IJSTE - International Journal of Science Technology & Engineering | Volume 2 | Issue 2 | August 2015
ISSN (online): 2349-784X

Review: "Design and Development of Gamma Type Striling Engine for Waste Heat Recovery"

Punam Kumar Aagade
PG Student
Department of Mechanical Engineering
Rajiv Gandhi Proudyogiki Vishwavidyalaya

Ajit Prakash Rastogi
Assistant Professor
Department of Mechanical Engineering
Rajiv Gandhi Proudyogiki Vishwavidyalaya

Rohit Kumar Choudhary
Head of Department
Department of Mechanical Engineering
Rajiv Gandhi Proudyogiki Vishwavidyalaya

Abstract

Recent trend concerns about the best ways of using the deployable sources of energy in to useful work in order to reduce the rate of consumption of fossil fuel as well as pollution. There are different ways to recover the heat available with the waste or rejected heat from different sources. Out of all the available sources, Gamma type Stirling engine is be used to convert waste heat in to useful work. A single power piston, gamma-configuration, low-temperature differential Stirling engine is design, develop and tested with air by using a gas burner as a heat source. The engine testing is performed with four different heat input. Variations of engine torque, shaft power and brake thermal efficiency with engine speed and engine performance at various heat inputs are presented. The Beale number, obtained from the testing of the engine, is also investigated.

Keywords: Striling, Waste, heat, Recovery, heat exchanger, Gamma

I. INTRODUCTION

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then dumped into the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its value. The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved. Large quantity of hot flue gases is generated from Boilers, Kilns, Ovens and Furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved.

A. Waste Heat Recovery:

There exist today worldwide concerns about the best ways of using the deployable sources of energy, and of developing techniques to reduce pollution. This interest has encouraged research and development efforts in the fields of alternative energy sources, cost effective use of the exhaustible sources of energy, and the re-use of the usually wasted forms of energy. A large number of industrial processes, covering most industrial sectors, use significant amounts of energy in the form of heat, which is rarely utilized efficiently. M Thus there is considerable scope for the use of heat exchangers and other forms of heat equipment to enable waste heat to recover. The energy that is wasted by industry takes the forms of unburned but combustible fuel, sensible heat discharge from drain water, and more notably, the sensible and latent heat discharge from the gases. Gateman and Zwickler made a survey of the waste heat related industries and concluded that refuse incineration, sewage incineration, cement factories, glass furnaces, foundries, and industrial incinerators provided ample opportunities for waste hear recovery. They suggested that the recovered waste heat be used for water desalination. Waste energy can be recovered by the installation of combustion equipment to utilize the wasted fuel, and the provision of heat recovery equipment to regain sensible and latent heat. Much effort has been expended during the past two decades to re-use the wasted heat.

B. High Temperature Heat Recovery:

The table 1.1 gives temperatures of waste gases from industrial process equipment in the high temperature range

Table - 1.1
Typical Waste Heat Temperatures at High Temperature Range from Various Sources

Types of device	*Temperature 0C*
Nickel refining furnace	*1370-1650*

Glass melting furnace	*1000-1550*
Hydrogen plants	*650-1000*
Solid waste incinerators	*650-1000*
Steel heating furnaces	*925-1050*
Copper refining furnace	*760-815*

C. *Medium Temperature Heat Recovery:*

The table 1.2 gives the temperatures of waste gases from process equipment in the medium temperature range. Most of the waste heat in this temperature range comes from the exhaust of directly fired process units.

Table - 1.2
Typical Waste Heat Temperatures at Medium Temperature Range from Various Sources

Types of device	*Temperature 0C*
Steam boiler exhaust	*230-480*
Gas turbine exhaust	*370-540*
Reciprocating engine exhaust	*315-600*
Heat treating furnaces	*425-650*
Drying and baking ovens	*230-600*

D. *Economic Evaluation of Waste Heat Recovery System:*

It is necessary to evaluate the selected waste heat recovery system on the basis of financial analysis such as investment, depreciation, payback period, rate of return etc. In addition the advice of experienced consultants and suppliers must be obtained for rational decision.

E. *Waste Heat Recovery Devices:*

The commercial waste heat recovery devices are Heat pipe, Economizer, Shell and Tube Heat Exchanger, Plate Heat exchanger, Waste Heat Boilers, Recuperators, Heat Pumps etc.

F. *Utilization of Waste Heat:*

There are many methods through which waste heat energy can be recovered and utilized. Depending on the temperature level of the wasted heat and the proposed application, different heat exchanger devices can be employed to facilitate the use of the recovered heat. Fig. Shows a schematic of possible energy utilization schemes. Energy storage is needed when there is a time span between energy recovery and use. The application of heat recovery should be physically close to the source of waste heat for maximum benefits from recovered energy.

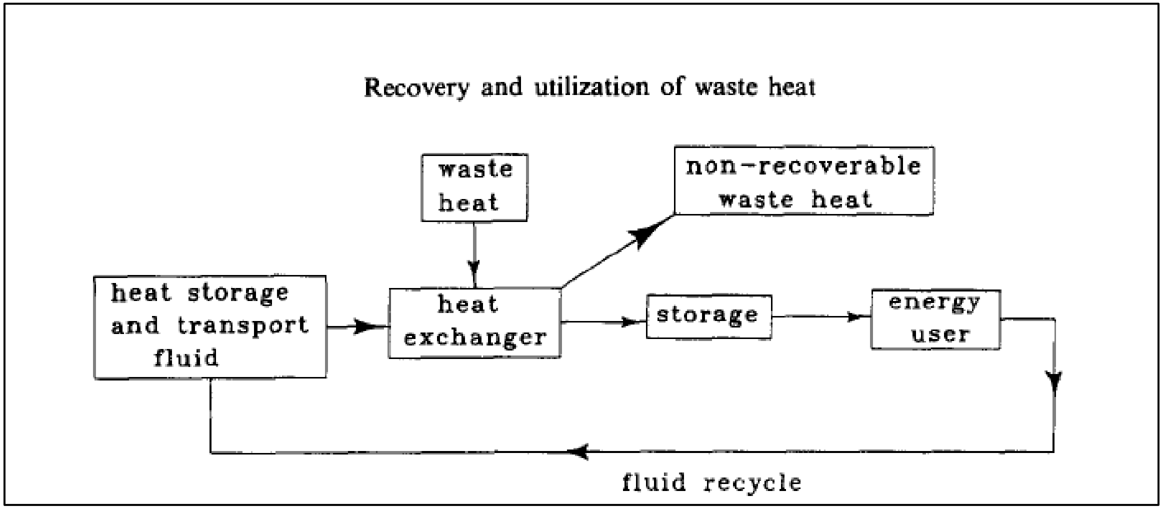

Fig. 1: One Way to Utilize Waste Heat

Among the seasoned technologies for waste heat utilization is cogeneration, i.e. generation of electricity and process steam. Both the topping cycle (generation of electricity first and then recovering of waste heat as process steam), and the bottoming cycle (recovering of waste heat first and then using this recovered heat for electricity or mechanical power generation) were explored for the recovery of waste energy. Fig.1.6 shows an illustration of the gas turbine topping cycle, where electricity is the main product, and energy from the exhaust gases is recovered for the production of process steam.

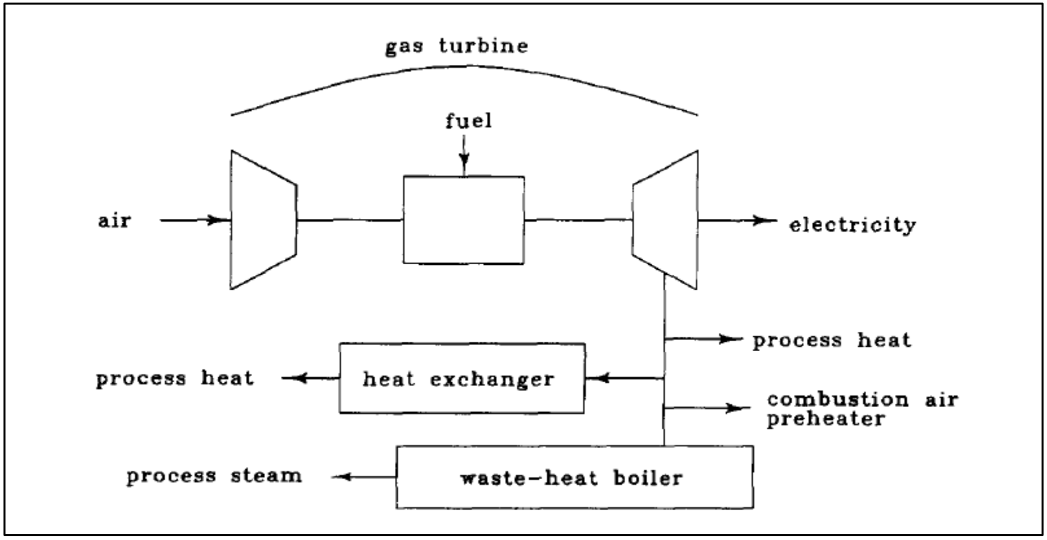

Fig. 2: The Topping Cycle in Co-Generation

An exhaust heat recovery apparatus is available that, using a heat engine, recovers them exhaust heat from an internal combustion engine that is mounted on a vehicle, such as a passenger car, a bus and a truck. In the exhaust heat recovery the apparatus used for such a purpose an external combustion engine is used, such as Stirling engine, which is excellent in theoretical efficiency. The Stirling engine is also used as a device for recover the waste heat now a day. If the waste heat is not available continuously than the waste heat can store in heater.

G. Stirling Engine:

The Stirling engine is continuous process; it can burn fuel more completely and is able to use all kinds of fuel with any quality. Because of its simple construction, and its manufacture being the same as the reciprocating internal combustion engine, and when produced in a large number of units per year, the Stirling engine would obtain the economy of scale and could be built as a cheap power source for developing countries.

H. Stirling Cycle:

The ideal Stirling cycle has three theoretical advantages. First, the thermal efficiency of the cycle with ideal regeneration is equal to the Carnot cycle. During the transfer strokes, the regenerator, which is typical temporary energy storage, rapidly absorbs and releases heat to the working fluid which is passing through. Therefore, the quantity of heat taken from the external heat source is reduced; this results in improving the thermal efficiency Fig 1.7. The second advantage, over the Carnot cycle, is obtained by substitution of two isentropic processes with two constant-volume processes. This results in increasing the p–v diagram area. Therefore, a reasonable amount of work from the Stirling cycle is obtained without the necessity to use very high pressures and large swept volumes, as in the Carnot cycle. The Stirling cycle compared with the Carnot cycle between the same given limits of pressure, volume, and temperature, is shown in Fig.

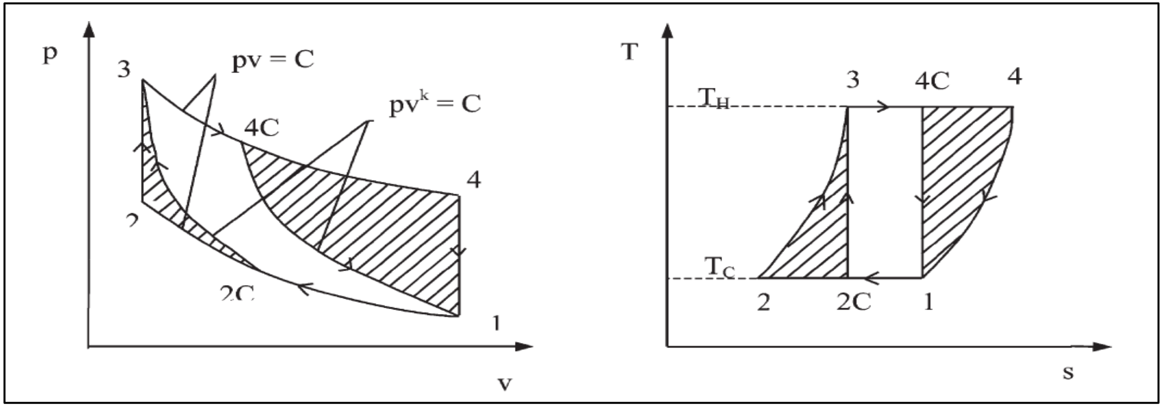

Fig. 3: Stirling and Carnot Cycle

II. LITERATURE REVIEW

A. Shah Alam:

In year 2006 three fluid vapor absorption systems is used for air conditioning of four strokes, four cylinders passenger car. The capacity of air conditioner is one ton. The exhaust of car is used to heat the ammonia solution in the generator. The temperature of exhaust heat is measured at different engine speed under 1/4th and half opening of throttle valve. The analysis shows that the maximum amount of useful heat available in the exhaust gas is about 6 KJ/sec. It is found that the amount of heat required for generator is 3.02 KJ/sec. However the heat present in the exhaust is more than this amount. Therefore, the required heat to run the one-ton air conditioner that is needed to convert ammonia solution into ammonia vapor is sufficient. The three fluid used in this system are ammonia, water and hydrogen. The exhaust gas is used to heat the ammonia solution in the generator. A rectifier is used before condenser, which removes water from ammonia vapor. The ammonia vapor is condensed and flows under gravity to the evaporator where it meets the hydrogen gas. The hydrogen of gas, which is being feed to the evaporator, permits the liquid ammonia to evaporate at low pressure and temperature. During the process evaporation the ammonia absorbs the latent heat from refrigerated space and produces cooling effect. The mixture of ammonia vapor and hydrogen is passed to the absorber where ammonia is absorbed while hydrogen raises the top and flows back to the evaporator. In the proposed model condenser and evaporator are arranged same as the conventional unit. However, absorber is fitted immediately below radiator and extends to one of the fenders. The dephlegmator is fitted against to the condenser as the latter has been so designed to make place for both the other units. The generator is mounted as close to the exhaust manifold as possible to save on heat losses from the gases before they are routed through the generator heat exchangers. Since the generator is actually a fairly large size unit. It can only be placed below the engine and slightly to the rare dynamo.

B. Bancha Kongtragool , Somchai Wongwises:

In year 2003 a power output determination of a gamma-configuration low temperature differential Stirling engine have study. The former works on the calculation of Stirling engine power output are discussed. Results from this study indicate that the mean pressure power formula is most appropriate for the calculation of a gamma configuration, low temperature differential Stirling engine power output. In the preliminary design phase, some design parameters are unknown. The Schmidt formula and West formula are more difficult to use when compared with the Beale formula and the mean pressure formula. In

Principle, the Beale formula is simpler, however, an accurate value of the Beale number is critical and the existing data on the Beale number are not available for LTD Stirling engines. The mean pressure power formula gives the same simplicity as the Beale formula and could be used for every temperature ratio and should then be used for this purpose. For design purposes, the mean pressure power formula can be used to calculate the engine rated output, or inversely, to evaluate the approximate operating parameters of the Stirling engine for a required or given power output. The mean pressure power formula allows us to initiate an initial design process rapidly. For LTD Stirling engines operated by a low temperature source, results from this study indicate that the rated power output of a LTD Stirling engine can be directly calculated from the mean pressure power formula by using an appropriate factor F.

C. Bancha Kongtragool , Somchai Wongwises:

In year 2005 an experimental investigation on the performance of a low-temperature differential Stirling engine has done. In this study, a twin power piston, gamma configuration, low-temperature differential Stirling engine is tested with non pressurized air by using a solar simulator as a heat source. The engine testing is performed with four different simulated solar intensities. Variations of engine torque, shaft power and brake thermal efficiency with engine speed and engine performance at various heat inputs are presented. The Beale number, obtained from the testing of the engine, is also investigated. The results indicate that at the maximum simulated solar intensity of 7145 W/m2, or heat input of 261.9 J/s, with a heater temperature of 436 K, the engine produces a maximum torque of 0.352 N m at 23.8 rpm, a maximum shaft power of 1.69 W at 52.1 rpm, and a maximum brake thermal efficiency of 0.645% at 52.1 rpm, approximately. The schematic illustration of the engine is shown in fig.

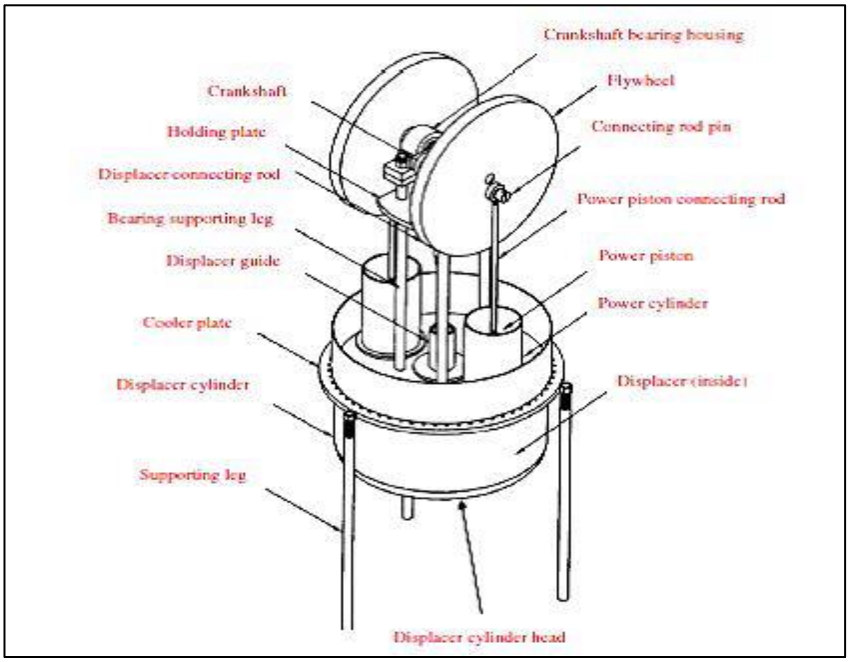

Fig. 4: Schematic Diagram of the Stirling Engine

D. Bancha Kongtragool , Somchai Wongwises:

In year 2006 a two single-acting, twin power piston and four power pistons, gamma configuration, low temperature Differential Stirling engine have designed and constructed. The engine performance is tested with air at atmospheric pressure by using a gas burner as a heat source. The engine is tested with various heat inputs. Variations of engine torque, shaft power and brake thermal efficiency at various heat inputs with engine speed and engine performance are presented. The Beale number obtained from testing of the engines is also investigated. The results indicate that, for twin power piston engine, at a maximum actual heat input of 2355 J/s with a heater temperature of 589 K, the engine produces a maximum torque of 1.222Nm at 67.7 rpm, a maximum shaft power of 11.8W at 133 rpm, and a maximum brake thermal efficiency of 0.494% at 133 rpm, approximately. For the four power pistons engine, the results indicate that at the maximum actual heat input of 4041 J/s with the heater temperature of 771 K, the engine produces a maximum torque of 10.55 Nm at 28.5 rpm, a maximum shaft power of 32.7W at 42.1rpm, and a maximum brake thermal efficiency of 0.809% at 42.1 rpm, approximately

III. CONCLUSIONS

1) The waste heat utilization is necessary now a day.
2) 2. Stirling Engine can fulfill the requirement for recover of waste heat.
3) 3. Stirling Engines show considerable promise for future applications. The Stirling engine efficiency may be low, but reliability is high and costs are low.

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