

DESIGN AND FABRICATION OF LIQUID AIR FUELED STIRLING ENGINE USING SOLIDWORKS

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ABSTRACT: *Liquid air powered vehicle are playing a vital role in the area of new energy vehicles. It is due to the reason of its advantages over electric vehicles. Electric vehicles have short battery life, long charging time, heavy metal pollution, spontaneous combustion in comparison with liquid air powered engines. In this article a comprehensive approach is established to describe the construction of SolidWorks model of liquid nitrogen fueled Stirling engine. Schematics of assembly of different parts of the proposed cryogenic heat Stirling engine is described. Force is applied on the Power piston to analyze the kinematics of engine. The simulation results are used to visualize the body movements and respective position, velocity and acceleration as well. Specifically, motion analysis of power piston and axis of proposed Stirling engine are taken in account.*

Keywords: Stirling Engine, Design, Solidworks, Simulation

INTRODUCTION

In current scenario of technology development and advancement, consumers demand for the devices having elevated qualities, efficiencies and functions. This competitive environment leads the engineers to design the products with certain level of qualities and having number of supporting functionalities. It is impossible to develop the prototype of every device for testing and analysis. In this situation computer aided software are used, for example, SolidWorks. SolidWorks is not only useful to make geometrical models of the system but can also perform operations like Kinematics and dynamics on different parts of the body [1, 2]. To obtain the visualization and control on different body parts of working machine, one is needed to integrate the Solidworks model with the Simulink environments. In this way we can control as well as visualize the motion of machine parts.

SolidWorks simulation software is utilized to build the mechanical model of proposed liquid nitrogen fueled Stirling engine. The proposed engine is unconventional Stirling engine in which working gas is liquid nitrogen. Liquid Nitrogen, at atmospheric pressure, has the temperature of -196 deg C. It is regarded as heat sink for Stirling cycle while atmosphere is taken as heat source. This phenomenon creates the temperature difference to convert the heat into work. That converted energy is referred as the cryogenic energy. To obtain this operation a flask is built in the SolidWorks to contain the liquid nitrogen. To increase the rate of heat transfer a porous disc of copper is introduced between the hot and cold spaces. In this paper the 1st section include the introduction, 2nd contain methodology to design model, 3rd & 4th elaborate the physical structure & operations of the proposed engine respectively while 5th explains the fabrication of hardware of CAD model in laboratory.

METHODOLOGY

Figure 1 depicts the flowchart of the SolidWorks operation specifically in the modeling of engines. In the very first stage key parameters of the engine are identified. Each part of the proposed engine plays its unique role in the operation of engine. Function and movements of every part are analyzed. Keeping in view the functions of engine main body or design is architected which can be seen in figure 2. Sketching of model is the basis of constructing the initial drawings which helps the designers to put forward their very idea [3]. Each

and every dimension of the every part of the engine should be sketched prior to the usage of the SolidWorks software tool. To obtain

Architecture Module

In this module, the user draws and creates sketches of the objects. It is the basis for creating an initial drawing for the designers to analyze the key parameters of the proposed product. The sketcher illustrates the ideas and themes to elaborate the objects to develop. All the dimensions of the different parts in the suggested model Stirling engine must be sketched in the drawing, before one can move forward to design the different parts by the usage of the SolidWorks software tool. In the recent SolidWorks software, a smart dimension tool is provided where the objects are measured and calculated automatically with the help of required dimensions. It provides the sketching of required design faster and easier [4]. The precise size and weight of prototype, body sizes and types are identified on the basis of need and functions. After designing and sketching of different parts of the engine, main joints and connections of engine's parts are identified. These joints are fixed on the basis of the basic principle of movements and rotation of the different parts of the proposed Stirling engine. Detailed process of construction of the mechanical modeling of the proposed air-fueled Stirling engine is elaborated in the following flowchart of figure 1.

Part Module

The part module in SolidWorks is associated to build-up a simple 2D sketch in one of the advance tool of sketching command-manager. It contains the geometry like as lines, circle, convert entities, trims, mirror entities, etc and convert that into the 3D models by the usage of different options like extruded boss, fillets, revolved boss, holes, swept cut, extruded cut, etc. Additional user-interface functions are also available in it that is given in the SolidWorks. It is quite and user friendly. For instance, wide range of tools is offered by the SolidWorks which contain the major element that are the Graphics-Window and here whole actions are taken places. In the part module all the features are listed by the Feature Manager. The Property Manager is the option where most of the data inputs are activated and the Command Manager is the option where all of the commands can be accessed in the software tool. In this module body's nature and sizes of used matters are elaborated [5].

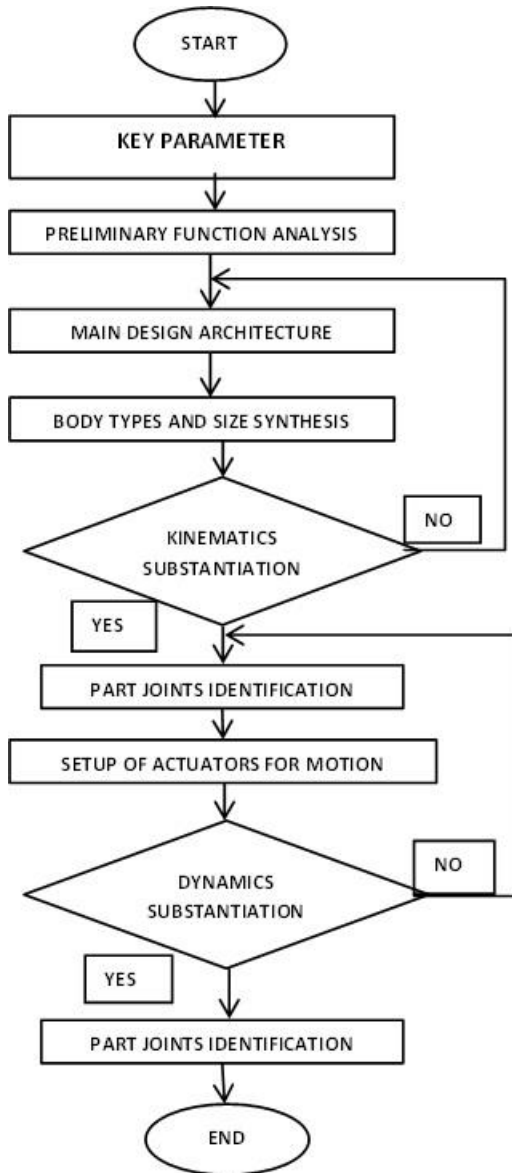


Figure 1 Flow Chart of Mechanical Design of Proposed Stirling Engine

Kinematics Module

The Kinematics module is the module in which different small and big single entities are accumulated to form the complete 3-D object. Two types of methods of design are usually adopted which are: i) Bottom-up method and second one is ii) Top-down design. We can also use the combination of the both methods. In case of top-down design, the combined effect of one or more than one attributes or characteristics of different parts are resized and are ameliorated the model parts. The design concept originates from the assembly module; and it shifts towards the parts module. In assembly module, the available mates have more importance in the joining different parts. In this

way it generates geometric relationship between the components of assembly [6]. In SolidWorks tool, property-manager give a different selection that assists to join the different parts like coincident, distance, concentric, screw, gear, etc. In this module, different types of joint and its positions are established. Very much accurate positions of those bodies and joints are validated in this part of design.

Dynamics Module

In spite of the fact that, assembled parts are observed rotationally and these are exploded by the usage of the interface, it is known as motion manager tools. The motion manager makes the system able to generate the animations which elaborate the motions of assemblies and parts that are based upon a timeline. The obtained results of the capabilities of motion are described as motion study [12]. Three primary methods to create motion in assemblies are used normally that are basic motion, animation and motion analysis. And these relative motions are validated in this section. Different body joints and their relative motion is identified in this part of design.

PHYSICAL STRUCTURE OF ENGINE

After following the above given flowchart, we designed the mechanical structure of the proposed stirling engine. Here, we can view the Isometric and front views of the finally designed stirling engine.

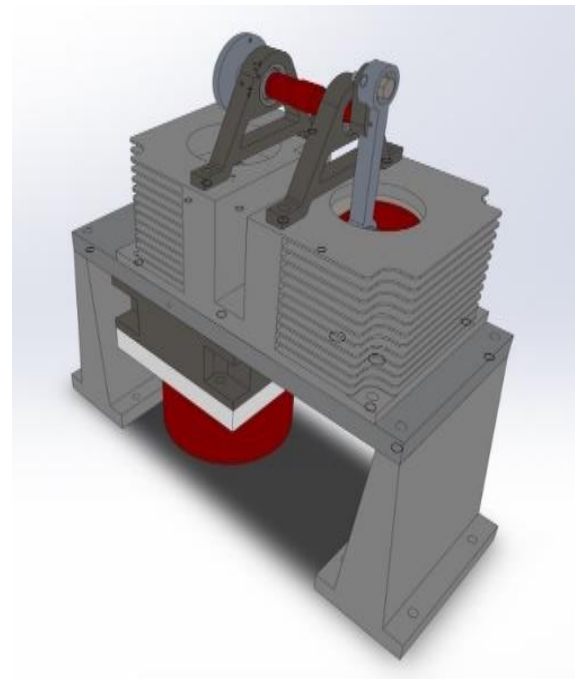


Figure 2 Exploded View of the Stirling Engine (isometric-view)

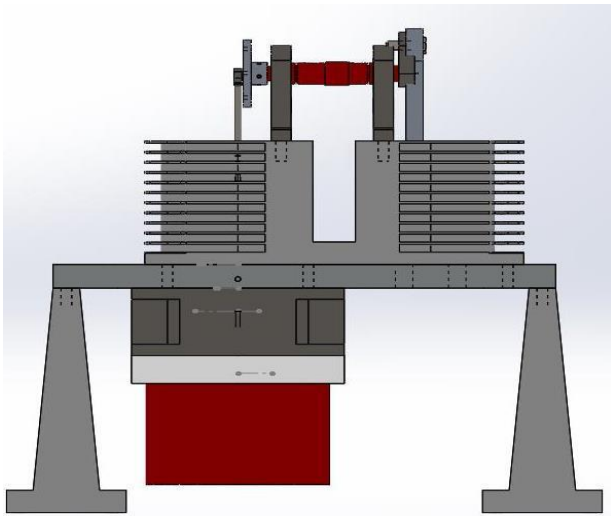


Figure 3 Exploded View of the Stirling Engine (front-view)

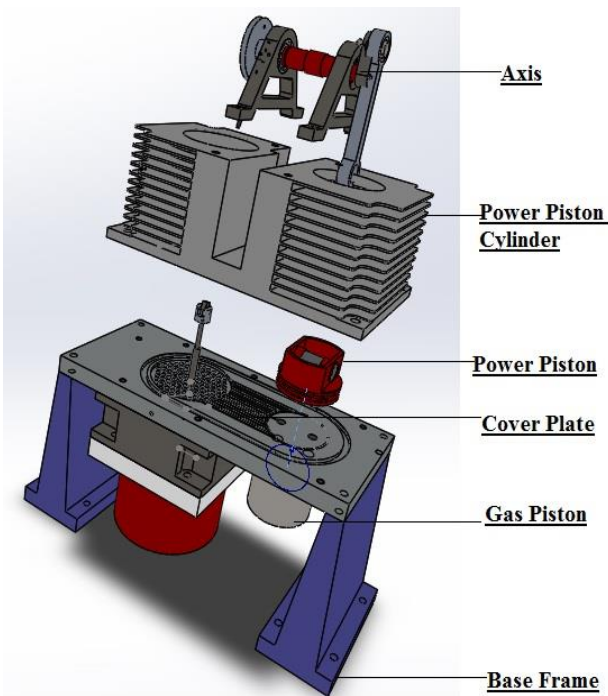


Figure 4 Exploded View of the Stirling Engine

In figure 4, it shows the components of the proposed stirling engine that have been separated slightly with minor distance or it is suspended in the space surrounding on the platform of a three dimensional exploded-diagram [7].

OPERATIONS OF CAD MODEL OF PROPOSED STIRLING ENGINE

To obtain the open-closed mechanism exhaust ports are introduced on the cold space body. Expansion in the hot space leads the power piston to move in the direction of +y-axis and it can be seen in given figure below (Fig. 2-2). In this way position of power piston and angular displacement of axis-rod can be visualized and analyzed. After every cycle of axis-rod around its axis, exhausts ports become open to

discharge the gas. These ports are designed to open after every cycle with the help of port-sensors. Constructed model is the assembly of different parts of the engine. An assembly of different body elements would be used solely for the purpose of simulation analysis. It is due to the reason that in such cases there is always present an interaction between individual parts, which leads to introduce the control system and operate different motion analysis. Thus, every simulation model contains the assembly of individual of sub-assemblies [8].

Construction of the every part of geometric model in SolidWorks which is similar to that one which is most currently used for that type of applications, it starts with defining a 2D geometry that constructs the surface or solid after the completion of one of th main operations (pocket or extrusion). Then, relying on modification or expansion of the achieved element constructed by removing or adding material, the creation of parts is continued. Most of the CAD systems present normalized elements which can be used to construct assemblies. The final assembly of different elements has a permanent link to the each single part file. It shows that alteration created in one of the files is by default associated to the linked files, respectively. The products do not contain its own geometry, rather, it contains of a set of links to the elements and constraints which were used to connect these parts of the machine. The obtained geometric models ought to be parametric that permits the changing positions and dimensions of components that are relative to one another to perform analysis of motion [9]. These geometrical models are not only used for the creation of the simulation model but they also can be used to perform other different of analysis, e.g. modal or stress analysis.

FABRICATION OF HARDWARE MODEL

According to the design formulated in the Solidworks software, a hardware is fabricated in the Laboratory of Energy Conservation and Pneumatic Control, Beihang University, Beijing. The hard is expressed is in figure 5 and figure 6 which is fabricated in the lab [10].

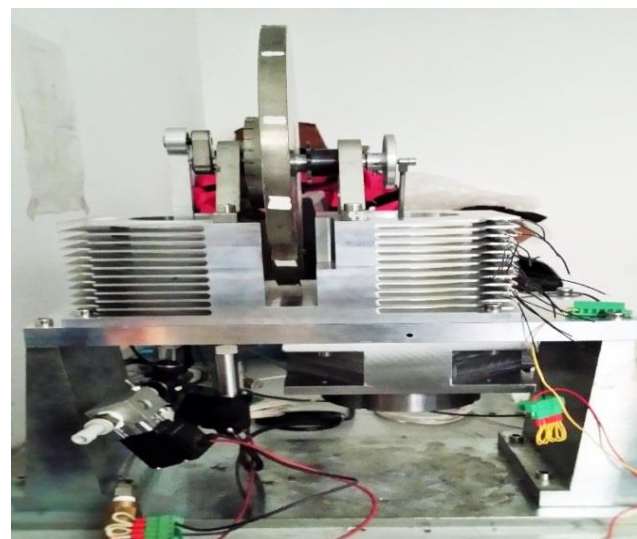


Figure 5 Hardware model of stirling engine (front view)

We can distinguish the major parts of the engine in the given figures like power piston, axis of rotation, power piston cylinder and gas piston etc. The two main concerned parts of this research are Axis and Power Piston of the proposed stirling engine. We can observe the movement of the power piston is the translational motion. The direction of movement of the power piston is in the +y-axis direction. On the other hand movement of axis is rotational and it rotates around the x-axis. The maximum range of axis is therefore, from -180 degrees to +180 degrees [11, 12].



Figure 3 Hardware model of stirling engine (side view)

CONCLUSION

This paper presents the design, modeling, assembly and fabrication of the air fueled stirling engine using the SolidWorks 3D CAD software. Different parts of the proposed stirling engine are sketched and designed. Those parts were combined with each other using different types of required joints. To make sure the required rotation and direction of motion of moveable parts of the engine, angular joints are utilized. The designed model was then fabricated in the lab to perform the practical analysis. The SolidWorks simulation is easy to use and enabled easy and quick detection of errors in the design of the parts. By applying boundary conditions; testing and calculation of various parameters could be carried out which enabled analysis of the model performance. The flow simulation study enabled pressure; density and velocity analysis to be carried out to ensure the flow rates obtained is as per specification. The motion study of proposed engine helps the designer to imagine the observe movement thus enable him to develop the movement of the model to be realistic.

RECOMMENDATION FOR FUTURE DEVELOPMENT

In SolidWorks, there are certain sections that can be improved. Integration of SolidWorks with LabVIEW allows customers to develop their motion control algorithm and use the 3D CAD model created within SolidWorks to evaluate

the system behavior and performance. By applying realistic motion control, it is possible to simulate real-world operating conditions for the design, check for colliding parts, output numerical and graphic data of the results, and use of the CAD model for 3D visualization.

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