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Design, construction and performance test of a Ltd Stirling engine

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A low temperature difference (LTD) Stirling engine runs on any low temperature differential. Modified LTD Stirling engine has been recently introduced in the application of automotive engines, electric vehicles, aircraft engines, marine engines, combined heat and power, Stirling cryocoolers, heat pumps etc. However, LTD Stirling engines are not big power producers. This paper outlines the design and performance of a LTD Stirling engine. The performance is carried out between the temperature differences 71^0C to 91^0C. The maximum efficiency is 24.52 % when the engine is running at 74 r.p.m. which is considerable. The paper shows the Stirling Engine in combination with renewable energy sources can be part of a sustainable energy supply.

Key wards: LTD, Stirling engine, Sustainable energy.

Field of Research: Thermodynamics.

1. Introduction

A Stirling engine is a heat engine that operates by cyclic compression and expansion of air or other gas, the working fluid, at different temperature levels such that there is a net conversion of heat energy to mechanical work. The engine is like a steam engine in that all of the engines heat flows in and out through the engine wall. This is traditionally known as an external combustion engine in contrast to an internal combustion engine where the heat input is by combustion of a fuel within the body of the working fluid. Unlike the steam engine's use of water in both its liquid and gaseous phases as the working fluid, the Stirling engine encloses a fixed quantity of permanently gaseous fluid such as air or helium. As in all heat engines, the general cycle consists of compressing cool gas, heating the gas, expanding the hot gas, and finally cooling the gas before repeating the cycle.

The Stirling engine has numerous natural benefits over other heat engines. A prime benefit of the engine stems from the ability to operate from any heat source including continuous combustion of sustainable fuels, solar energy, factory waste heat, geothermal energy, or numerous other sustainable energy sources.

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Due to the external combustion, a laminar flow engine produces little noise, allowing its use in locations that are not preferable for internal combustion engines, such as in homes or buildings for electric power generation or other noise sensitive areas such as submarines. The Stirling engine also has the theoretical efficiency of the Carnot cycle, creating tremendous development potential. In a conventional Stirling engine, there are two chambers and the heating and cooling is achieved by moving the gas between a hot chamber and a cold chamber. Current Stirling engines are expensive to produce, primarily due to the complex heat exchangers, which are required to heat and cool the gas outside of the working chambers. The need for external heat exchangers is a result of near-adiabatic operation in the compression and expansion chambers, reducing efficiency and power. But LTD Stirling engine is less expensive and easy to construct. Another prime benefit of the engine is the ability to operate from any heat source including continuous combustion of sustainable fuels, solar energy, factory waste heat, geothermal energy, or numerous other sustainable energy sources.

2. Literature review

The Stirling engine (or Stirling's air engine as it was known at the time) was invented and patented by Robert Stirling in 1816.It followed earlier attempts at making an air engine but was probably the first to be put to practical use when in 1818 an engine built by Stirling was employed pumping water in a quarry. The main subject of Stirling's original patent was a heat exchanger which he called an "economiser" for its enhancement of fuel economy in a variety of applications. The patent also described in detail the employment of one form of the economiser in his unique closed-cycle air engine design in which application it is now generally known as a 'regenerator'. Subsequent development by Robert Stirling and his brother James, an engineer, resulted in patents for various improved configurations of the original engine including pressurization which had by 1843 sufficiently increased power output to drive all the machinery at a Dundee iron foundry.

In the spring of 1983, prof. Ivo Kolin of university of Zagreb in Croatia pleasantly started the Stirling engine world by publicity exhibiting an engine running on heat of boiling hot water. The setting was at a short course on Stirling engines taught by Prof. Kolin, Prof. Walker, and myself at the inter university center in the historic coasts city of Dubrovnik. While Prof. Kolin described to the audience the engine that he had been developing about three years, his wife, Vlasta, devotedly poured boiling hot water into one compartment of the engine and cold water into another.

Prof. Kolin’s engine was built entirely with hand tools. It featured a square displacer chamber and a rubber diaphragm in place of a piston and cylinder. The Styrofoam displacer was 20 cm (7-7/8 in) square. A unique feather of this engine was a “slip link” drive for the displacer which gave it an intermittent motion; this type if motion is thermally beneficial in slow moving engines. A speed of 50 rpm was typical for his engine with a temperature difference of 50°C in its reservoirs. This first LTD engine is completely described in Ivo koflin’s book isothermal stirling cycle engine which even includes fully dimensioned drawings (in metric units) so that anyone interested can make an exact replica.

In the fall of 1983 the first ringbom type of LTD Stirling engine was built at Argonne National Laboratory. This engine design it introduce a round horizontally oriented displacer chamber which could be placed over a container of hot water for the heat source. The displacer of the engine was about 8.5" in diameter and was driven by a small piston and cylinder unit to grove an intermittent motion with a phasing the varied with the engine speed. The main piston drives features a rocking lever which the freed piston of virtually all side loading for low friction and wear.

From these first two engine prof. Kolin and the James R. senft work parallel over the next decayed each developing a series of LTD engine. There are three different type of engine were introduced L-27 solar rinbom engine, P-19 ultra-low temperature differential engine, N-92 NASA demonstration engine whose construction is descried in this report.

3. Design of 3D Parts

In order to fabricate the LTD Stirling engine various parts are designed as shown in Figure 1 to Figure 22.

Fig.1: Top plate

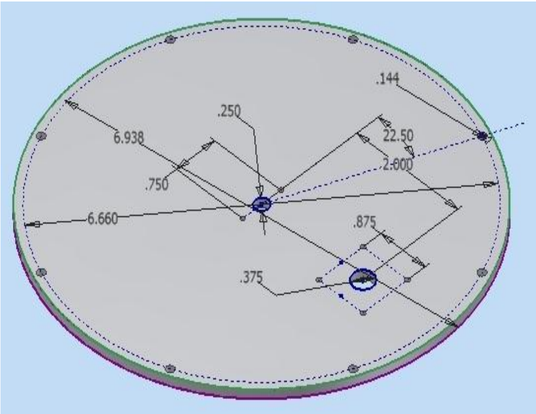


Fig. 2: Bottom plate

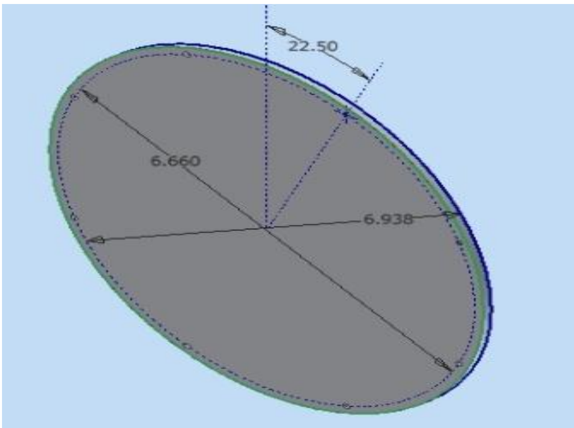


Fig. 3: Displacer piston

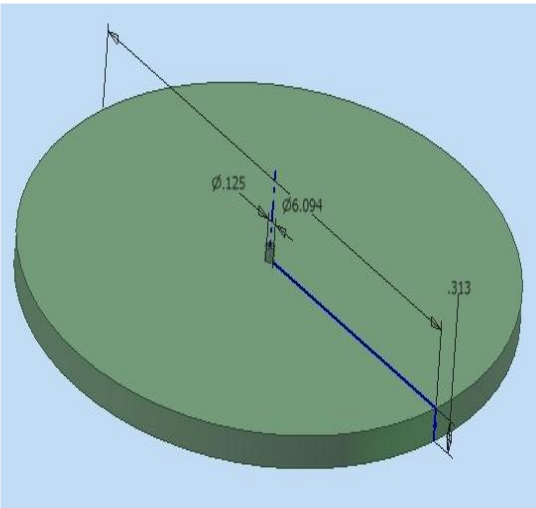


Fig.4: Chamber Ring

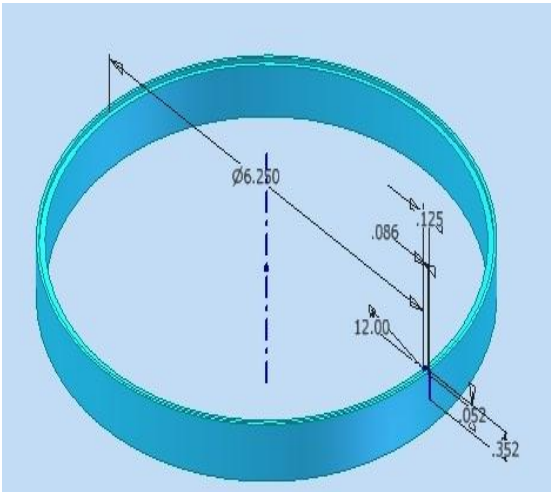


Fig. 5: Flywheel

Fig. : Flywheel Housing

Fig. 5: Flywheel

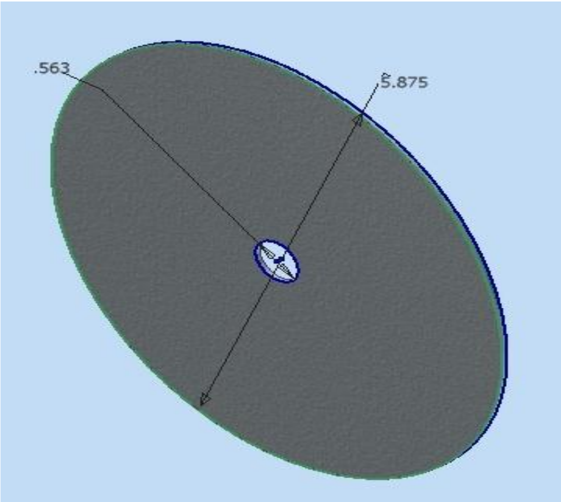


Fig.6: Flywheel Housing

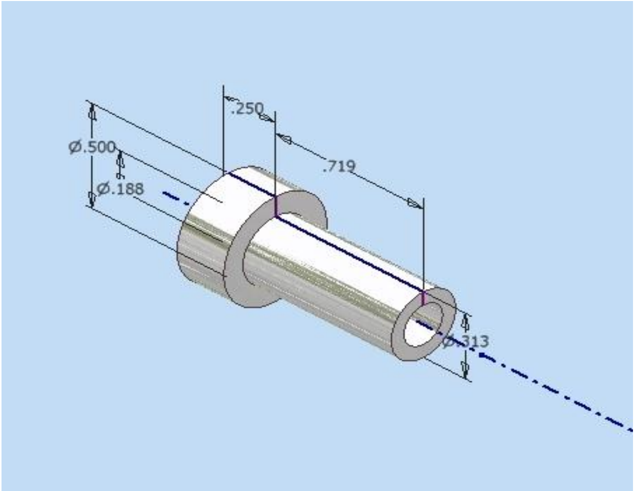


Fig. 7: Flywheel Stand

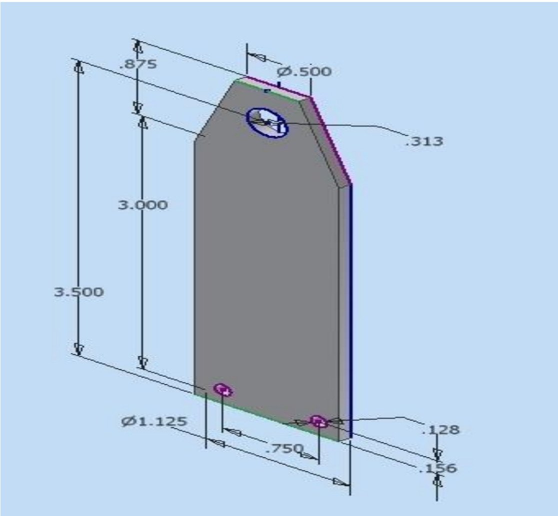


Fig. 8: Flywheel Hub

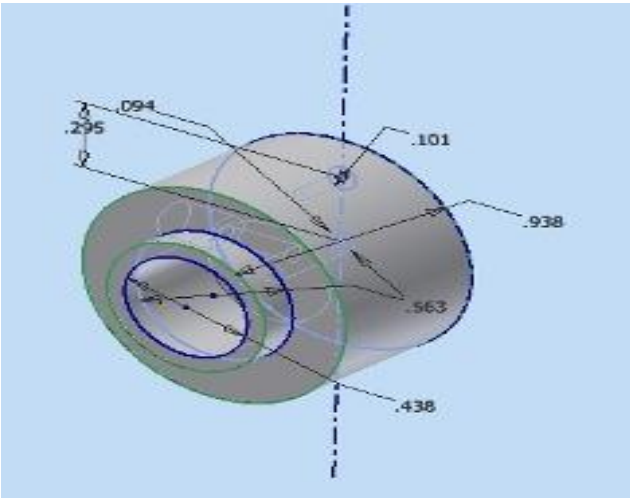


Fig. 9: Bearing Collar

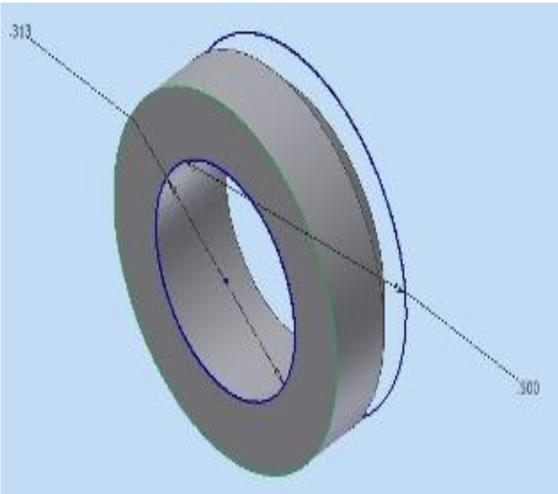


Fig. 10: Cylinder

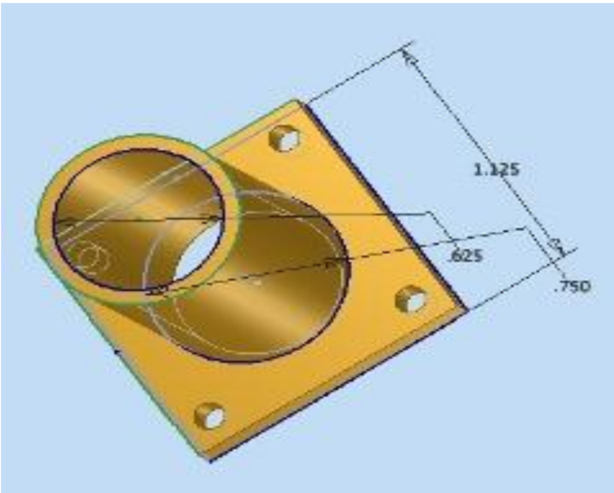


Fig. 11: Piston

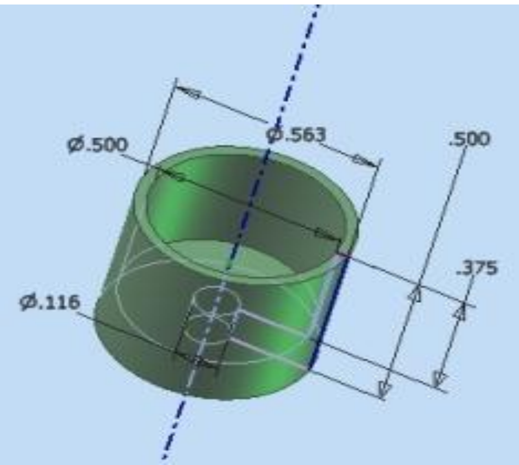


Fig. 12: Cylinder Base

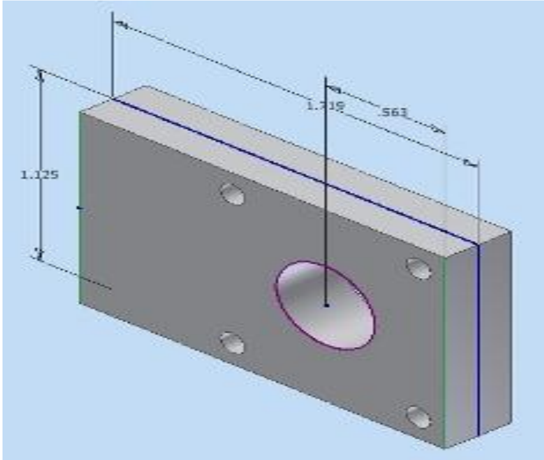


Fig. 13: Piston Yolk

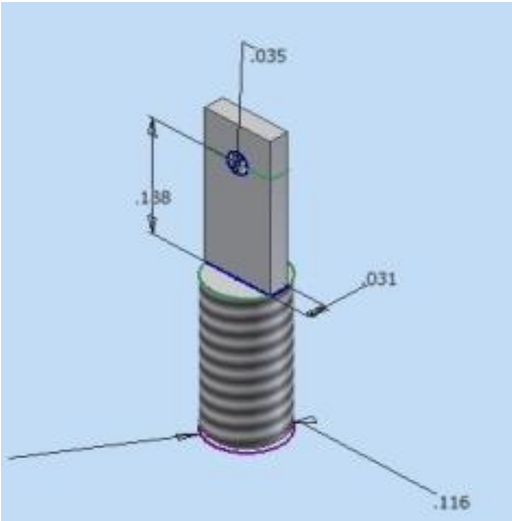


Fig. 14: Displacer Gland

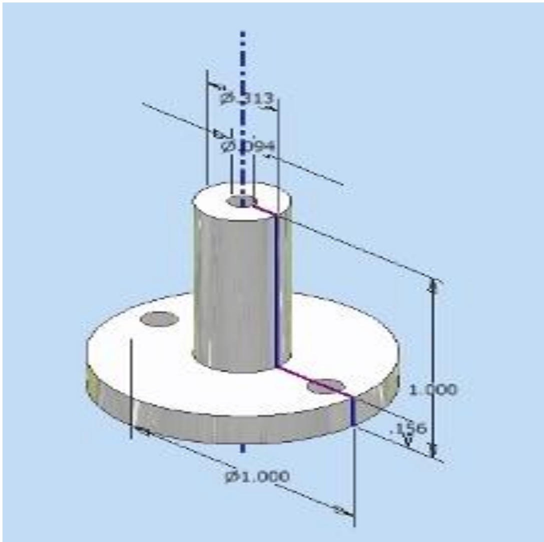


Fig. 15: Gland Rod

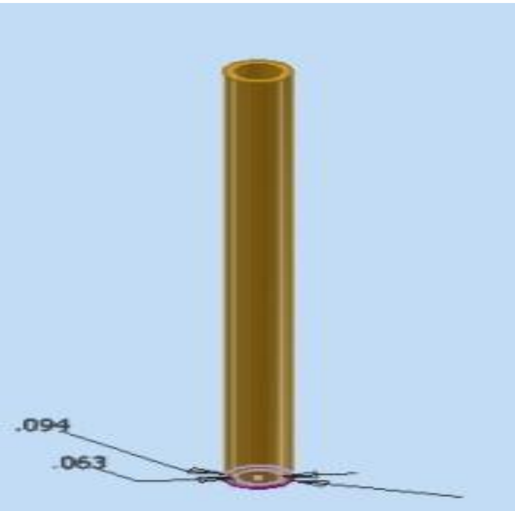


Fig. 16: Crank Shaft

Fig. 17: Displacer Rod

Fig. 18: Bearing Collar

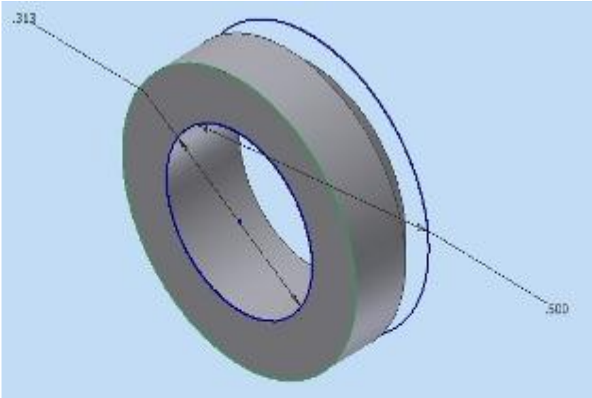


Fig. 19: Bearing Ring

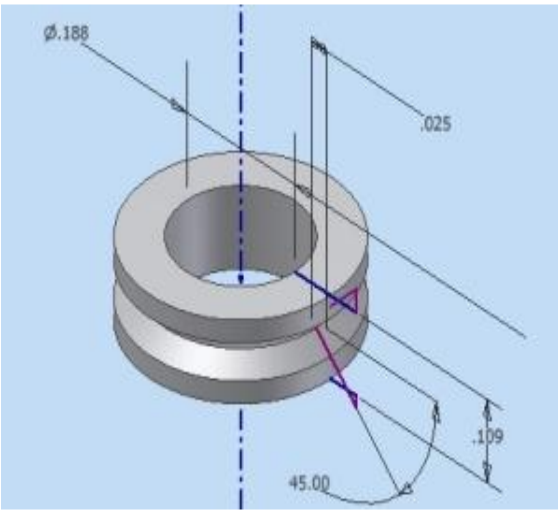


Fig. 20: Displacer Connecting Rod

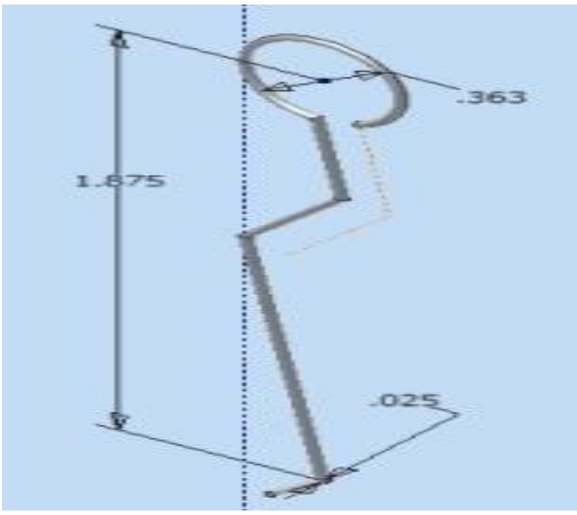


Fig. 21: Piston Connecting Rod

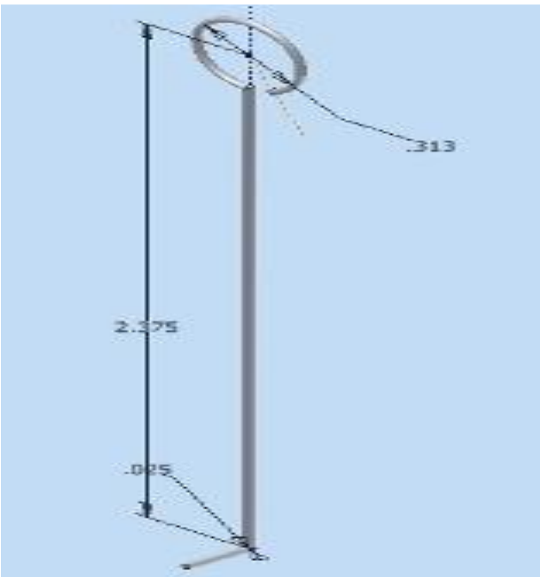
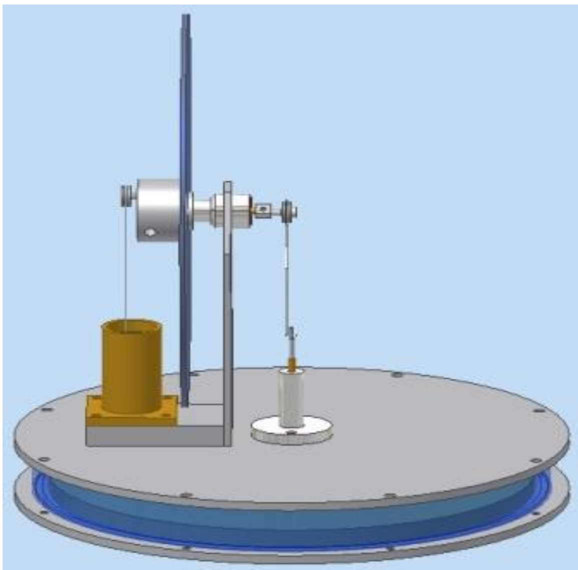


Fig. 22: Prototype



4. Methodology

After manufacturing all parts individually the final assembly of engine is done as shown in Figure 23. Firstly, two rings are put into the groove. The fly wheel stand, the piston, the displacer piston are attached with the top plate. Before attaching the flywheel stand the flywheel housing is put into the stand hole. Secondly, Bearings are attached to the two end of the housing to hold the crankshaft. At the two end of the crankshaft flywheel hubs are attached. Then, one end of the connecting rod is joined into the two hubs and other end of the connecting rod is attached with the displacer piston and the power piston. Finally, the displacer chamber rings is set between two plates and join them by screws. This setup was then investigated for numerous observations to determine its efficiency without load and with load.

Fig. 23: LTD Stirling engine setup

5. Result and Discussion

The manufactured LTD Stirling engine is carried out for numerous investigation to find out the efficiency. The findings from the engine are shown in Table I to Table IV.

Observation no	Temperature of hot plate(°c)	Temperature of cold plate (°c)	Temperature difference (°c)	R.P.M
1.	80	7	73	69
2.	84	7	77	74
3.	89	7	82	87
4.	93	7	86	94
5.	98	7	91	107

Table I: Performance Data without Load

Table II: Performance Data with Load

Observation no	Temperature of hot plate(°c)	Temperature of cold plate (°c)	Temperature difference (°c)	R.P.M
1.	78	7	71	61
2.	86	7	79	63
3.	91	7	86	67
4.	94	7	87	71
5.	98	7	91	74

Table III: Efficiency without Load

Temperature difference (°c)	Efficiency %	R.P.M
73	20.68	61
77	21.56	63
82	22.65	67
86	23.49	71
91	24.52	74

Table IV: Efficiency with Load

Temperature difference (°c)	Efficiency %	R.P.M
71	20.23	61
79	22.00	63
86	23.63	67
87	23.80	71
91	24.52	74

Fig. 24: Temperature Vs. speed curve without load

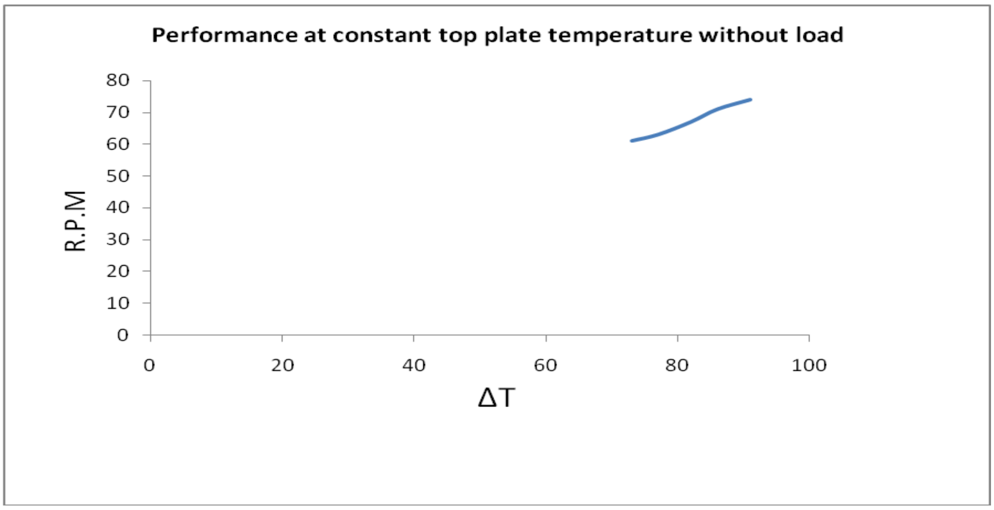
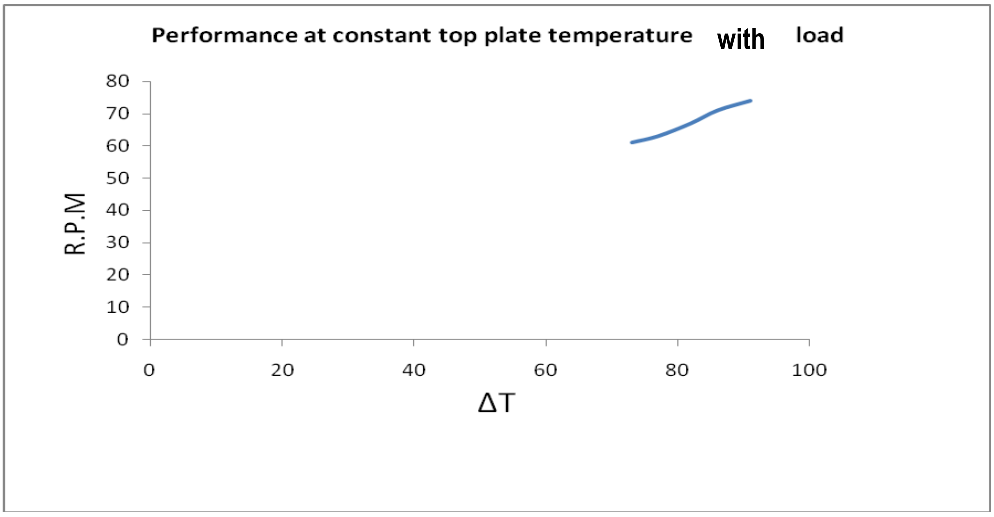


Fig. 25: Temperature Vs. speed curve with load



From the above Table I to Table IV and Figure 24 to Figure 25, it is found that the engine speed is increased with increase of temperature difference. The efficiency of engine is also increased with increase of temperature difference in case of both without load and with load.

6. Conclusions

The LTD Stirling engine is designed and fabricated to carry out its performance. The construction of LTD Stirling engine is slightly different than the James Senft's recommended N-92 model. The temperature differences used in LTD Stirling engine between 71^0C to 91^0C is smaller than the conventional Stirling engine. The maximum efficiency of LTD Stirling engine is 24.52 % competitive to conventional Stirling engine as nearly 27%. There is a significant change of r.p.m with the changing of temperature difference.

7. References

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