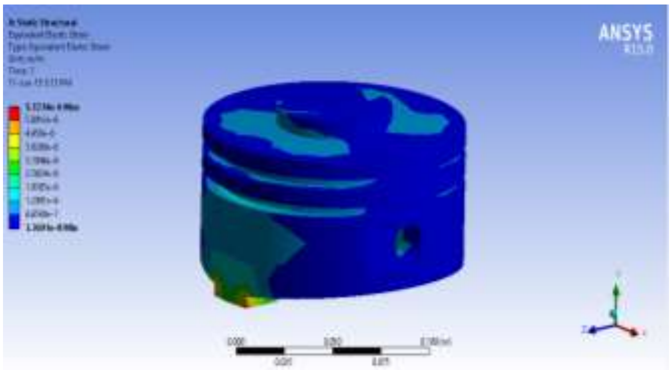

Fig-7: Showing Equivalent stress (modeled using Ansys Fluent 15.0

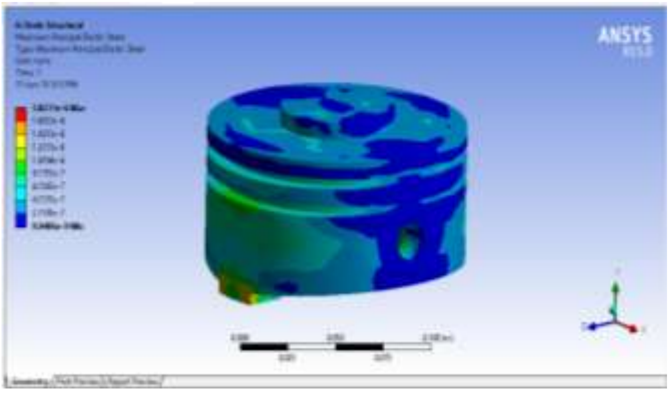

Fig-8: Showing Maximum Principal Elastic Strain (modeled using Ansys Fluent 15.0)

Fig-8 explains the Maximum Principal elastic strain acting on the piston under 4 Bars pressure. On analysis we found that Maximum Principal Elastic Strain was reached to 8.177e-7.

6. TESTING

Testing of INCO was carried out using standards such as ISO14396:2002 for performance testing and ISO8178-1:2006 for Emission testing were perused.

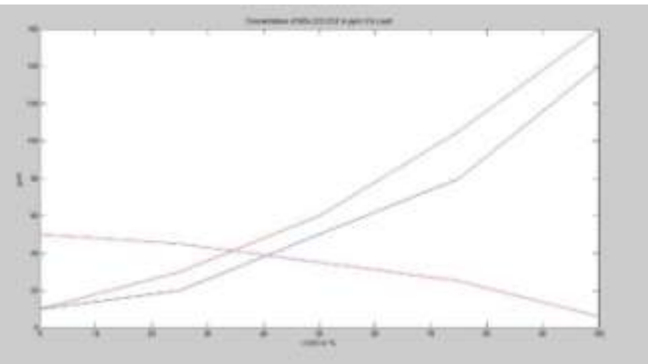

Fig-9 graph showing the Emission of NOx, CO2 and CO V/S Load

The variations of Emission such as NOx, CO2 and CO V/S Load are shown in Fig-9. It is observed that emission is less at lower loads and it goes on increasing as the load increases. CO has decreased since excess air was available due to the compressed air injection along with the fuel which facilitated oxidation of CO to CO2.
NOx Emission is a direct function of engine loading and exhaust temperature. Since the combustion temperature was low (80^{o}C to 90^{o}C) the NOx values were also low in comparison with the conventional 4 stroke engines (53% less). Since Compressed Air and Gasoline were injected simultaneously, premixed combustion has occurred (higher initial rate of combustion) which has resulted in lower values of NOx. Another reason for temperature ranges being low is that, the last two strokes are run by Compressed Air which has brought in inbuilt cooling effect of the engine.

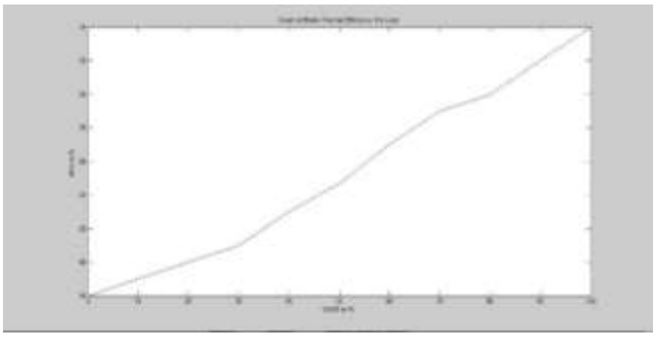

Fig-10: Graph showing Brake Thermal Efficiency (BTE) V/S Load

Fig-10 shows the variation of Brake Thermal Efficiency (BTE) at different loading conditions. Brake Thermal Efficiency (BTE) for CO-MAG-IC is 34% at full load. This is 44% higher that the efficiency in comparison with conventional engines.

6.1 Test setup of INCO

Fig-11: Experimental setup for CO-MAG-IC

7. CONCLUSIONS

After designing, modeling and realization of INCO, and consequent testing and analysis the following conclusion are made.

- Use of pressure energy(Compressed Air) and Gasoline has shown synergetic effect associated with these energies in running the INCO. This is evident by the testing of INCO which has shown BTE of 34% and overall efficiency of 68%.
- The market survey and economic analysis has emphatically proved that there could be huge market run by INCO in the coming years in the context of fossil fuel depletion, energy sustainability and environmental pollution.
- Usage of Compressed Air in the 5th and 6th stroke has led to the decrease in cylinder temperature. Further the exhaust products which remains in the combustion chamber will be swept from the cylinder.

8. REFERENCES

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9. BIOGRAPHIES

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