Design and Testing of Thrust Measurement System for Rotary Engine

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ABSTRACT

Here, the scientific concepts in physics, thermodynamics, aerodynamics and mathematics are combined with a hands-on experiment to demonstrate propulsion system concepts. The experiment is conducted on a small-scale highly instrumented rotary engine. The experimental measurements and physical observations are used to confirm the accuracy of the mechanical and engineering models used to design and to build thrust cradle systems. The Thrust Cradle experiment is designed to attach propulsion system hardware to computer simulations and mathematic models often used to explain Thrust Force Measurement concepts.

***Key Word**: Thrust, Thrust Cradle, Estimate Propeller Static Thrust, Propeller Speed, Sea level, High altitude*

I INTRODUCTION

The goal of this project is to design, develop, and test on the thrust measurement test set up. A variable helicopter rotary engine is used to study the effect of changing on the thrust, the blade rotational speed, fuel required, Temperature of the engine. Motor speed and propeller pitch are controlled by separate electronic speed controller device. The Thrust Cradle designed using a Computer Aided Design (CAD) i.e. Auto-Cad. The model will help to test of rotary engine & comparing the actual data with threshold data & also understand the principles of thrust and various variables affect the thrust produced by propeller. The goal is to develop the entire system for minimum cost. We get required information by designing the mechanical system, electrical hardware and software. The experiment will be able to determine how the thrust varies as a function of the design parameters. The design details, results and conclusion are discussed in the paper.

The new developing structure has potential to a wide range of attractive design solutions. In addition by substituting a Linear sliding ball bearing instead of roller bearing it will gives the more efficiency to obtained the thrust of the rotary engine & also it will be the more sensitive & weight reduction will be happen, these solutions can often bring space saving. Company is in need of development of mobile thrust cradle platform to test the fuel injected rotary engine at different high altitude locations.

To accomplish this, the following specific objectives are outlined-
1. Review the theory of Mobile Thrust Cradle.

2. Design and build a Mobile Thrust Cradle for a rotary engine.
3. Numerically determine the theoretical thrust in KG.
4. Generate models of Mobile Thrust Cradle Structure by using Auto-Cad.
5. Determine the Thrust of the engine with respective speed by using software ESTIMATE PROPELLER'S STATIC THRUST.
6. Compare Analytical and Numerical result of Thrust of the engine with respective speed.
7. Determine the deflection in Thrust power of the engine by using Thrust Cradle
8. Check the experimental and Analytical result of deflection of Thrust with respective speed.
9. Manufacturing of Thrust measuring device by selection of linear ball bearing block. .

II LITERATURE REVIEW

Extensive work has been carried out on the Thrust measurement various static models. The purpose of this literature review is to go through the main topics of interest.

[1] Lu Jie, Zheng, Wang Zhiwu, Peng Changxin, Chen Xinggu Three kinds of thrust measurement systems are integrated to carry out thrust measurements system. direct thrust measurement with a force transducer, indirect thrust measurement impulse method. The force transducer is mounted on the structure block and the moving frame is connected to the load indicator through a spring which has a stiffness of 240 N/mm.

[2] **Dr. Adeel Khalid** In this research project, undergraduate students were involved in the design and development of a variable pitch propeller based thrust measurement apparatus to be used in the Aerospace engineering laboratory at Southern Polytechnic State University. The undergraduate research helped the students in gaining theoretical and practical knowledge for conducting and completing research. Through various research activities as part of the Peach State LSAMP program. It helps to think critically, solve engineering problems, trouble-shoot, and better understand engineering principles. The students presented the research at the Peach State LSAMP annual conference in Savannah, GA. Although the students have submitted their work, the apparatus needs to be improved and made more robust before it can be safely used in a laboratory environment.

[3] S.Jeon, J. Kim, H. Choi. *Data acquisition-* The measured data in the test were summarized. The mass flow rate measurement was noticed in any analysis due to a reason which the flow meter could not operate properly in vacuum environment. Therefore the flow rate is calculated from the chamber pressure, temperature, and regulated pressure along with the throat diameter. The specific heat ratio is assumed to be 1.4 and the specific impulse is determined by the calculated flow rate and the thrust.

[4] C.M. Jeruzal, K.D. Brinker author have been studied that , to determine theoretical and measured engine thrust, efficiencies of the compressor, the combustion chamber, and the turbine. He also determines the effect of engine speed on thrust-specific fuel consumption (TSFC) and engine emissions. He also analyze the combustion process and to perform a complete energy balance on the jet engine.

[5] Li Pengfei Wang ,Yang Wang author have been studied that, classical electromagnetic theory, this paper introduces a new kind of propellant less microwave thrust measurement device for use in space. This device is able to directly convert microwave radiation into thrust. It does not need for any propulsion medium. The difference of this propulsion system is it does not require carrying the large propellant tank. The problems of emissions polluting the space can be eliminated.

III.METHODOLOGY

Design Procedure

1 Torque

T = F x L x FOS

2 Shaft Diameter

$$M = \frac{\pi}{32} \times \sigma \times D^3$$

3 Bearing Life Span in Km:

$L_{10} = f_s (C/P)^n$ X 100 Km

4 Life span in Hr:

$$Lh = \frac{L \times 10^3}{2 \times Ls \times 60}$$

Table1.Design Parameter

Parameter	Values
Torque (N-mm)	919687.5
Diameter of Sliding shaft (mm)	36.05≈ 40
Bearing Life Span (Km)	415.864
Bearing Life Span (Hr)	173.276×10^6

5 Theoretical Propeller Thrust

We have the input data,

a) N = Propeller Revolution Speed = Variable from 3500 RPM to 6500 RPM
b) D = Propeller Diameter in inches = 39.37 inch
c) ρ = Air Density in Kg/m^3 = 1.225 Kg/m^3 at sea level and 1.053 Kg/m^3 at high altitude
d) K_t = Static Trust Coefficient ≈ 0.53
e) T = Propeller Thrust

$T = 1.283 \times 10^{-12} \times N^2 \times D^4 \times \rho \times K_t$

Table 2. Theoretical Thrust results at sea level and high altitude

Sr. No.	RPM	Thrust at sea level (Kg)	Thrust at high altitude(Kg)
1	3500	24.515	21.073
2	4000	32.019	27.524
3	4500	40.525	34.835
4	5000	50.031	43.006

5	5500	60.537	52.037
6	6000	72.044	61.929
7	6500	84.551	72.680

IV.PREPARING THE3-D MODEL

Thrust cradle is the main unit of the test set up. The actual engine is being mounted on the thrust cradle to measure the thrust of the rotary engine. The relative rpm and temperature of the engine also measured. Comparing the values of thrust, rpm and temperature with the threshold value after the testing is completed. The whole assembly of the thrust cradle as shown in fig .3

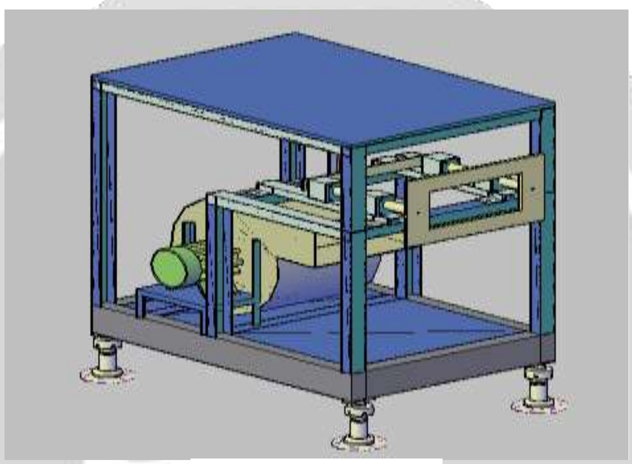

Fig.1 Thrust Cradle

There are different components that are used to manufacture the thrust cradle are as follow,

a) Base mounting unit
b) Sensors and Testing arrangement
c) Blower unit
d) Thrust transfer arrangement

V. Propeller Thrust measured by using a software

Computer generated result can be find by using online software ‘Estimate Propeller’s Static Thrust.’ The software requires the input parameter like weather conditions that is temperature; density of air depends on altitude. RPM and the pitch of the propeller is very important parameter to calculate the thrust of propeller. Thrust is also depends on the diameter of the propeller. These all the parameters are required to calculate the thrust by using online software Estimate Propeller’s Static Thrust.’ After putting the values of RPM from 3500RPM to 6500RPM, the result obtained is as under. Also the corresponding graphical results are shown.

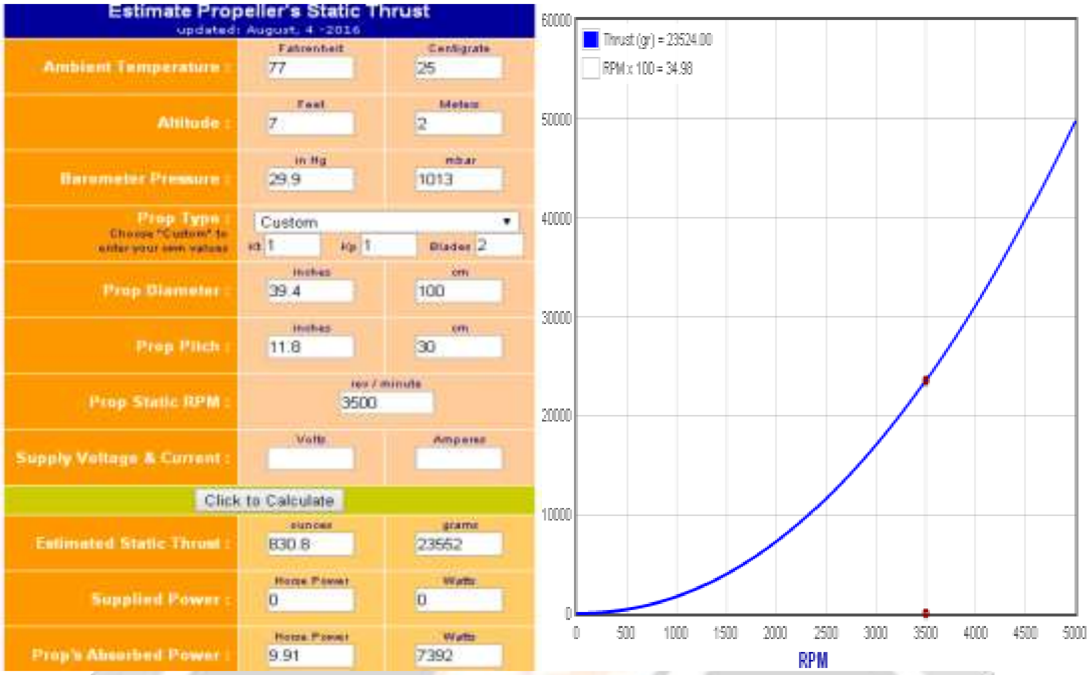

Fig.2 Thrust at 3500 RPM at sea level

Similarly we getting the software results as shown in the table.

Table3.Computer generated Thrust results at sea level and high altitude

Sr. No.	**RPM**	**Thrust at sea level (Kg)**	**Thrust at high altitude(Kg)**
1	3500	23.552	21.789
2	4000	31.175	28.841
3	4500	39.648	36.935
4	5000	49.466	46.081
5	5500	60.428	56.292
6	6000	72.542	67.578
7	6500	85.821	79.947

VI. Experimental Propeller Thrust

The engine mounted on the thrust cradle to measure thrust of the engine at different RPM of propeller of the rotary engine. The engine is run by using give the initial rotary motion with the help of engine starting trolley. Once the engine starts it rotates for a few times at ideal speed that is minimum speed of the engine. There is the load cell is connected to the reciprocating plate which is mounted on the reciprocating shaft through linear ball bearing block. The test set up as shown in fig. 14

Fig.3 Rotary Engine on test set up

Load cell absorb the physical signal from the engine force that is thrust. These physical signals are converted into the electrical signal and give the output in milivolts. These milivolts signals with the help of AD converter convert the signals into digital form and display on the screen in the form of Kg. The Experimental test was carried out at different speed of propellers, at sea level and high altitude and getting the results are as follow.

Table. 4. Experimental Propeller Thrust at sea level and high altitude

Sr. No.	RPM	Thrust at sea level (Kg)	Thrust at high altitude(Kg)
1	3500	22.53	20.73
2	4000	30.27	26.80
3	4500	38.57	33.93
4	5000	47.78	41.52
5	5500	58.98	50.10
6	6000	70.87	59.81
7	6500	83.18	69.23

VII. RESULTS & DISCUSSION

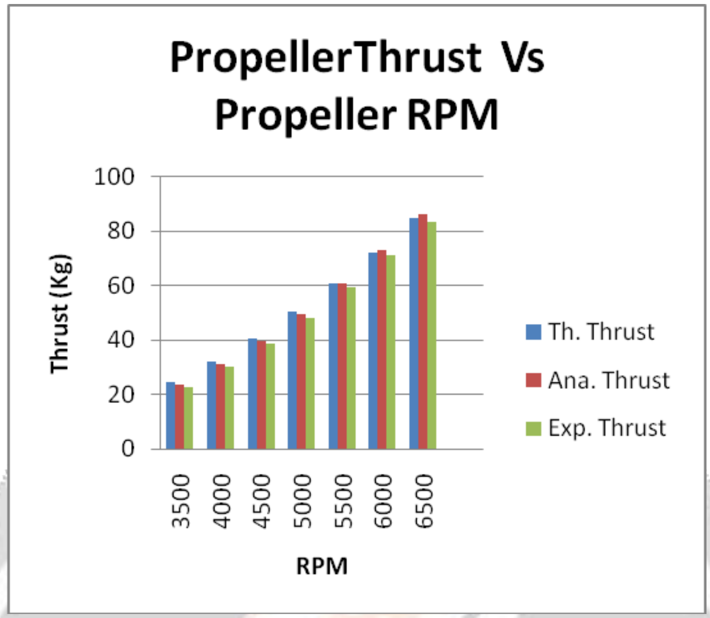

Fig. 5 Graphical Results at sea level

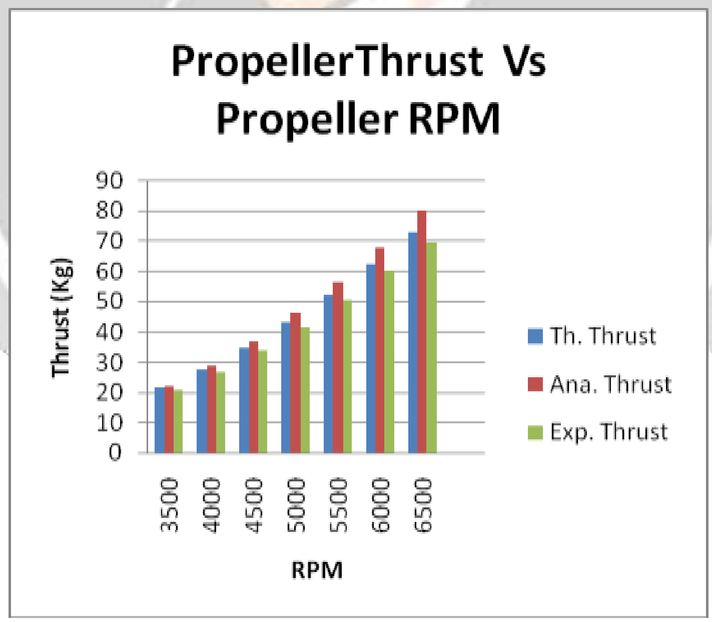

Fig.6 Graphical Results at high altitude

VIII.CONCLUSION

1. In this system the thrust transfer arrangement with roller is replaced by the thrust transfer arrangement with Linear Ball Bearing Block. It will be more smoothly slide & transfer the more thrust.
2. The actual thrust of the rotary engine at the sea level & high altitude is achieved very nearly to the theoretical thrust and analytical thrust of the rotary engine.
3. The thrust is gradually increases with RPM of the propeller. The rotary engine at ideal speed 3500RPM give the minimum thrust 22.53Kg and at maximum speed 6500RPM gives the maximum thrust 83.18Kg.
4. The thrust produced by the rotary engine at high altitude also increases with increase in speed of the propeller of the rotary engine. The thrust produced by the rotary engine at high altitude comparatively less than the thrust produced by the rotary engine at sea level.

VIII.CONCLUSION

1.The deflection and self weight of Web core sandwich structure is small as compare to the X core and Vf core sandwich structure.
2.In sandwich structure the weight of web core sandwich sandwich structure is 221.34 kg is small as compare to the Vf core and X core sandwich structure.
3.The deflection of web core sandwich structure is 1.0955 mm is also small as compare to I section, Vf core sandwich structure, and X core sandwich structure.
4.Then web core sandwich structure is optimum sandwich structure.

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