A Review on Stirling Engine Performance

Pratik Sirsath[#1], Sumit Raut[#2], Swapnil Pawar[#3], Nikhil Parmar[#4], Rajan Petkar[*5]

[#]*Student, Department of Mechanical Engineering, Zeal College of Engineering and Research, Pune, India*

[*]*Assistant Professor, Department of Mechanical Engineering, Zeal College of Engineering and Research, Pune, India*

Abstract— **An important aspect of using energy is to maintain pollution to a minimum level. Stirling engine offers an alternative to fossil fuels. It converts heat form of energy to kinetic energy of a mechanism. Present paper reviewed different factors that affect the performance of Stirling engine. There are three types of Stirling engines: alpha, beta and gamma type of engine. This study helps to improve design, thermal characteristics, frame work and efficiency of Stirling engine.**

***Keywords*— Stirling engine, temperature difference, gamma type engine, beta type engine, numerical model**

I. Introduction

Energy used all over the earth for different applications is mostly obtained from fossil fuels and natural gas. Use of these resources produces pollution. Stirling engine can be used to do work using heat from solar energy as well as other sources of heat energy.

Stirling engine is a kind of heat engine which produces no emission. It can also be used for applications like, waste heat recovery. Types of Stirling engine are alpha, beta and gamma. Stirling engine is very efficient for given temperature difference between heat source and heat sink [1]. It can be very small and run with only small temperature difference. Along with solar energy, geothermal heat can also be used as a renewable source of energy to produce electricity. It requires only a few calories of energy to drive Stirling engine and keep it running. Auxiliary cost of the engine is low. Stirling engine is a need of sustainable development.

II. Performance of Stirling Engine

Stirling engine converts energy in the form of heat to mechanical work by continuous compression and expansion of a gas in cyclic manner. Fig. 1 shows an ideal Stirling cycle which consist of two isochoric processes and two isothermal processes [2].

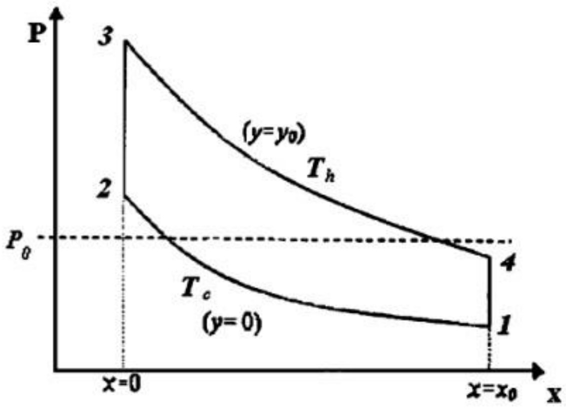

Fig. 1 Ideal Stirling cycle

Dmitry et al. [1] proposed design framework of Stirling engine which provides a reduction of time and resources. The parameters were decided with trial and error method. Gamma and beta type of engines combine power generation and efficient design for small range applications. Tavakolpour et al. [2] tested a Stirling engine which is operated on solar energy and designed for low temperature difference. They designed Stirling engine without regenerator and studied its effect on thermal efficiency of the engine. The effect of variation in regenerator efficiency corresponding to theoretical efficiency of the engine was simulated by a computer program. It has been observed that more the regenerator efficiency more is the thermal efficiency of Stirling engine.

Fig. 2 shows structure of a Stirling engine [3]. Scotch yoke mechanism can be used to construct a compact type of engine. The development cost can be reduced by using high speed tool steel, linear bearing, etc. which are standard parts. When temperature difference is high, displacer design has length to bore ratio of about 3 to 4 while for low temperature difference, it is less than unity. The length to bore ratio affects heat transfer. Power piston has to be designed robust enough to bear pressure difference. In order to maximize power output leakage through piston clearance is minimized by piston ring. To ensure relative motion between power piston and displacer a brass bush can be used to suspend the displacer rod. Halit et al. [4] provides useful information regard thermal analysis of low temperature difference (LTD) Gamma configuration Stirling engine with mat lab software. The geometrical parameters like displacer and power piston stroke increase by scale factor for checking the maximum indicated power. Also the heat sink temperature is affected by indicated power. The calculation work is done for temperatures as heat source temperature and heat sink temperature 303K and 307K respectively. Mohd et al. [5] shows the information about development and improvement of Stirling engine for reducing low emission level considered for beta type engine. They performed the research work on ideal adiabatic model of berchowitz and ureli .The efficiency of this design can be increased by increasing temperature difference between source and sink. Stirling engine driven by temperature biomass gas are able to achieve a valuable output power [6]. Maximum brake power output was obtained with helium 550 c heat source temperature and 10 bar charge pressure at 700 rpm at 96.7 watt. Most power can be obtained from the sawdust (46 watt). At maximum power, the internal thermal efficiency of Stirling engine was measured as 10%. Result of work encourages initiating design of single cylinder gamma type Stirling engine of 1 kg capacity for rural electrification.

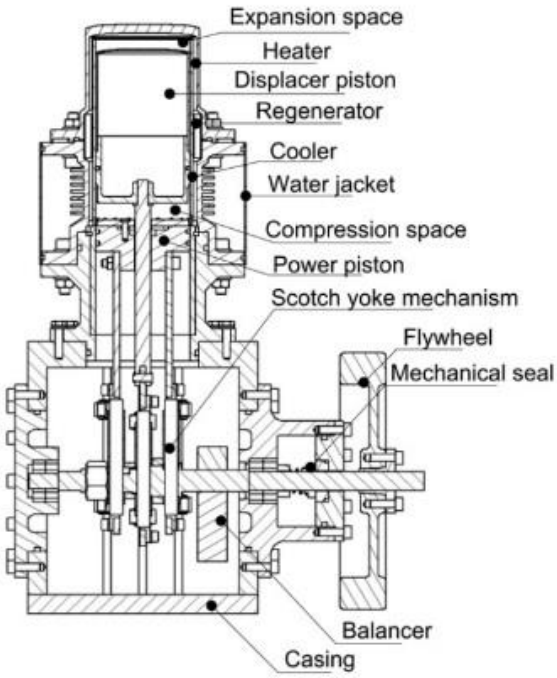

Fig. 2 Details of Stirling Engine

Khaled et al. [7] studied a more realistic thermodynamic model for alpha type Stirling engine. The main differential Stirling engine that stakes thermal losses into account utilizing rose yoke drive mechanism derived. According to simulation results engine performance can be improved and can be achieved by increasing the thermal conductivity of regenerator, matrix, increasing generator heat capacity, optimizing generator volume, optimizing working frequency, and optimizing working mass of gas.

K.G. Maheshwaran [8] explained the design and fabrication of beta type Stirling engine. This type of engine uses power sources like solar, sugar-cane leaves, wheat stalk. This engine can be applicable certain rural areas there are energy which cannot be gain conventional energy source. In this paper design and manufacturing of beta type Stirling engine with rhombic drive was analysed. The design of the engine was limited for certain efficiency due to drive complexity and tight tolerance. The accuracy of the result and difficulty of design calculation depend on no of assumed unknown and in this work 200W of power beta type Stirling engine was analyzed. Abuelyamen et al. [9] worked on parametric study of β - type Stirling engine with no regeneration or was conducted with numerically method using ANSYS fluent 14.5 software there are three parameter that work concern i.e. a) air-initial charge pressure. b) He-thermal boundary condition. With respect to this type of working fluid the engine was analyzed and it was seems like H2 gas is most efficient of engine. It is conclude that a comprehensive parametric study of laminar flow of Stirling engine. There are some points concerned the optimum charge pressure which is for operational temperature end limits between 300 to 800k .So we get optimum pressure for a) air-1.75 bar b) He-2.5bar c) H2 -10 bar For air and He gases the power o/p increases proportionally temperature between TH and TC. Halit et al. [10] analyzed a novel configuration of β - type Stirling engine. He revealed kinematic and thermodynamic point of view by means of nodal analysis the instantaneous temperature distribution of working fluid, through the heating-cooling passage conducting the cold to hot space. It is observed that comparison of novel engine with crank driven and rhombic –drive engine indicates that compression ratio of novel engine is lowest among three engines.

Tie Li et al. [11] presented development and test work of Stirling engine applied for micro-CHP system. The test work confirmed that the Stirling engine could be drive mid-high temperature waste gases. The loss between inlet and outlet regeneration is more than twice of that between the inlet and outlet. Jirí Podesva et al. [12] evaluated four mechanisms with the hook’s joint and it seems to be very satisfactory. It is simple to design and leads to good shape of the transferring piston path. Valenti et al. [13] developed numerical model of Stirling engine which is validated by experimental results. Experimentation includes Stirling engine and heat recovery setup. It has been observed that inlet temperature affects net output of electric power. The total electrical efficiency was calculated as about 15% while it was measured is observed above 9%.

III. Conclusions

In this review paper following points can be concluded:

- Temperature difference affects efficiency of Stirling engine. Increase in temperature difference increases efficiency of the engine.
- Single cylinder Stirling engine can be used for electricity generation in rural area.
- Stirling engine can be used for less temperature difference applications.
- Stirling engine produces no pollution, thus can be used for waste heat recovery.
- Numerical model can be used to predict performance of a Stirling engine.

References

[1] Dmitry Smirnov, Alessandro Golkarb, "Stirling engine Systems Tradespace Exploration Framework," 2015 Conference on Systems Engineering Research. doi: 10.1016/j.procs.2015.03.010

[2] Ali Reza Tavakolpour, Ali Zomorodiana, Ali Akbar Golneshanb, "Simulation, construction and testing of a two-cylinder solar Stirling engine powered by a flat-plate solar collector without regenerator," Renewable Energy 33 (2008) 77–87. doi:10.1016/j.renene.2007.03.004

[3] Angkee Sripakagorn, Chana Srikam, "Design and performance of a moderate temperature difference Stirling engine," Renewable Energy 36(6):1728-1733 · June 2011 with 147 Reads doi: 10.1016

[4] Nattakil Tongdee, Mongkhol Jandakaew, Teetul Dolwiknai, "Thermodynamic analysis for optical geometrical parameters and influence for heat sink temperature of Gamma- configuration Stirling engine," Energy Procedia 105 (2017) 1782 – 1788. doi: 10.1016/j.egypro.2017.03.516

[5] Autor:-mohd farid zainadin, Rosti abu bakar,gan leong ming ."Thermodynamic cycle evaluation of rhombic drive beta configuration Stirling engine", Modern Mechanical Engineering 6(4):113-128 · November 2016 with 275 Reads DOI: 10.4236/mme.2016.64012

[6] Hojjat Damirchia, Gholamhassan Najafia, Siamak Alizadehniab, Barat Ghobadiana, Talal Yusafc, Rizalman Mamatd, "Design, Fabrication and Evaluation of Gamma-Type Stirling Engine to Produce Electricity from Biomass for the micro-CHP system," Energy Procedia 75 (2015) 137 – 143. doi: 10.1016/j.egypro.2015.07.240

[7] Khaled M. Bataienely, "Numerical thermodynamic model of alpha-type Stirling engine," Case Studies in Thermal Engineering 12, 2018, 104-116.

[8] K.G.Maheshwaran, "Design and manufacturing of Beta type stiring engine" March 2017- International Journal of Innovative Research in Science, Engineering and Technology An ISO 3297: 2007 Certified Organization Volume 6, Special Issue 7, April 2017 5th National Conference on Trends in Automotive Parts Systems and Applications

[9] A.Abuelyamen,"Parametric study on beta-type Stirling engine" Energy Conversion and Management 145:53-63 · August 2017 with 51 Reads DOI: 10.1016/j.enconman.2017.04.098

[10] Halit karabulat ."Thermodynamic Analysis of a β - type stiring engine with a displacer driving mechanism by means of a lever", Renewable Energy 34(1):202-208 · January 2009 with 155 Reads DOI: 10.1016/j.renene.2008.03.011

[11] Tie Li,Dawei Tanga ,"Development and test of a striling engine driven by waste gases for the micro-CHP system ", 31 May 2018 Applied Energy 226 (2018) 522–533 0306-2619/ © 2018 Elsevier Ltd.

[12] Jiri Podesva "The Stirling engine mechanism optimization" Elsevier (Nov -2015) Journal code 1544040 Article code 2061624

[13] Gianluca Valenti, Paolo Silvaa, Nicola Fergnania, Gioele Di Marcoberardinoa, Stefano Campanaria, Ennio Macchia, "Experimental and numerical study of a micro-cogeneration Stirling engine for residential applications," Energy Procedia 45 (2014) 1235 – 1244. doi: 10.1016/j.egypro.2014.01.129