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Stirling Engine used in Car

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Abstract: Stirling engine is used for the traditional method of external combustion involving heat transfer in the fluid present in the engine.The main focus of this analysis is to determine the best fuel to be used in the Stirling engine to achieve best speed, higher effectiveness and low carbon dioxide emissions.Designing the Stirling engine involves few considerations that are relevant to the gear and body design aspect.Design selection of the engine is also the main focus of this study in which the alpha engine is selected for the Stirling engine design.Stirling engines work on using the heat energy as the energy input and are based on the Stirling cycle.Next is the type of fuel to be used in the engine where ethanol and acetone have been tested in this experiment.The result shows that ethanol is better than acetone because at low time it produces the best speed with low carbon dioxide emissions.The design of Stirling engine car consists of wheel, chassis, and alpha Stirling engine. Each component is fabricated with different type of material.

Keywords: Acetone, Alpha Engine, Ethanol, Rubber, Stirling Engine.

INTRODUCTION

Stirling engine is a heat engine that works at different temperature levels by cyclic compression and expansion of air such that a net transfer of heat energy to mechanical work. Stirling engine is classified as an external combustion engine, since all heat transfer to and from the working fluid takes place through the engine wall.It compares with an internal combustion engine, where heat emission is generated by combustion of a fuel in the working fluid body[1].When a steam engine uses a working fluid in both its liquid and gaseous stages, the Stirling engine has a fixed amount of air in it.The general cycle consists of compressing heating the gas, cool gas, expanding the hot gas, and finally cooling the gas before the cycle.The process's output is strictly restricted by the Carnot cycle's performance, which depends on the temperature between the hot and cold reservoir.Stirling engine has high efficiency compared to steam engines, quiet operation and the ease with which almost any heat source can be used[2].The need for a Stirling engine has a cooler and heater to produce different temperatures but the Stirling engine car is designed for children to play.The Stirling engine car is not meant to be very big and if the energy supply is needed so use the atmospheric temperature as cooler.The difference in temperature is small so that the output of force is not sufficient to drive the toy car, using the gear to minimize the force needed to accelerate the car and to provide external force to move the flywheel[3].

1. *Stirling Engine:*

Stirling engine is a heat engine developed in 1816 by Robert Stirling. It uses an external energy source to heat the gas inside a cylinder. Hence it can use various types of heat sources and different types of fuels.Its theoretical cycle has an efficiency of Carnot. This engine represents a good candidate for alternative powertrain [4].A Stirling engine runs on a closed cycle. The working fluid is compressed in its theoretical cycle at the lowest constant temperature T_L (1-2), and Q_L is rejected as heat. The fluid is heated by the heat Q_R contained in the regenerator, at constant volume (2-3).At the highest temperature T_H, the expansion work at constant temperature (3-4) is produced by the externally supplied heat Q_H to the gas. Finally the fluid is cooled from T_H to T_L, and the corresponding heat is stored at constant volume (4-1) in the regenerator during the process.Both isochoric processes take place in a porous heat exchanger called the regenerator [4-5] whose efficiency is a key element of the performance of Stirling engines.In motor operation, heat is supplied to the engine during the expansion stage (3-4) and in compression stage (1-2) is rejected to the cold sink[5].Both isochoric processes take place in a porous heat exchanger called the regenerator [4-5] whose efficiency is a key element of the performance of Stirling engines.In motor operation, heat is supplied to the engine during the expansion stage (3-4) and in compression stage (1-2) is rejected to the cold sink.The engines use two pistons: a piston dedicated to shaft work, and a displacer piston dedicated to the gas transfer between the spaces of compression and expansion.The pistons and cylinders can have different mechanical arrangements. A Beta engine is used in which both pistons are in the same cylinder. With a

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mechanical crankshaft connection, the power pistons lag behind the displacer at an angle of 90° in motor action[6]. Figure 1 shows the PV and TS diagram of theoretical Stirling cycle.

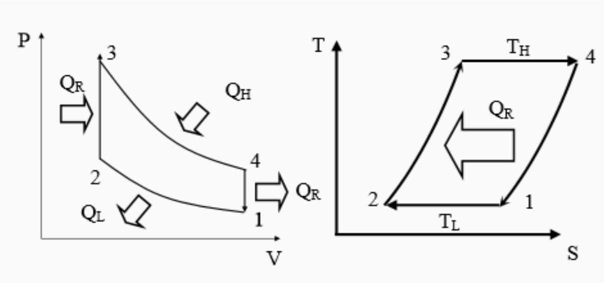

Figure 1: PV and TS Diagrams of Theoretical Stirling Cycle

2. *Design of Stirling Engine:*

Stirling engine car design consists of wheel, chassis, and alpha or beta Stirling engine. Each part is manufactured of different material types. First of all, the vehicle wheel selected for rubber to move the car.The aim of choosing rubber is also to help connect shaft and chassis of Stirling engine car due to good friction between surfaces.The frame made of aluminium and some metal parts. Lightest weight content in aluminium with strong strength.The Stirling engine operates on a Stirling cycle with a theoretical efficiency similar to that of Carnot efficiency[7]. A Stirling engine consists of a number of basic components which depends on type and configuration.Some of the basics outlined for the alpha Stirling engine are power piston and cylinder, heat source, displacer piston, heat sink and regenerator. It is an internal heat exchanger and temporary heat store positioned between the hot and cold spaces so that the working fluid flows through it first in one direction then in the other.The device purpose is to retain heat that would otherwise be shared with the environment. So, it helps the thermal efficiency of the cycle to reach the limiting Carnot efficiency[8]. Figure 2 shows decomposition of Stirling engine.

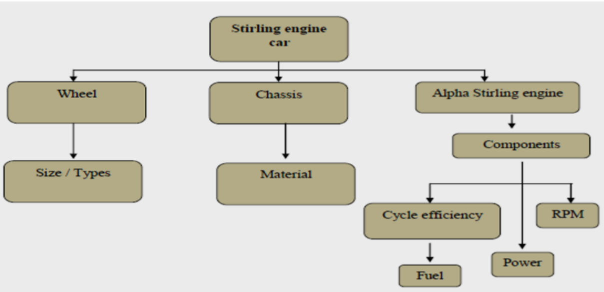

Figure 2: Decomposition for Stirling Engine

Decomposition of functions generates a diagram, called a structure of functions. A function structure is a block diagram that depicts energy, material, and signal labelled arrows moving between function block. The function structure for Stirling engine car is shown in Figure 3.

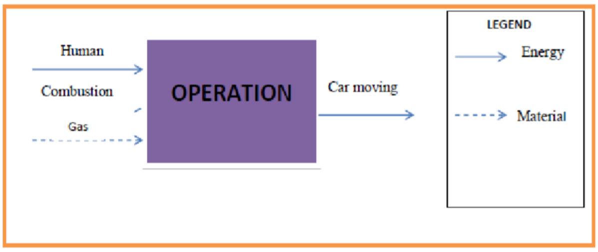

Figure 3: Function Structure for Stirling Engine

3. *Design Configuration:*

Alpha Stirling engine is composed of cold and hot pistons. In motion, the piston shifts to rotate the flywheel in which the gears are attached. The rotation begins from hot to cold piston.A rubber tube serves as a connector between the pistons; the rubber tube lets the air move between two pistons.The power generated by Stirling engine is transmitted to the flywheel in which the gear A is attached.The gearing system's aim is to step up the initial power generated to the higher ratio.For greater power the wheel shaft is shifted. All the plans are brought together in this area, and the decisions are finalized.By using simultaneous engineering methods allowed through computer-aided engineering (CAE), the distinction between embodiment design and information design has become blurred and moved forward in time. Figure 4 shows the Stirling engine car finalised[9].

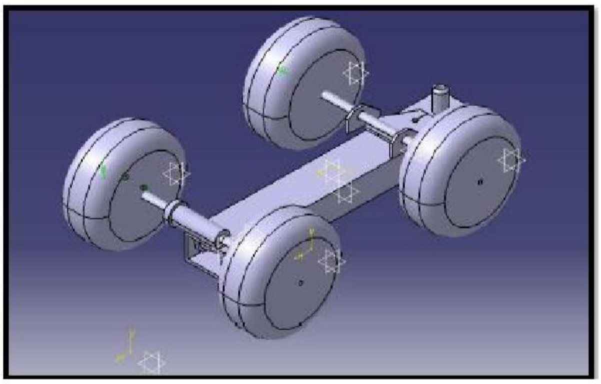

Figure 4: Body of the Stirling Engine

4. Thermodynamic Engine Model:

The transformations in the compression and expansion spaces are isothermal, the average pressure in the system can be linearized, the pressure drops in the exchangers linearized, the lack of conduction or radiation in the machine are neglected.The following sets of equations define the machine:

$$p = \frac{m_g r}{\frac{V_c}{T_k} + \frac{V_k}{T_k} + \frac{V_{reg}}{T_{reg}} + \frac{V_h}{T_h} + \frac{V_e}{T_h}}$$

where p denotes the machine mean pressure, r gas constant, m_g the mass of gas in the machine, V_e,V_c, V_k, V_{reg}, V_h, expansion volumes, compression, cold exchanger, regenerator, hot exchanger, respectively, T_{reg}, T_k, T_h, regenerator, compression or cold exchanger, expansion space or hot exchanger temperature respectively.

$$V_e = V_{cle} + \frac{V_{swe}}{2}\left(1+\cos(\theta+\alpha)\right)$$

$$V_c = V_{clc} + \frac{V_{swc}}{2}\left(1+\cos(\theta)\right) + \frac{V_{swe}}{2}(1-\mathrm{co}$$

Where V_{cle}, V_{clc} denotes expansion and compression clearance volumes respectively, V_{swe}, V_{swc} denotes the compression and expansion swept volumes respectively, α is the phase angle between the displacer and piston, θ is the angular position.

$$Q_i = W_i = \oint p \frac{dV_i}{d\theta} d\theta \quad with \ i = e,c$$

$$W = W_i + W_e$$

$$\eta = \frac{W}{Q_e}$$

Where W work, η thermodynamic efficiency, and Q_i denotes heat exchanged in the expansion or compression space. Additional losses are taken into account by modifying W or Q_e by corresponding amount[10].

5. Acetone and Ethanol Used as a Fuel:

Various fuels have varying levels of energy content and are related to the energy released by combustion. The higher the energy content, the higher the fuel efficiency, which is inversely proportional to its complexity in chemical terms.Acetone liquid fuel with alcohol content 99.51% has higher Lower Heating Value (LHV) and Higher Heating Value (HHV) compared with Ethanol 95.01%.The result shown in Figure 5 is 29.588MJ/kg (LHV) and (HHV) 31.863 MJ/kg for Acetone.In opposite trend for Ethanol shows (LHV) are 26.953 MJ/kg and for (HHV) is 29.847 MJ/kg. Hence, Acetone burning material has higher calorific value or energy value compared to Ethanol[11].

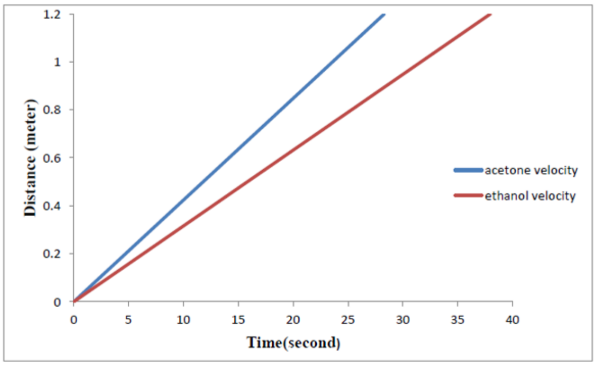

Figure 5: Constant Velocity for Acetone and Ethanol

CONCLUSION

Stirling engine car may use fundamental thermodynamics. Stirling engine is a heat engine that works at different temperature levels by cyclic compression and expansion of air such that a net transfer of heat energy to mechanical work. By producing best speed in the lowest time, Acetone shows better result than Ethanol in Stirling engine car.Stirling engine has high efficiency compared to steam engines, quiet operation and the ease by which any heat source can be used.A Stirling engine consists of a number of basic components which depends on type and configuration. Some of the basics outlined for the alpha Stirling engine are power piston and cylinder, heat source, displacer piston, heat sink and regenerator. It is an internal heat exchanger and temporary heat store positioned between the hot and cold spaces so that the working fluid flows through it first in one direction then in the other. Alpha Stirling engine is composed of cold and hot pistons. In motion, the piston shifts to rotate the flywheel in which the gears are attached. The rotation begins from hot to cold piston. Acetone burning material has higher calorific value or energy value compared to Ethanol.

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REFERENCES

[1] F. Kreith, "Stirling engines," in *Energy Conversion, Second Edition*, 2017.

[2] M. H. Ahmadi, M. A. Ahmadi, and F. Pourfayaz, "Thermal models for analysis of performance of Stirling engine: A review," *Renewable and Sustainable Energy Reviews*. 2017, doi: 10.1016/j.rser.2016.09.033.

[3] A. Z. Hafez, A. Soliman, K. A. El-Metwally, and I. M. Ismail, "Solar parabolic dish Stirling engine system design, simulation, and thermal analysis," *Energy Convers. Manag.*, 2016, doi: 10.1016/j.enconman.2016.07.067.

[4] E. Cardozo, C. Erlich, A. Malmquist, and L. Alejo, "Integration of a wood pellet burner and a Stirling engine to produce residential heat and power," *Appl. Therm. Eng.*, 2014, doi: 10.1016/j.applthermaleng.2014.08.024.

[5] C. J. Paul and A. Engeda, "Modeling a complete Stirling engine," *Energy*, 2015, doi: 10.1016/j.energy.2014.11.045.

[6] F. Formosa and G. Despesse, "Analytical model for Stirling cycle machine design," *Energy Convers. Manag.*, 2010, doi: 10.1016/j.enconman.2010.02.010.

[7] K. Wang, S. R. Sanders, S. Dubey, F. H. Choo, and F. Duan, "Stirling cycle engines for recovering low and moderate temperature heat: A review," *Renewable and Sustainable Energy Reviews*. 2016, doi: 10.1016/j.rser.2016.04.031.

[8] J. H. Shazly, A. Z. Hafez, E. T. El Shenawy, and M. B. Eteiba, "Simulation, design and thermal analysis of a solar Stirling engine using MATLAB," *Energy Convers. Manag.*, 2014, doi: 10.1016/j.enconman.2014.01.001.

[9] D. J. Shendage, S. B. Kedare, and S. L. Bapat, "An analysis of beta type Stirling engine with rhombic drive mechanism," *Renew. Energy*, 2011, doi: 10.1016/j.renene.2010.06.041.

[10] W. Jan and P. Marek, "Mathematical Modeling of the Stirling Engine," in *Procedia Engineering*, 2016, doi: 10.1016/j.proeng.2016.08.376.

[11] J. A. Araoz, M. Salomon, L. Alejo, and T. H. Fransson, "Numerical simulation for the design analysis of kinematic Stirling engines," *Appl. Energy*, 2015, doi: 10.1016/j.apenergy.2015.09.024.

[12] Vishal Jain and Dr. S. V. A. V. Prasad, "Mapping between RDBMS and Ontology: A Review", International Journal of Scientific & Technology Research (IJSTR), France, Vol. 3, No. 11, November, 2014 having ISSN No. 2277-8616.

[13] Vishal Jain and Dr. S. V. A. V. Prasad, "Mining in Ontology With Multi Agent System in Semantic Web : A Novel Approach", The International Journal of Multimedia & Its Applications (IJMA) Vol.6, No.5, October 2014, page no. 45 to 54 having ISSN No. 0975-5578.

[14] Vishal Jain, "A Brief Overview on Information Retrieval in Semantic Web", International Journal of Computer Application, RS Publication, Issue 4, Volume 2 (March - April 2014), page no. 86 to 91, having ISSN No. 2250-1797.

[15] V.M. Prabhakaran, Prof S.Balamurgan ,A.Brindha ,S.Gayathri ,Dr.GokulKrubaShanker,Duruvakkumar V.S, "NGCC: Certain Investigations on Next Generation 2020 Cloud Computing-Issues, Challenges and Open Problems," Australian Journal of Basic and Applied Sciences (2015)

[16] V.M.Prabhakaran, Prof.S.Balamurugan , S.Charanyaa, "Data Flow Modelling for Effective Protection of Electronic Health Records (EHRs) in Cloud", International Journal of Innovative Research in Computer and Communication Engineering, Vol. 3, Issue 1, January 2015

[17] R. Santhya, S. Latha, S. Balamurugan and S. Charanyaa, "Further investigations on strategies developed for efficient discovery of matching dependencies" International Journal of Innovative Research in Science, Engineering and Technology Vol. 4, Issue 1, January 2015