STIRLING ENGINE: FROM DESIGN TO APPLICATION INTO PRACTICE AND EDUCATION

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ABSTRACT

Stirling motor is a type of outside ignition heat motor that can utilize various fuel sources from customary structures (coal, oil, kindling, rice husk, and so forth) to sustainable power sources (sun-oriented energy), climate, squander heat usage, and so forth). The article centers around introducing the fundamental highlights of the improvement history, activity qualities, and plan techniques for certain sorts of Stirling motors, in this way offering useful appropriateness as well as a college preparing for understudies. The understudy studying Thermal Engineering in our nation today.

Keywords*: Recycled energy; Stirling engine; Education program; Design.*

1 INTRODUCTION

Stirling engine is a type of engine external combustion heat using piston, is bright formulated by Robert Stirling in 1816. In principle of operation, the Stirling engine uses using a gas (usually air, hydrogen or helium) as the active medium in a closed cycle. Other than internal combustion engines, Stirling engines do not have intake and exhaust valves, meaning no circulation in and out of the medium. The working process of Stirling engines are based on expansion and contraction return of the air mass during motion in the closed cycle inside the engine thanks to the temperature difference between two hot sources, cold. During operation, the air mass in the motor will be pushed back and forth from the part hot to cold or vice versa, thanks to movement of pistons or runner has the function of exchanging the volume of gas between two parts. Air mass when oscillating back and forth between

The hot part and the cold part will do the work a bearing piston, through which the flywheel is operated and outside machinery. From the original practical application of a Stirling engine in pumping water in quarry in 1818, the Stirling engine was developed quite strongly in the second half of the 19th century. By the beginning of the 20th century, with the appearance of types of internal combustion engines using cycles heat Otto and Diesel, along with the explosion of oil extraction and production industry mines, all kinds of external combustion engines such as engines Stirling and steam engines were gradually replaced so. Notwithstanding, beginning from the following phase of the twentieth century, because of its unfriendly impacts on the climate of the field and the earth (nursery impact, a worldwide temperature alteration, ocean level ascent, and so forth), patterns in the utilization of petroleum product sources are being prescribed by numerous nations to slice dropping to change over to fuel sources cleaner and all the more harmless to the ecosystem. Coins trend has motivated many individuals and organizations as well as companies in recent times return to focus on research, manufacturing and development developed a variety of Stirling engines to deliver into use in many different fields such as: solar generators, car engine, chip cooler computers, submarine engines, etc.

In recent times, the works Research on Stirling engines has attracted much attention from many scientists, research institutions in the world. Some directions the main research can include the following:

- Research direction on environmental change used inside the engine to increase efficiency engine power and power, typical as a series of research works by Philips aims to develop the dynamic line Stirling engine using hydrogen with work series operating capacity up to 30kW, efficiency reached 36%.
- Research direction to use Biogas fuel source for engine heat Stirling to generate electricity for the countryside. Wallet For example, Podesser designed and manufactured make a Stirling diesel

engine using fuel biogas to provide electricity for the region countryside, capacity 3.2 kW, efficiency 25%.

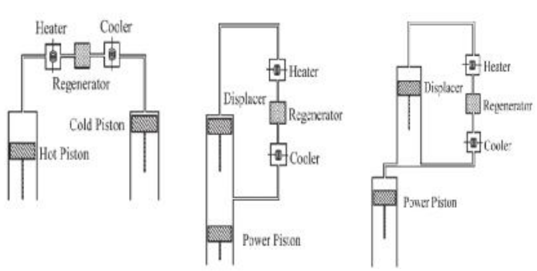
- Some other research directions focus on designing and manufacturing systems produce electricity from solar energy, use Stirling engines with various types of connections different configurations to increase efficiency use.

In Southeast Asia, much Research work from hypotheses to assembling and useful applications connected with motors Stirling has been engaged by nations like Malaysia, Thailand, China Singapore, and so forth created as of late. Among them, most of the authors focus on studying the ability of Stirling engine to generate electricity [21], in addition, some other authors analyze the application of Stirling engine in utilizing waste heat, water pumping, as well as some refrigeration applications.

Thus, research works on Stirling engines in the world have formed and developed from the beginning of the 20th century to the present day, forming a highly inherited knowledge system, developed in parallel between the two countries. Theory and experiment, combining from research and manufacturing from small models to complex practical applications. In Vietnam, researches on this type of external combustion engine are quite limited. Some major research works can be mentioned such as: research and survey on solar thermal power (CNDMT) technology and manufacturing capabilities in Vietnam; research on Stirling engines receiving heat from solar collectors to generate water pumping work; Master's thesis "Application of Stirling engine in refrigeration equipment", etc. The domestic research works are in general still fragmented, there is no synthesis and unification between theoretical calculations, theory and experiment. Besides, the results obtained to be able to be applied in practice are still quite far away

2. MATERIALS AND METHODS

In terms of structure, in general, Stirling engines built in the world can be classified into one of three types Alpha, Beta, and Gamma as shown in Figure 1.



a) Type Alpha b) Type Beta c)Type Gamma

Figure 1. Structure of three types of Stirling engines

In terms of operating principle, all three types of Stirling engines above have the same characteristic that they have 3 main parts arranged in series: the heat receiver (Heater), the heat recovery part (Regenerator) and the unit. cooler (Cooler). However, due to the different structural characteristics (number of cylinders, arrangement of pistons in cylinders, etc.), the three types of engines Alpha, Beta and Gamma will have some different characteristics as shown in Table 1.

Table 1. Structure and operation characteristics of 3 types of Stirling engines

Alpha	Gamma	Beta
- There are 2 cylinders; - The heat receiver (Heater) and cooler (Cooler) are located on 2 different cylinders; - Large compression ratio; - Sealed rod on both pistons; - Working piston must work at high temperature.	- 2 separate cylinders; - The heat receiver (Heater) and cooler (Cooler) are located on 2 different cylinders; - Compression ratio is smaller than Alpha type; - Only need to seal in 1 piston, the other piston moves without friction in the cylinder; - Pistons work at low temperatures	- Only 1 cylinder; - Heater (Heater) and cooler (Cooler) are on the same cylinder; - Compression ratio is smaller than Alpha type; - Only need to seal in 1 piston, the other piston moves without friction in the cylinder; - Pistons work at low temperatures.

Corresponding to the above 3 types of Stirling engines, many theoretical computational models have been developed in the world. The first theoretical model developed by Schmidt is based on the hypothesis that the compression and expansion of the gas inside the engine is an isothermal process of the ideal gas. Schmidt's theory leads to the establishment of a system of linear thermodynamic equations that can be easily solved, thereby determining the work Stirling engine performance and thermal efficiency. Due to its simplicity and tolerable deviation between theoretical and practical results, Schmidt's computational model was widely used in the preliminary design of Stirling engines. However, some studies show that when the engine speed exceeds 1000 rpm, the compression and expansion of the gas in the Stirling engine cylinder is closer to the adiabatic process than the isothermal process. led to the formation and development of the ideal adiabatic model and the subsequent non-ideal adiabatic taking into account the effects of frictional flow losses and heat loss at the reheater. With two computational models of ideal adiabatic and non-ideal adiabatic, the connection between the boundaries of strain, volume, and temperature in districts in the Stirling motor is appeared through an arrangement of differential conditions and is given by a bunch of differential conditions. decided mathematically. This paper does not present in detail the sequence of Stirling engine calculation using the above three models, however, the evaluation of the difference between these three theoretical methods with experimental results can be verified one by one. The overall way through the reference brings about the report and When considering the p-V graph for the straightforward investigation introduced in Figure 2 beneath, obviously the thought of the non-ideal hotness exchangers caused a bigger deviation from the ideal p-V outline than that of the adiabatic examination. Peruser (1983) states that this peculiarity happens because of the way that the chamber dividers don't give a hotness move mode of adequate high conductance to guarantee steady gas temperatures inside the chambers, along these lines causing deviation from the isothermal circumstances and consequently the thought of the non-ideal hotness exchangers. Peruser (1983) likewise specifies that the deviation is more articulated on the hot side of the motor than on the virus side, as shown in Figure 2 and Tables 2, table 3.

Table 2. Experimental parameters of the motor

Operation parameters	Value
Mean pressure (Pmean)	1.148 bar
Cold source temperature (T_k)	46^{0}C
Heat source temperature (T_h)	448^{0}C
Frequency (f)	1.22Hz

Table 3. Simulation and experimental results

	Experim ent	Tempera ture is not ideal	Ideal temperat ure	Schm idt
Power	14	14.21	16.2	21.81
Efficie ncy	35.1	38.4	42.1	55.76

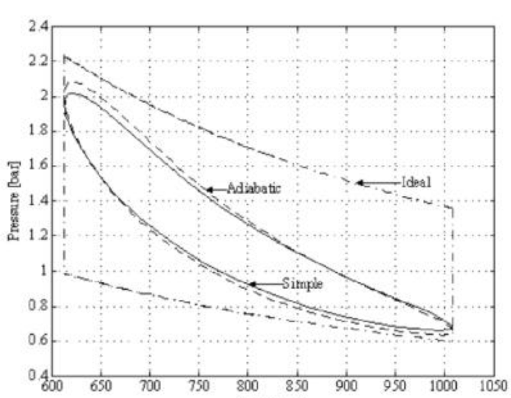


Figure 2. Operating cycle of the motor according to 3 methods Schmidt (Ideal), ideal adiabatic (Adiabatic) and non-ideal adiabatic (Simple)

The results show that the Schmidt method has the most errors compared to the other two methods. Table 3 also shows that the theoretical analysis by non-ideal adiabatic is closest to the experimental results.

3. RESULTS AND DISCUSSION

The results from research works around the world show that theoretically, the Stirling engine can achieve 50% to 80% of the ideal efficiency of the reversible thermodynamic cycle (such as the Carnot cycle) in the conversion of heat energy into work. Unlike internal combustion engines, this type of heat engine can operate with a variety of heat sources, from cheap, locally available fuels to renewable energy sources such as solar energy, heat generated by chemical reactions, waste heat sources, to nuclear reactions. Besides the outstanding advantages, the Stirling engine also has its own disadvantages. Based on the analysis of research works on Stirling engines, the main advantages and disadvantages of this type of engine can be summarized as follows:

Advantage:

- Easy to use with many different heat sources: direct heating, solar energy, geothermal, nuclear reaction, industrial waste heat, etc…;
- Can operate with temperature difference between hot and cold sources only from a few tens of degrees Celcius;
- The structure is simpler than the internal combustion engine because there is no need for intake and exhaust valves; the combustion chamber has a simple structure, requires little lubricating oil, etc;
- Quieter operation, less vibration and stability than internal combustion engines;
- Simpler maintenance than internal combustion engines;
- Safer in operation due to lower working pressure than steam engines and internal combustion engines;
- The internal working medium is air or an inert gas (such as Helium), operating in a closed space inside the engine, so it is not capable of causing fire and explosion, with high safety in use;
- The burning chamber is situated outside, the ignition happens persistently, it is feasible to control not to leave overabundance fuel, so it ought to restrict harmful material contrasted with the burning cycle in the inward chamber;
- Does not need an air supply (if the heat source is not from burning fuel) so it can operate under submarines or in space;

- Can start more easily in cold weather than internal combustion engines.

Defect:

- Because the heat transfer coefficient of air (as well as other inert gases used in Stirling engines) is not high, Stirling engines (especially those operating with low temperature difference between hot and cold sources) has a larger size than an internal combustion engine at the same power, resulting in a higher cost of manufacturing materials per unit of power than an internal combustion engine;

- Unlike the internal combustion engine, the Stirling engine has a rather large temperature difference between the hot and cold parts, leading to requirements on the quality of the materials used and the need for heat exchangers in the hot and cold parts. high efficiency refrigeration;

- Due to the complexity of the heat exchange process in the Stirling engine, the actual heat cycle of the engine is considerably less efficient than the theoretical cycle;

- Stirling engines cannot be started immediately, but require warm-up time, which makes them more suitable for applications with steady, uniform operating speeds.

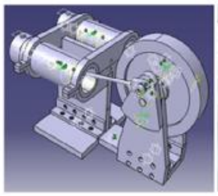
With the above operational characteristics, the Stirling engine has great potential in our country in taking advantage of many cheap fuel sources available locally, in remote areas, on islands, etc. to supply the power supply is applied in many areas of life such as: electricity generation, water pumping, rice milling, ice production, refrigeration etc. In addition, due to its ability to operate with low temperature difference, A very remarkable direction of Stirling engine in Vietnam is the applicability of this engine in taking advantage of waste heat sources from industrial and agricultural production (such as exhaust fumes at factories). The Cement machines, steel mills, fertilizer production, etc.), as well as using solar energy as a source of heat for engines.

Besides the potential for practical applications, the Stirling engine can also be used as a useful teaching tool in the University, especially suitable for students of the Faculty of Mechanics, Transport and Refrigeration. Some ways to integrate Stirling engine into subjects (such as “Engineering Thermodynamics”, “Heat Transfer”, “Heat Engine”, “Mechanical Design”, “Study Project”, etc) can be applied as follows:

Use as a visual model for classroom instruction: in this method, the teacher will use a commercially available Stirling engine model with a cylinder body made of several transparent materials (glass, plastic), works with simple heat sources (candles, alcohol wicks) to help students easily observe directly the operation of engine parts from the inside out, thereby analyzing , discuss as well as manually measure the parameters of hot source temperature, cold source temperature, engine size, etc. and apply theoretical knowledge to calculate related heat exchange processes.

Use as a machine design exercise: in this method, from the initial requirement of engine power, students can apply one of three theoretical models (isothermal, ideal adiabatic, adiabatic) not ideal) for the calculation and preliminary design of a type of Stirling engine (Alpha, Beta or Gamma). Design drawings and assembly drawings can be instructed and required by the teacher with the support of some 3D mechanical design software such as Solidworks, Solid edge, Catia, Pro Engineer, etc.

Use as a manufacturing project to help improve teamwork and creativity for students: in this way, teachers can introduce Stirling engines through video clips, images or some model implementation keyword first, then ask students to find out more on the Internet, books, etc. and combine with specialized knowledge they have learned to build a simple Stirling engine model from available items (soft drink cans, CDs, wire ropes, etc.). Depending on the level of simplicity or complexity, this project may be required to be done individually or in groups. The final score will include an evaluation of the presentation, a student report on the sequence of calculations, design, and fabrication, and an evaluation of the actual performance of the model.



3D design by solidworks

Build and test engines in the classroom

Figure 3. Application of Stirling engine design and manufacture in the thermal engineering engineering training program at the University in Viet Nam

Figure 3 shows some pictures of the application of Stirling engine integration in the teaching process of some specialized subjects of Heat and refrigeration at the University in Viet Nam. The results show that the application of computational, design and manufacturing models such as Stirling engines to teaching has brought good effects in improving students’ dynamism and creativity, helping them understand and I love more than my chosen field of engineering.

4. CONCLUSION

After nearly 200 years of development history, the Stirling engine is still proving its role and position as a useful device capable of converting heat supplied from many different energy sources into mechanical energy. Usability in many practical applications. Through the article, the authors wish to bring a clearer view of the potential applications in practice as well as in teaching of this type of external combustion engine, thereby promoting more in-depth research. From materials, internal structure, layout of external heat sources of domestic engineers, experts and scientists in order to develop and widely apply this type of engine in Vietnam in the future.

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