



EXPERIMENTAL STATE OF THRUST TESTING OF AIRCRAFT RECIPROCATING INTERNAL COMBUSTION ENGINE

Matúš Mrva

Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26, Žilina
mattusmrva@gmail.com

Pavol Pecho

Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26, Žilina
pavol.pecho@fpedas.uniza.sk

Michal Hruz

Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26, Žilina
michal.hruz@stud.uniza.sk

Iveta Škvareková

Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26, Žilina
iveta.skvarekova@fpedas.uniza.sk

Martin Bugaj

Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26, Žilina
martin.bugaj@fpedas.uniza.sk

Abstract

The project "Experimental State of Thrust Testing of Aircraft Reciprocating Internal Combustion Engine" is aimed at creating a complex measuring device in order to obtain selected characteristics and parameters of the engine using different types of propellers. In addition to the basic measured parameters such as thrust, temperature, speed and fuel flow will be a state of the art to test the latest prototype propellers designed for aircraft models. After its construction, the experimental state will be used as a study aid for testing various types of conventional as well as currently developed propellers, engine characteristics and teaching of the whole equipment in the process of teaching, training of aircraft mechanics and for presentation purposes of the University of Žilina.

Keywords

aircraft engine, aircraft propeller, thrust test

1. Introduction

At present, simple experimental stands with insufficient sensor equipment are used in radio controlled (RC) aviation to measure thrust and engine parameters. If electronic systems are used, these devices are costly and therefore the designers resort only to a cheap, basic and often quite inaccurate variant of the production of a simple stool using a load cell (Kovář, 1962). At present, there is no similar and unique experimental state within the universities in the Czech Republic and Slovakia focused on aircraft technology for experimental measuring thrust testing characteristics of RC aircraft propellers, which gives the project uniqueness. Manufacturers of large propulsion units and propellers test their prototypes in test rooms that are financially unaffordable for the needs of the university (Beňo, 1985). It is the use of a model combustion piston engine and propellers to the required scale that make it possible to imitate the conditions of large test rooms on campus for relatively small funds in the form of experimental measuring device. In addition to the design, it should be noted that the technologies themselves for monitoring the parameters of model engines and their use, whether in solving problems with new propeller prototypes or as a laboratory prototype designed for teaching and measurement exercises make the project unique.

1.1. Innovative solution

The creation of such a device could bring a financially inexpensive variant of the device for experimental measuring thrust testing of various types of engines, testing new types of propellers for the University of Žilina and at the same time serve as a teaching aid for students studying this field and increase learning efficiency and interest about field of study. In addition to the teaching process itself, the project would be a contribution to the certification of an aircraft maintenance technician under the "EASA Part 147" regulation, which will be an essential part of the Aircraft Maintenance Technology study field. Specifically, it would be category B1 - certifying maintenance technician for two subcategories. They are B1.2 - Aeroplanes with Piston Engines, B1.4 - Helicopters with Piston Engines. And at the same time category B2 - certifying maintenance technician for all types of aeroplanes. The possibility of designing a fully functional prototype to test the characteristics on a reduced scale and while maintaining the relevance of the outputs is the main essence of an innovative solution for research and study of current needs of construction and design of aircraft propellers.

2. Materials & Methods

The implementation of the design and construction of the device is expected to be implemented in three main phases of

the project schedule. According to the chronological point of view, we can divide them into:

- construction,
- software and electronic part,
- running-in, calibration and testing.

2.1. Construction

In this phase, we focused on the construction of the experimental prototype itself to measure the thrust characteristics, which must meet the given strength and static conditions. The prototype itself will be constructed from available iron semi-finished products using different types of profiles. We used steel semi-finished products of class STN 42 11,600 to construct the table on which the device will be mounted.

In project was used three general types of construction segments:

- square profile 30x30x1000 mm,
- rectangular profile 50x20x700 mm,
- L - profile 30x30x800 mm.

After cutting the correct lengths of the individual profiles, were proceeded to join them using electrode welding. We welded a rectangular platform to the back of the basic structure of the table, which serves as a weight holder. After finishing the welding work, we continued with the surface treatment. The whole table was sprayed with black matt synthetic spray paint. After thorough drying, we sprayed three coats of matt synthetic varnish on the entire structure to protect against chemical damage from the exhaust gases (figure 1). Concrete was used for the production of the weight, which was embedded in the mold together with the half-cast holder.



Figure 20: Finished table, platform, and weights. Source: Authors.

After curing, the same surface treatment was applied as for the table construction, with the difference that a different shade of paint was used. The next part followed, namely the production and mounting of the movable platform to the table using a linear guide. The platform on which the internal combustion engine, electronic sensors, fuel and electrical system will be mounted was made of a steel plate which was reinforced with two steel semi-finished products of the type: square profile 10x10x250 mm. The same surface treatment followed as the weights. The platform and table were connected using the

necessary screws and a linear guide consisting of a pair of supported bars dimensions 25x450mm and four carts for the type of bar. The connection had to be perfectly centered and fine-tuned to ensure a smooth operation.



Figure 21: Internal combustion engine DLA 64 with three-bladed propeller. Source: Authors.

We succeeded and therefore we were able to proceed with the installation of a combustion, two-stroke, two-cylinder engine brand DLA (figure 2) with a capacity of 64ccm (2DLA0064 - Engine DLA 64 ccm, 2020). Together with the electronic ignition, was attached it to the platform using a screw connection. The engine is attached to the platform via four pieces of silent-blocks. The 500 ml fuel tank is attached to the platform in the bed and secured with cable ties. To control the entire our experimental measuring thrust testing device, a 3D design of the remote control unit was created, which was printed using a 3D printer from ABS material.

2.2. software and electronic part

The controller controlling the entire our experimental measuring thrust testing device contains a throttle lever, which is connected via a Bowden cable to the engine carburetor throttle, electronic ignition supply battery, two alphanumeric displays, a series of switches and signaling LEDs, a potentiometer and an Arduino Mega ADK control unit. A complex ARDUINO microprocessor system was used to measure individual variables such as thrust, temperature and fuel consumption. The whole system consists of the following components used:

- Arduino MEGA ADK control unit,
- 2x Alphanumeric displays 20x4 with circuit PCF8574, (LCD Diplej, 2020)
- Flow meter BioTech FCH-m-POM-LC, (HAREENDRAN, 2020)
- 2x Pt100 temperature sensor, (Měření teploty pomocí Pt100, 2020)
- 2x HX711 module,
- Weight sensor, (Arduino Scale With 5kg Load Cell and HX711 Amplifier, 2020)

- Wiring,
- DC source.

The individual sensors were placed on the platform and specific points so as to ensure the most reliable measurement and protection against vibrations. The software part consisted of designing and developing a simple code with which the control unit could perform individual measurements. The code was created in the Arduino IDE program, which works with the Wiring environment. After the successful installation of all sensors and the upload of the created program to the control unit, the completion of the entire electronic part followed, the connection of the electronic circuit and the preventive test of all sensor parts. (Čtení dat z arduina a ukládání dat do PC, 2020)

2.3. Running-in, Calibration and Testing

After these operations, the experimental measuring thrust testing device was theoretically completely finished. In practice, it was necessary to run the internal combustion engine first, before the measurement itself.



Figure 22: Engine run-in DLA 64. Source: Authors

During the run-in, all instructions from the engine manufacturer, DLA, were followed. Specifically, it was about adjusting the combustion mixture, the correct procedures for the initial setting of the carburetor and its subsequent tuning, the use of the specified propeller size and engine speed control. (Nový motor, 2020) After the successful start-up of the engine, the individual sensors were calibrated using calculations of the components used and designed by us. These calculations were then correctly defined and tested by editing the code. After performing these measures, the testing of the entire our experimental measuring thrust testing device was started. This consists of the following steps:

1. Switching on the system: Switch No. 1 turn on the power supply of the Arduino, all sensors, the display (the display shows a welcome message / the name of the device), then the current temperature of both temperature sensors starts. Switching on the system is indicated by an LED diode and a switched on display.

2. Start the engine: Start the combustion engine - manually. (Authorized and trained teacher) Switch No. 2 turns on the ignition. Ignition on is indicated by a lit LED.
3. Warming up of the engine to the operating temperature: After starting the engine, waiting for the operating temperature of the engine, which we find out from the data on the display, which are still measured by temperature sensors.
4. Starting the measurement: After reaching the correct operating temperature of the engine, we start the measurement. We start this with switch No. 3, which will be a single-position reversible one. The start of the measurement will be indicated by an LED diode. The displays will show "Measurement", current engine thrust, fuel consumption and individual temperatures. The time (2-5min) will also be counted down, which will be divided into 5 sections according to which the engine speed will be added. E.g. 0-30s - 20% gas, 30-60s - 40% gas ...
5. End of measurement: After the end of the measurement time, the measurement is switched off with switch no.3. The measured values will be recorded by a connected laptop and in Microsoft Excel it will create graphs from individual measured quantities. The LED indicating the ongoing measurement goes out. At the end of the measurement, the throttle lever is set to idle speed position.
6. Switching off the system: The engine is switched off, then the ignition is switched off (the LED goes out) and finally the entire power supply of the system.

After a successful calibration and a series of tests, the latest imperfections have been fine-tuned. The device was prepared for operation, teaching, presentation and defense of the diploma thesis of the student Bc. Matúš Mrva.

3. Results

The project "Experimental state of thrust tests of aircraft piston internal combustion engine" will serve as a practical and at the same time theoretical part of the diploma thesis of the student Bc. Matúš Mrva. The resulting experimental state will consist of a prototype of a thrust characteristic measuring device, a combustion piston model engine with accessories for its operation and a series of test model propellers with different properties. After the end of the project, such an experimental state will serve, in addition to the research focus, mainly as a teaching aid for students dealing with the issue and for future aviation technicians. In addition to practical outputs, the project is also focused on the presentation of achieved results in publications at domestic and foreign conferences and magazines.

3.1. Project Benefits

3.1.1. Scientific addition

The main scientific contribution of this project is to bring a modern instrumental teaching aid that will use current technologies in the field. The task of this device will be to measure the selected parameters and properties of the engine

depending on the type of propeller used. Based on these data, it will then be possible to analyze specific modifications and modifications in the development and innovation of aircraft propellers. In the course Aircraft Propellers, students are acquainted with the current trend in the development of aerodynamic properties and materials used in aircraft propellers, with emphasis on reducing noise and increasing thrust efficiency while reducing overall aerodynamic drag. For these reasons, the Department of Air Transport is also focused on research and innovation in this area with material support through external manufacturers in the final work.

3.1.2. *Addition for practice*

We emphasize the simplicity and efficiency of the project, and the result of the project will be fully functional instrumentation that can be used to monitor various types of internal combustion piston engine parameters, based on which it will be possible to determine further procedures in the development of the tested propeller. In case of successful test results, the device is planned to be used as a practical teaching aid for students of the Department of Air Transport, especially for students of Aircraft powerplant, Aircraft Propellers and Maintenance Procedures 1 and 2. The device will be designed and constructed so that in the future modify its components, optimize it and integrate new installations. These include modifications to the use of other internal combustion engines, the addition of additional sensors or the updating of the program for the Arduino microcomputer unit. In terms of usability for direct practice, the project is focused on cooperation with aircraft manufacturers

model propellers, which could be measured in the future as part of joint research and processed in the form of final theses of students at the Department of Air Transport, respectively to verify the design and innovative designs of new types of propellers designed for civil aviation.

4. Conclusion

The aim of the article and the project was to construct a comprehensive device for aircraft engines, whose main task will be to monitor selected engine parameters with their subsequent analysis and use of this information for the purpose of modifications and design of new prototype propellers, whether for aircraft modeling or civil aviation. At the same time, the project will serve as a study aid within the teaching process, as well as in solving final and semester works. The whole device is made of easily accessible components and materials so that there is no problem with the availability of spare parts or modification for the use of another type of engine or configuration. This opens up new promising opportunities for various developments in the coming years. In conclusion, we can state that we were advised to build a functional experimental measuring thrust testing device that can measure the specified parameters using different types of propellers and engines and we can adequately evaluate and apply the measured quantities for different types of use.

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References

- 2DLA0064 - Motor DLA 64 ccm (dvouválec) včetně tlumiče a příslušenství, viewed 15 September 2020 [online: <https://www.tatramodel.sk/zakladna-ponuka/spalovacie-motory/nahradne-diely/nahradne-diely-dla/2DLA0064-motor-dla-64-ccm-dvouvalec-vcetne-tlumice-a-prislusenstvi/>]
- Arduino Scale With 5kg Load Cell and HX711 Amplifier, viewed 21 September 2020 [online: https://www.instructables.com/Arduino-Scale-With-5kg-Load-Cell-and-HX711-Amplifi/?fbclid=IwAR0m_un_7ReagvY1SoH2oQV9jGDpMMY2sz3iTFMjVxHMLnTs8MH5sDm8fzg]
- BEŇO, L., Letouny a jejich systémy: Vrtulové pohonné jednotky s pístovými motory. 1985. Bratislava: VIDEOPRESS
- Čtení dat z arduina a ukládání dat do PC, viewed 21 September 2020 [online: <https://arduinoprojekt.webnode.cz/news/cteni-dat-z-arduina-a-ukladani-dat-do-pc/>]
- HAREENDRAN. T.K., Working with Water Flow Sensors & Arduino, viewed 20 September 2020 [online: <https://www.electroschematics.com/working-with-water-flow-sensors-arduino/?fbclid=IwAR3K-L9xYE7reAd1qo7SAwBpRS2nEmjokUANL-TkbFMgc2TOhydFLKIJoc>]
- KOVÁŘ, R., Zkoušení leteckých motorů. [s.l.], 1962. 387 s. Skriptum. Vojenská
- LCD Displej, viewed 20 September 2020 [online: <https://navody.arduino-shop.cz/zaciname-s-arduinem/lcd-displej.html>]
- Měření teploty pomocí Pt100, viewed 21 September 2020 [online: <https://navody.arduino-shop.cz/arduino-projekty/mereni-teploty-pomoci-pt100.html>]
- Nový motor, viewed 14 September 2020 [online: http://www.kolmanl.info/index.php?show=smotory_nove#smotory_nove_uv]