USE OF DATA FROM ON-BOARD DATA RECORDERS FOR ACCEPTANCE TESTS OF AVIONIC DRIVING UNITS

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Abstract

The paper explains how information stored in on-board recorders of flight parameters can be used for acceptance tests, also referred to as qualification tests. The disclosed example refers to the An-28 'Bryza' aircraft where an old airscrew was substituted with the new generation Hartzell airscrew of the HC-B5 MP-3D type. The airscrew is an integral part of the driving system for the airscrew propelled aircraft that is provided with the TWD-10B engine. After revamping of the airscrew, the aircraft was named as TWD-10B/PZL-10S. The follow-up investigations were carried out with the aim to find out how much the airscrew substitution affected the alteration of key performance characteristics achieved by the driving unit of the aircraft. The investigations comprised both ground and in-flight tests and have led to determination of the essential characteristics for the engine operation as well as variations of the operational parameters in time. In some cases also so called phase portraits were found out for parameters of the engine operation so that to reflect dynamic properties of the engines. Such investigations are indispensable since the aircrafts are subject to operational limitations and technical conditions that must be mandatory fulfilled due to requirements of flight safety. The paper demonstrates that the data stored in on-board recorders of flight parameters can be really useful for execution of such acceptance (qualification) tests.

Keywords: *diagnostics of aircraft engines, qualification tests for avionic driving units*

1. Introduction

The key precondition for operation of aircrafts is the need to guarantee a high level reliability of equipment and safety of flights. The issues associated with evaluation of reliability demonstrated by specific mechanical objects, such as turbojet aircraft engines, is really important in theoretical and practical aspects. The distinctive feature of such objects is a very high number of various components and subassemblies, which is the reason why a systemic approach to monitoring and troubleshooting of such objects is really sophisticated and needs the application of innovative methods. For instance, such an unusual approach to monitoring and evaluation of aircraft driving units may consists in benefiting on-board recorders of flight parameters for routine inspection of these driving units.

The use of information stored in recorders of flight parameters is also vital when the point is to analyze operational parameters of upgraded driving units that either underwent structural alterations or were provided with completely new components (units) that had never been in use at all or in the resultant configuration. The data retrieved from data recording modules make it possible to compare the new solution against the original one and to ascertain real benefits that are achieved owing to the upgrade, structural alteration, or similar measures.

Such investigations are really indispensable since the aircrafts are subject to operational limitations and technical conditions that must be mandatory fulfilled due to the requirements of flight safety. The analysis covers such parameters as minimum power, maximum ceiling, maximum speed of flights, minimum conditions to start-up the engine in flight.

The examples of how the information from recorders of flight parameters can be used for such factory-based and qualifying examinations are disclosed on the basis of experience with and An-28

Bryza aircraft, where the aircraft upgrade consisted in substitution of an original airscrew with a five-blade airscrew of the HC-B5 MP-3D type from Hartzell. The methodical approach to investigations with the application of information from on-board data recorders to acceptance tests of upgraded driving units is dedicated to specific driving units of individual aircrafts. Primarily, it needs determination of performance characteristics and alterations of timings for key operational parameters or, in some cases, development of phase portraits that reveal dynamic features of key operational parameters.

2. Substitution of an airscrew for the driving unit of the *Bryza* aircraft

The upgrade of the An-28 *Bryza-1R* aircraft was limited merely to installation of a new HC-B5 MP-3D airscrew from Hartzell. The follow-up analysis of the driving unit performance was aimed at verifying operational parameters of the TWD-10B/PZL-10S engine after providing it with a new airscrew type as well as checking how the automatic control of the airscrew performs during ground tests and in flights.

The methodology of in-house tests included evaluation of the driving unit performance at the following aspects:

– coincidence of technical parameters measured for both the engine and the airscrew with the corresponding technical conditions prescribed by the operation manual for that driving unit over the entire range of the engine operation,
– reliable operation of the automatic hardware for the airscrew, its parking brake and the control system for the airscrew,
– reliable and timely tripping of limit switches for the engine rpm, temperatures, etc.

The ground tests demonstrated that the graph for variation of the turbocompressor rpm as a function of the tilt angle for the engine control lever (DSS) for both the right-hand site and left-hand site engines are correct and in line with the corresponding graphs prescribed by technical documentation for these types of driving units (Fig. 1). Pretty close matching between the results obtained from experiments and requirements imposed by technical documentation serves as the evidence that all adjustments for both the engines had been carried out correctly and substitution of the airscrew has no impact onto the driving unit performance.

Similarly, waveforms for variation of driving turbines rpm for the both engines (also determining the behaviour of the airscrews) demonstrates close correlation to technical conditions (Fig. 2).

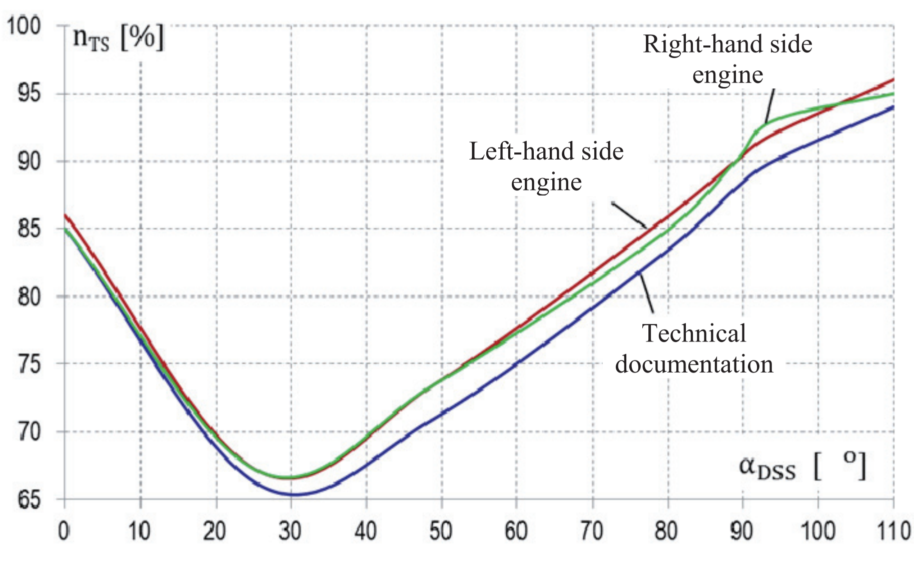

Fig. 1. Relationships between turbocompressor rpm for the right-hand side and left-hand side engines and the tilt angle of the Engine Control Lever (DSS)

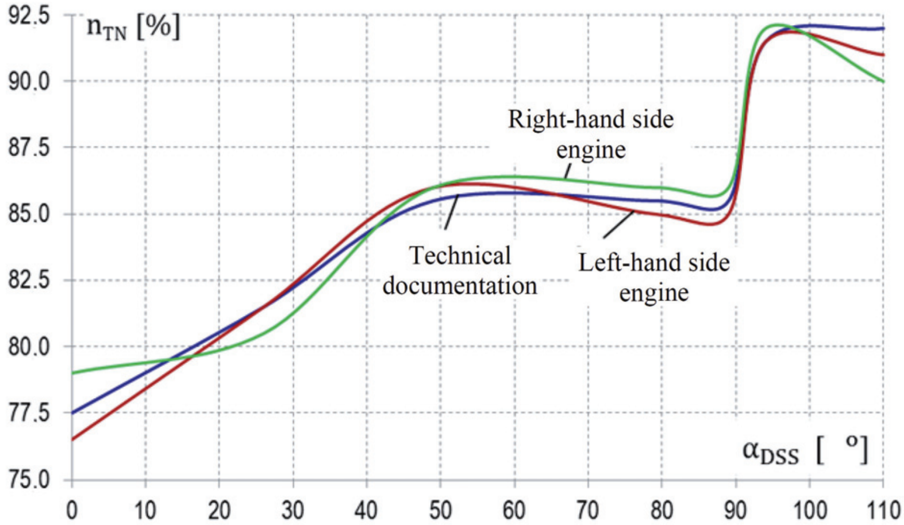

Fig. 2. Relationships between driving turbine rpm for the right-hand side and left-hand side engines and the tilt angle of the Engine Control Lever (DSS)

The behaviour of the turbocompressor and the driving turbine for the right-hand side engine during the full test of the engines operation is shown in Fig. 3 (the left-hand side engine behaved in a very similar way). The graph confirms that rpm ranges for collaboration of the two major subassemblies of that driving unit are adjusted in the optimum manner. In addition, the moment is indicated when speeding up of the driving turbine commences (about 25-28% of the turbocompressor rpm) that corresponds to the indications displayed by cockpit instruments during the engine start-up procedure.

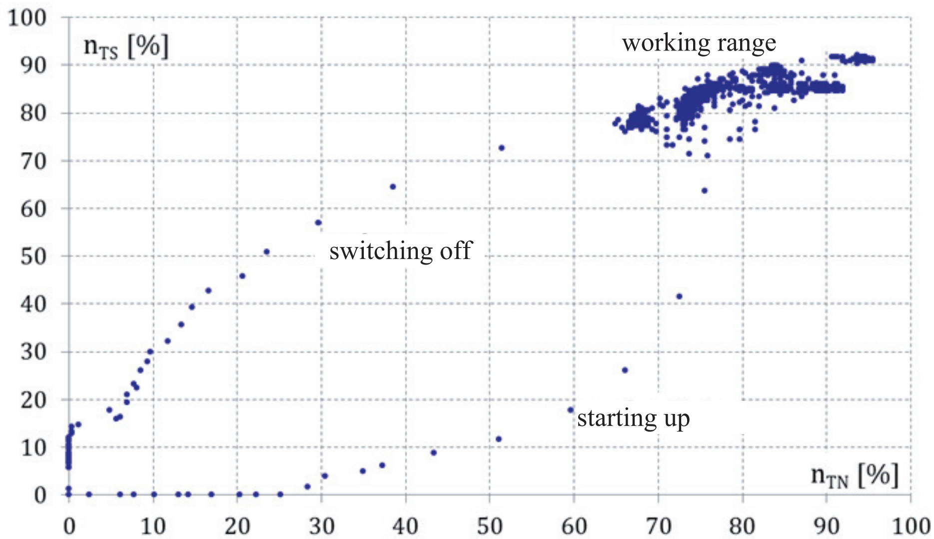

Fig. 3. Interaction between the turbocompressor and the driving turbine of the TWD-10B/PZL-10S engine

An interesting characteristic curve that was plotted on the basis of information downloaded from the on-board recorder is the variation of fuel consumption for individual operation ranges of the engine – Fig. 4. A slightly higher fuel consumption was found out for the left-hand side engine but the general appearance of the curve is in line with technical conditions for these engine types. It was found out that the lowest fuel consumption per hour occurs for the range of α_{DSS} between 25° and 45°, i.e. between the low throttle position of ground operation (ZMG) and the low throttle position in flight (LMG) – the nomenclature according to the operation manual for that engine type.

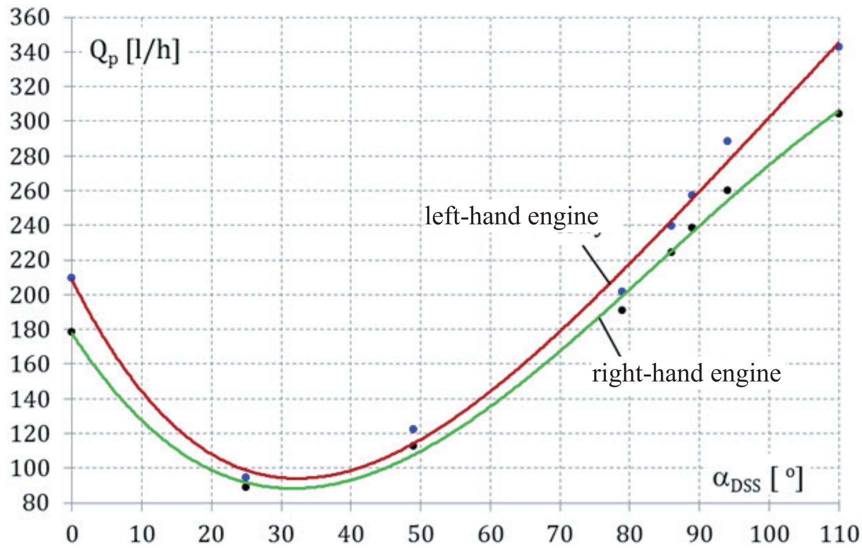

Fig. 4. Fuel consumption of TWD-10B/PZL-10S engines as a function of the tilt angle α_{DSS} for the Engine Control Lever (DSS)

In-flight tests carried out at the same altitudes and the same flight speed values were performed with the aim to find out how the flight altitude and speed affect the performance parameters of both the turbocompressor and the driving turbine at the defined settings (α_{DSS}) for the Engine Control Lever (DSS). An example of the achieved results is shown in Fig. 5 that depicts the relationship between the aircraft speed V_p indicated by its instruments during a horizontal flight and the tilt angle α_{DSS} of the Engine Control Lever (DSS). The graphs are plotted for various flight altitudes.

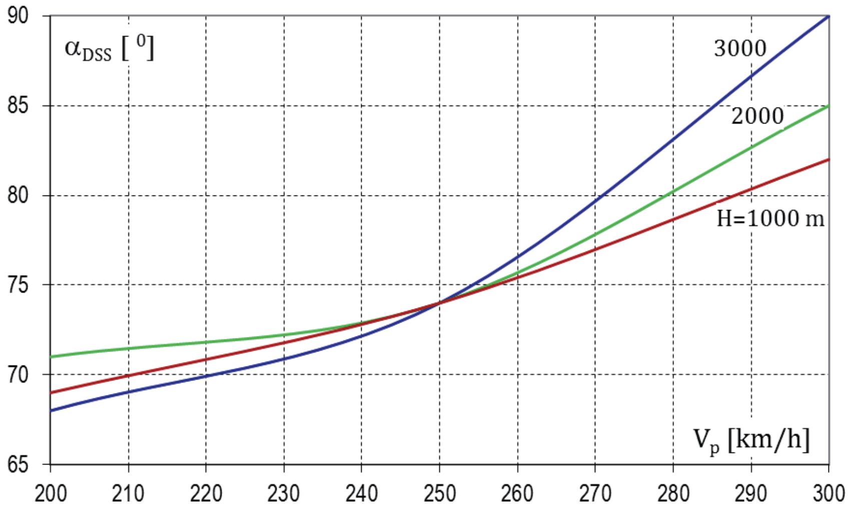

Fig. 5. Variations of the tilt angle for the Engine Control Lever (DSS) and the aircraft speed indicated by its instruments for various flight altitudes.

The graphs show that the position of the Engine Control Lever must be permanently readjusted to keep the constant instrumental speed at the specific altitude. It is more distinctively seen for higher values of flight speed where the tilt angle for the Engine Control Lever must be increased to keep the constant flight speed at higher flight altitudes. For low values of flight speed (below 250 km/h) the range of such lever repositioning is much smaller and their slight dispersion (about 1%) chiefly results from accuracy of the indicators applied.

In addition, flight test must comprise checking the performance parameters demonstrated by the aircraft driving units at several altitudes and for several flight speeds in order to plot the envelope for start-ups of the engine incorporated into such types of driving units.

The method for determination of the envelope for the engine start-ups assumes that engines must be started up in air at various flight altitudes and for several points that belong to the existing envelope (i.e. for the speed range from 180 to 200 km/h and altitudes from 4000 to 3000 m) as well as at several points that are located outside the existing envelope (reaching even as little as about 250 m of altitude at the speed of 200 to 220 km/h). The test demonstrated the envelope area can be expanded – see Fig. 6.

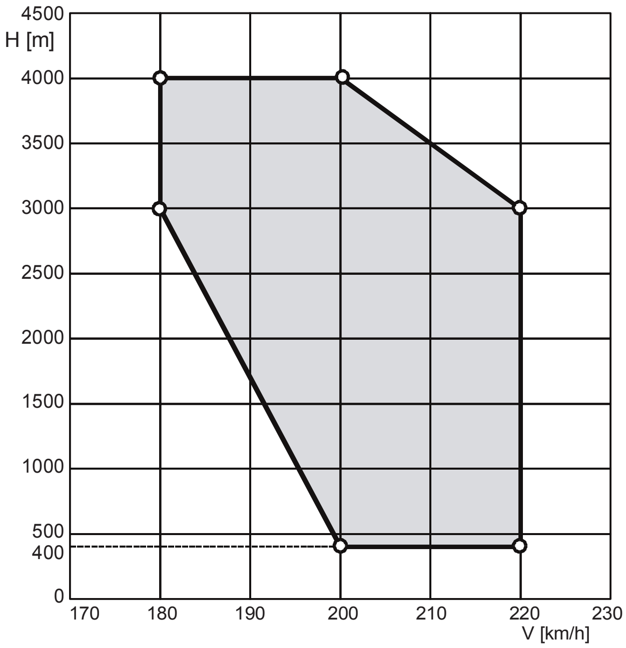

Fig. 6. The enveloped of engine start-ups plotted for the Bryza-1R aircraft with the TWD-10B/PZL-10S engine furnished with the HC-B5MP-3D/M airscrew from Hartzell

The finding is important from the point of flight safety since it enables in-flight start-ups of the engine within a broad range of flight speeds and altitudes.

Fuel consumptions at specific flight altitudes and during typical manoeuvres, such as engine start-up, taxing, take-off, take-off climb, aerodrome circuit, landing, runoff and cooling is shown in Fig. 7. Consumption of fuel drops in pace with the flight altitude, which results from diminished demand for fuel due to reduced resistance of air inflow that is lower at higher altitudes.

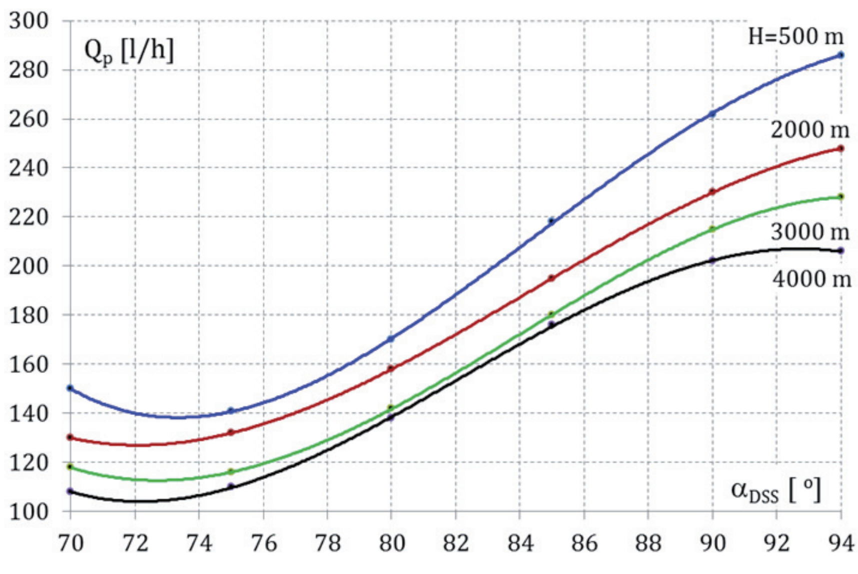

Fig. 7. Fuel consumption of the TWD-10B/PZL-10S engine as a function of variable flight altitude

All the foregoing examples clearly demonstrate that the use of measurement results stored in on-board recorders of flight parameters offer wide diagnostic opportunities to verify technical condition of units and subassemblies after major overhauls, such as upgrade of the driving unit of the An-28 *Bryza-1R* aircraft.

3. Conclusions

The completed investigations confirmed that acceptance tests can be carried out only with the use of information stored in on-board recorder of the aircraft flight parameters.

The results obtained from both ground tests and in-flight investigations of the TWD-10B/PZL-10S driving unit for the An-28 aircraft of the *Bryza-1R* make are satisfying and meet requirements imposed by Operation Manuals, recommendations of the Air Force headquarter and well as NLGS and FAR-23 regulations. Some performance parameters, such as power, compression or noise were even improved as compared to the parameters achieved by the driving unit with the old, three-bladed airscrew of the AW-24AN type.

Supplementary in-flight investigations made it possible to find out that the TWD-10B/PZL-10S driving unit can be started up in the air at more harsh conditions, e.g. at low altitudes, starting from 400 m at the aircraft speed of 200 to 220 km/h.

The final conclusion is that the investigated driving unit (i.e. the TWD-10B/PZL-10S engine with the five-bladed HC-B5MP-3D/M airscrew from Hartzell) meets the acceptance criteria imposed by the Air Force Headquarter, NLGS-2 and FAR-23 regulations and can be used for driving AN-28 aircrafts of the *Bryza-1R* make.

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