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A Study of Test Bench for Testing the Propeller Torque

Kuljeet Kaur
B.E Student
Department of Aerospace
Chandigarh University,Gharuan
sohikuljeet@gmail.com

Kajol Hole
Student (B.E. aerospace)
Department of Aerospace
Chandigarh University,Gharuan
Kajolhole@gmail.com

Milandeep
Student (B.E. aerospace)
Department of Aerospace
Chandigarh University,Gharuan
Milandeep1910@gmail.com

ABSTRACT

PROPELLER Test bench is designed to calculate the thrust, torque, speed and various performance parameter of the propeller. In the reciprocating and rotary aircraft engines propellers are used for providing appropriate power to the aircraft to move forward. Propeller is a sort of fan that transmits power by converting rotational motion into thrust. A pressure distinction is formed in between forward and rear surfaces of surface formed blades and air is accelerated behind the blade. The mechanical device dynamics is modelled by each Bernoulli's equation and Newton's Third Law. This paper focuses on fabricating a mechanical device take a look at rig for conniving the thrust of the mechanical device and therefore measures the mechanical device performance. A 2-stroke spark ignition engine of Yamaha RX one hundred is mounted over a beamed structure i.e. velocipede with that a 2-blade mechanical device is hooked up. Load cell, an electrical device, is employed to live the thrust. The one finish of the load cell was connected to the velocipede on that engine was mounted and another finish was connected to a rigid beam. The S.I. engine rotates the mechanical device that successively produces the thrust to maneuver the velocipede forward. Our objective is to review the impact of advance magnitude relation, thrust constant, power constant and speed power constant on mechanical device potency at constant blade angle. These parameters play a significant role to decide the take-off thrust of associate degree craft. to realize the target, the mechanical device thrust was recorded with the assistance of load cell at completely different engine speed (rpm). The engine rate was varied victimization the throttle regulator to get {different totally completely different completely different} thrust values at different mechanical device rate. Also, the flow speed across the mechanical device disk was measured victimization gage and different parameters like advance magnitude relation, mechanical device mechanism disk potency, thrust constant, power constant, etc. were conjointly calculated to review their effects on the mechanical device performance.

Keywords

PTB, adjustable test bench, holding mechanism, BLDC, propeller, torque, coefficient

1. INTRODUCTION

Propeller test bench is a testing bench designed to calculate torque of the propeller. To achieve better gains in a test bench, all the mentioned functions should be available in a single device—which allows for more efficient use in testing and proving grounds as well as for measurement and automation in the production area. By combining versatile hardware with data recording at the highest data rate and resolution, users will expertise up to ten times the time and price savings.

1.1 Description and Development

Industries wherever energy potency is very important, like the automotive and aviation industries, are increasing specialize in engine development, rolling resistance and energy-conversion potency. makers have the possibility to boost testing by implementing structures quickly. Essential preconditions for quick check implementation are high-quality measured values and proper activity. Essential preconditions for fast check implementation are high-quality measured values and correct activity. Additionally, the mensuration electronic equipment and system should be capable of additional process the activity knowledge in real time so the test bench is regulated. It's in addition essential to capture activity information at a high resolution for analysis and to avoid wasting it.

2. PROPELLER TEST BENCH:

In the Reciprocating and Rotary Aircraft Engine Propellers are used for providing appropriate power to Aircraft to move further. Propeller is a type of Fan that transmits power by converting rotational motion into thrust. The Propeller Dynamics is modelled by Bernoulli's Equation and Newton's third Law. Propeller test bench consisting of ESC unit, BLDC motor, and propeller. At various operating conditions power, thrust, speed, density, and weight factor are measured. In the configuration shown, a weighing scale is designed to measure the force applied on it, where the force is proportional with the thrust generated by the propeller.

3. DESIGNING AND DEVELOPMENT:

An electric craft propulsion takes a look at rig was designed and fictitious to predict thrust, torque and battery discharge profiles for an electrical craft. just in case of an electrical plane take a look attest bench DC brushless motor, carbon fiber mechanical device, charger, electronic controller and metal chemical compound batteries square measure used. Take a look at test bench is Adjustable. varied parts square measure made and purchased so as to fabricate the optimum take a look at rig equipment. This equipment permits for coincident activity of the torsion and thrust of the system through the utilization of a biaxial detector. The take a look at rig additionally measures system voltage and current that permits the user to see the discharge profile of the metal chemical compound battery pack at varied throttle settings. One in every of the foremost vital goals of this project was the flexibility to live each torsion and thrust. one in every of the first take a look at rig style concepts enclosed mounting the equipment on rails and mensuration the displacement to get thrust and additionally attaching a flash arm to a gage to see the torsion. Thanks to the resistance losses within the rails and moment arm it absolutely was determined that this technique wouldn't be the foremost correct and economical style.

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Therefore, a multi-axis detector was accustomed take the measurements at the same time. This detector had to be able to live the complete vary of torsion and thrust loading exerted by the motor and mechanical device severally. When intensive analysis into the applicable detector technology and victimization the revealed motor and mechanical device information to see the loading vary, a torsion & Thrust biaxial detector from FUTEK Advanced Detector Technology also are used these days. This detector may be mounted at the tip of the shaft associate degreed outputs an amplified analog signal, which can then regenerate to a digital signal employing a data converter, which can be mentioned later. It will live thrust and torsion up to five hundred lbs. and five hundred in-lbs.

4. COMPONENTS AND MATERIAL:

Test bench consisting of ▪ esc unit ▪ Propeller ▪ brushless direct current (BLDC) motor ▪ Battery ▪ Load cells

4.1 Sensors:

sensor is a device, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics often a laptop processor conjointly detects or measures a property and records, indicates, or otherwise responds to that. A detector could be a device that detects and responds to some kind of input from the physical surroundings. The particular input can be light-weight, heat, motion, moisture, pressure, or anyone of a good range of alternative environmental phenomena. The output is mostly a proof that's born-again to human-readable show at the detector location or transmitted electronically over a network for reading or additional process. There are totally different sensors obtainable within the markets for police investigation light-weight, motion, temperature, magnetic fields, gravity, humidity, moisture, vibration, pressure, electrical fields, sound, and alternative physical aspects of the external surroundings. They use totally different techniques for the detection functions.

Required parts: DF-13 cable, simple potentiometer

4.2 Load cell:

A load cell could be a kind of force gauge. It consists of an electrical device that's wont to produce associate electrical signal whose magnitude is directly proportional to the force being measured. Load cells are wide employed in modern-day test components benches. They work well for top thrust devices, however within the case of micro-thrusters that have low thrust to mass ratios, the load cell measure is plagued by the thruster weight. The availability of load cells with decent sensitivity permissible their introduction to low thrust measure applications.

4.3 Electronic controller (ESC):

Electronic speed controller or ESC is associate electronic circuit that controls and regulates the speed of an electrical motor. The current rating of the ESC ought to be determined when choosing an acceptable motor size. the utmost current draw of the motor at 100% throttle helps USA to a get an acceptable current rating. It may conjointly give reversing of the motor and dynamic braking. Miniature electronic speed controls are employed in electrically hopped-up radio controlled models. large electrical vehicles even have systems to regulate the speed of their drive.

5. TORQUE

Torque, moment, moment of force or "turning effect" is that the move equivalent of linear force. Even as a linear force could be a push or a pull, a force will be thought of as a twist to associate object. Torque is outlined mathematically because the rate of amendment of momentum of associate object and SI UNIT of force is N-M.

5.1 Torque sensor:

Measuring force, rotational speed, angle of rotation and also the quantities derived from these variables are more and more essential within the style of latest test bench. The most vital science properties of force sensors include: Accuracy category, sensitivity, tolerance, temperature stability, one-dimensionality deviation and physical phenomenon. The user ought to conjointly note the appliance areas and cargo limits, including: move speed limits, permissible oscillation bandwidths, lateral limit and longitudinal forces, most temperatures. Force is measured exploitation integral load cells, and conditioned exploitation internal natural philosophy before transmission to the flight information recorder. A mechanism in every detector permits the device to still operate as an impact linkage within the unlikely event of detector failure.

6. ENHANCING THE PERFORMANCE OF TORQUE MEASUREMENT

To optimize torque data, a measuring amplifier system must include a series of internal computing channels specifically designed for operation and use of torque transducers A 21-point linearization of the characteristic curve of the transducer for the torque sensor improves the raw signal, which can then be further processed to increase the measurement quality of the test bench. Polynomials and straight pitches: —especially with the use of polynomial-scaling—can increase efficiency because they represent the sensor characteristic with greater accuracy. Using the polynomials for sensor adjustment is more accurate than two-point scaling or a characteristic table. Determining peak values or mean values of measurement signals can document test limits. These control values can be monitored in turn with limit values or tolerance bands in real time, making it possible to control the test bench. Calibration equipment can capture the behavior of the sensor to increase

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its accessible accuracy under various load cases, which include dynamic right and left rotation as well as highly accurate measurement in partial ranges. The ability to measure partial ranges is necessary to capture the residual breaking torque, in which different applications are measured during the calibration of the sensor. Mathematical computing channels can calculate and output the application of torque in real time if the raw values of the torque measurement with torque and speed are available.

7. THRUST:

Thrust could be a reaction force delineate quantitatively by Newton's third law. Once a system expels or accelerates mass in one direction, the accelerated mass can cause a force of equal magnitude however other way thereon system. The force applied on a surface in a very direction perpendicular or traditional to the surface is additionally known as thrust. Force, and therefore thrust, is measured exploitation the SI of Units (SI) in newton's (symbol: N), and represents the number required to accelerate one metric weight unit of mass at the speed of one meter per second per second. In engineering, force orthogonal to the most load (such as in parallel coiled gears) is noted as thrust.

7.1 Thrust and calculation of equation of thrust:

In Aerodynamic Propeller Coefficient of lift CL is kept constant across blade span. Torque sensor in order to keep CL across a rotating propeller blade constant a "helical thrust" needs to be established from blade root to blade tip. F= Force in Newton's RPM= Revolutions per minute of propeller P=inches pitch of Propeller V0=Forward Flight. The thrust generated by a propulsion system of an airplane can be explained by using Newton's laws of motion. Figure shows the stream tube of the flow entering and exiting a generic propulsive device from left to right, where the reference frame is placed on the propulsion device moving at constant speed of Vi device. High thrust can be generated by accelerating a large mass of gas by a small amount as is done by propellers and turbofans or by accelerating a small mass of gas by a large amount like a turbojet, ram jet, or rocket. It should be re-emphasized that the thrust equations given above are based on the assumption that the effects of the additional forces exert by the pressure and shear forces acting on the side "walls" of the stream tube were neglected. More detailed and comprehensive derivations of the thrust equations that do not make these simplifying assumptions can be found in Anderson (1998) and Farokhi (2008). The reacting force T that the propulsion device exerts on the air can be determined based on Newton's second law, which can be expressed as follows. Force T that the propulsion device exerts on the air can be determined based on Newton's second law, which can be expressed as follows:

$$\sum F = \partial / \partial t \, C.V. \int V \rho \, d + C.S \int (V \rho V) \, dA \ldots (1)$$

Along the X direction, the above equation can be simplified with the assumption of steady flow condition inside the propulsion device and ignoring the effects of the pressure and shear stresses acting on the side "walls" of the stream tube. By invoking these assumptions, equation (1) becomes

$$T + P1A1 - P2A2 = \dot{m}2V2 - \dot{m}1V1 \quad (2)$$

Where $\dot{m}$, P, V, and A denote, respectively, the mass flowrate, pressure, fluid velocity, and cross sectional area at the inlet and outlet sections of the stream tube. According to the conservation of mass principle, the mass flow rate at the outlet is equal to the mass flow rate of the air entering the inlet plus the fuel added. However, as a first approximation, the fuel flow rate can be neglected because it is relatively low when compared to the air-flow rate so that $\dot{m} = \dot{m}1 \approx \dot{m}2$. Therefore, the thrust force produced by the propulsive device reduces to

$$T = \dot{m}(V2 - V1) + P2A2 - P1A1 \quad (3)$$

For propulsion systems like rocket engines, air never enters so that the air mass flow rate at the inlet section ($\dot{m}1$) will be zero (i.e., $\dot{m}1 = 0$). Thus, the thrust force produced by a rocket is

$$T = \dot{m}2V2 + P2A2 - P1A1 \quad (4)$$

The thrust given by equations (3) and (4) indicate that the amount of thrust generated by an airplane propulsion system depends primarily on how momentum of the mass entering the device is increased by the propulsion device. High thrust can be generated by accelerating a large mass of gas by a small amount as is done by propellers and turbofans or by accelerating a small mass of gas by a large amount like a turbojet, ram jet, or rocket.

7.2 Thrust Sensor:

So as to characterize the thrust and torsion generated by every motor and propeller, a MBA500 is mounted to the motor's finish. This multi-axial device, once used with a USB220, allows for a transportable setup wherever a check engineer will use a portable computer to investigate the live knowledge of a check each in an outside setting or in a very a lot of controlled, indoor atmosphere. When the motor is power-driven on and rotating, the thrust of the propellers is measured by the MBA500's Fz channel, and therefore the back-torque of the motor is measured by the Mz channel, all whereas maintaining low disturbance.

8. TESTING:

The performance characteristics that are measured are system voltage, system current, temperature, motor torque and propeller thrust. The system voltage and current knowledge are often wont to live the Li-polymer batteries discharge profile and develop the corresponding C rate. Also, torsion and thrust measurements are often used for craft style functions. The controller and device output knowledge is also in analog format thus a National Instruments DAC was used with LabVIEW for easy measurements. The custom style of the electrical craft propulsion checks rig permits for the measuring of many performance characteristics at the same time. The bi-axial device mentioned earlier outputs the torsion and thrust values of the system for craft style and performance calculations. However, since this testing isn't wiped out a structure the calculations square measure for static thrust.

9. PARAMETERS AND EQUATIONS:

- ADVANCE RATIO
- THRUST COEFFICIENT
- POWER COEFFICIENT
- SPEED [POWER COEFFICIENT
- PROPELLER EFFICIENCY AT A CONSTANT BLADE ANGLE

10. Conclusion:

It is concluded that the thrust coefficient is inversely proportional to the advance ratio. Therefore, at higher rpm the thrust delivered by the propeller increases, which is a

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desirable property when the aircraft is taking off. For the aircraft to take-off, the rpm of the propeller should be high enough so that it delivers enough thrust and the aircraft takes off smoothly. The thrust is directly proportional to the advance ratio. Thus, the aircraft moves greater distance at higher thrust, which is a straightforward physical aspect of any thrust producing engine. The propeller actuator disk efficiency is directly proportional to the advance ratio and speed power coefficient. This brings us to a conclusion that the aircraft should always fly at relatively high speeds for lower fuel consumptions, and thus, fuel consumption during take-off is more as compared to fuel consumption during cruise. Advance ratio and speed power coefficient is a linearly increasing curve. Thus as the velocity of the aircraft increases, the advancement of the aircraft is more, i.e. it moves greater distances with higher speeds. Power coefficient is inversely proportional to the advance ratio. Therefore, at higher rpm the power delivered by the propeller increases, which is a desirable property when the aircraft is taking off.

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