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METROLOGICAL SUPPORT OF ONBOARD REGULATORS MEASURING CHANNELS

The subject of research *was the development of a compact device that uses an imitator of a torque meter on the free turbine shaft to provide the metrological support for the development and production of RDC-450M-117V – the TV3-117VMA-SBM1V digital engine onboard regulator.* ***The purpose of this study*** *was to develop the torque meter imitator based on information about the real aircraft engine torque meter characteristics, but without its mechanical part, which is big enough and difficult to manufacture and use during the regulators' production. The real engine torque meter (which signal it was necessary to imitate) was a combination of the special free turbine output shaft (measuring shaft) with two inductors on it and a rotor rotation speed sensor (with frequency output signal). The tasks faced by developers were to investigate the real torque meter operating principle and its characteristics, first, the output signal characteristics, and to develop an electronic device that would provide the same signal reproduction.* ***The applied methods*** *are the real engine torque meter characteristics theoretical and experimental study on the stands of JSC "Motor Sich", processing of experimental data (waveforms of rotor rotation speed sensor) using a quantitative analysis method. The results. The design documentation and software for the torque meter imitator were developed, and the imitator was made. It is compact and comfortable to use a two-channel electronic imitator, which provides calibration and testing of the RDC-450M-117V regulator measuring channels and can operate in autonomous mode under operator control or as the engine stand-imitator part (or being connected to a PC with an installed engine mathematical model) under automatic control by the engine mathematical model. The scientific novelty of the obtained results is that the engine torque meter output signal was studied in detail and implemented in a compact electronic imitator that does not need a mechanical part similar to a real measuring shaft with two inductors on it and a rotor rotation speed sensor. The practical significance. As part of the metrological support for the development and production of aircraft engine regulators, a new compact, which is comfortable to use as a two-channel electronic imitator of a torque meter on the free turbine shaft, was developed. The developed torque meter imitator provides engine regulators with production tests. The imitator was verified during testing of the RDC-450M-117V regulator as part of the TV3-117VMA-SBM1V engine.*

Keywords: *aviation equipment components; engine regulator; torque measuring channel.*

Introduction

JSC Element (a certified developer and manufacturer of aviation equipment components) has developed and produced the aircraft engines' digital regulators under the technical requirements (Statements of work) of SE Ivchenko–Progress and JSC Motor Sich for about a quarter of a century. The important task is to provide the test base availability and metrological support for this activity. Specialists of Element JSC have always paid attention to this task, including developing specialized testing equipment, such as stands with built-in engines mathematical models provided engine imitation during digital regulators tests [1, 2].

The important part of such test equipment is the engine transducer imitators, which provide the regulators with measuring channels calibration [3].

1. Formulation of the problem

By 2021, the equipment specially designed and manufactured at Element JSC included a stand that simulated all the engine sensors with which by that time the electronic engine regulators being developed at the enterprise needed to interact. These were, in particular, meters of:

– rotor rotation speed (with frequency output signal);

– gas temperature (thermocouples);

– oil temperature (thermal resistance);

– angular position of the dosing element (sensors 45D-32 – linear rotating transformers);

– the angle of installation of the common propeller pitch (DBSKT sensors, the information signal of which is the ratio of voltages on the sine and cosine windings);

– vibration level (piezoelectric sensor, the conversion function is described as a directly proportional dependence of the electric charge Q at the output on the vibration acceleration amplitude α at the sensor input).

But for the new regulator RDC-450M-117V, whose development began at the end of 2021 [4], the list of measuring channels was not limited to the mentioned types of sensors. The task was set to process the torque sensor signal.

The device on the engine, used for torque measurement, is the combination of the special free turbine output shaft (measuring shaft) with two inductors on it and a rotor rotation speed sensor (with frequency output signal). One of the two inductors is installed on the unloaded part of the measuring shaft (on the so-called screen), and the other is installed on the loaded part (spring). This arrangement of the inductors leads to the fact that when the shaft rotates, an additional angular displacement occurs between adjacent teeth of the inductors, reflecting the shaft twist angle, and therefore proportional to the value of the torque on the shaft:

$$M_{tor} = k\varphi_{tw}.$$

Thus, the indicated additional angular displacement is in this case an informative parameter, which is converted into an electrical signal by the rotation speed sensor.

Of course, making an imitator of the described torque meter, which would have a mechanical part identical or close to the real one, would be a difficult task. But even if manufactured, such an imitator would not be convenient to use when calibrating and testing the measuring channels of the regulator under mass production conditions.

Thus, imitation of the mechanical part of the meter was not considered relevant and the developers of Element JSC were faced with the task of developing an electronic device (with built-in software) that would allow the generation of an electrical signal identical to the signal from a real speed sensor at given values of the shaft twist angle.

2. Results

The appearance of the developed imitator is shown in Figure 1. This two-channel torque sensor imitator is appropriate for use as an autonomous module or as an engine stand-imitator part, or being connected to a PC with an installed engine mathematical model.

When working in autonomous mode, the operator is allowed to set the required value of the shaft twist angle φ_{tw} (thereby setting the torque value) by rotating the encoder handle and observing the indicator readings.

When an imitator works as an engine stand-imitator part or is connected to a PC with an installed engine mathematical model, this model provides the automatic angle setting.

The block diagram of the imitator is shown in Figure 2. Information about the required (set) twist angle value is supplied to the microcontroller either from the encoder (in autonomous mode of imitator operation) or from the stand-imitator (or from PC). The RS-232 driver provides exchange with a stand-imitator or with a PC. The microcontroller, thanks to the specially developed software installed on it, processes the incoming data and generates the corresponding signals. From the outputs of the digital-to-analog converters (DAC) of the first and second channels, the signals are supplied to amplifiers and then through transformers (serving for galvanic isolation) to the imitator output (and then, accordingly, to the input of the regulator being tested).

Every of two equal output signals arrives at the regulator input.

Fig. 1. Imitator appearance

The imitator output signal is shown in Figure 3 (it is illustration for clarify the principle and we do not indicate the numbers on the axes). It reproduces the response of the rotor speed sensor when the teeth of each of the two inductors mentioned above sequentially pass over it.

These are two sequentially repeating quasi-sinusoidal oscillations with an interval (pause) between them. The duration of the interval depends on three factors:

– rotation speed of the measuring shaft;

– the value of the initial angular displacement between adjacent teeth of the inductors, which is determined by the design and is constant;

– the value of the additional angular displacement, that is, the shaft twist angle, and depends on the torque.

Shaft twist angle φ_{tw} can be calculated as the following:

$$\varphi_{tw} = (\tau_1 / \tau_{\Sigma}) \cdot \varphi_z - \varphi_{init},$$

where τ_1 – first oscillation duration (see Figure 3);

τ_{Σ} – oscillations duration sum;

φ_z – the angle between the inductor teeth (is equal to 360º divided by the number of inductor teeth);

φ_{init} – initial angular displacement between adjacent teeth of the inductors.

Thus (taking into account the above formula), to check the compliance of the output signals with a given twist angle using a standard verified oscilloscope, it is enough to determine the ratio τ_1/τ_{Σ}, which ensures the availability of monitoring the suitability of the imitator at almost any time.

The manufactured torque meter imitator has successfully passed the verification by comparing the calibration results of the RDC-450M-117V measuring channels and the measurement results when testing this regulator as part of the engine.

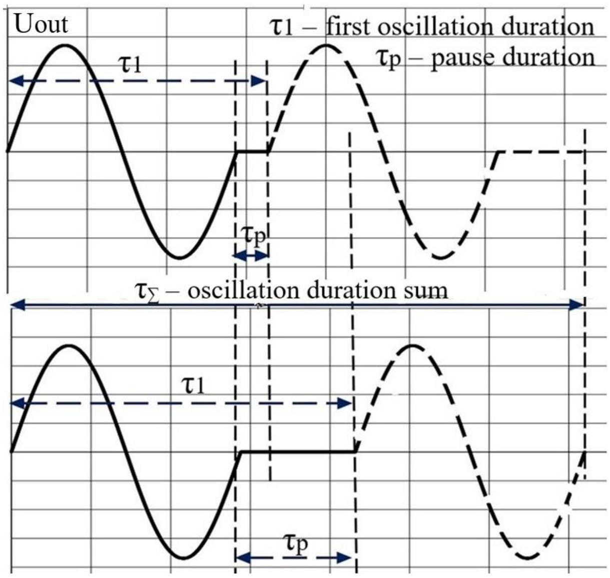

Fig. 3. Output signal graphs – the top graph corresponds to the absence of shaft twisting, i.e. zero angle, bottom graph – twist angle 2° under the same rotation speed of the measuring shaft

Conclusion

1. As part of the metrological support for the development and production of aircraft engine regulators, a new imitator has been developed, namely an imitator of a torque meter on the free turbine shaft.

2. A compact comfortable in using two-channel electronic imitator provides calibration and testing of the RDC-450M-117V regulator measuring channels and can operate:

– in autonomous mode under operator control;

– as the engine stand-imitator part (or being connected to a PC with an installed engine mathematical model) under automatic control by the engine mathematical model.

3. The checking imitator metrological characteristics is provided using standard measuring equipment.

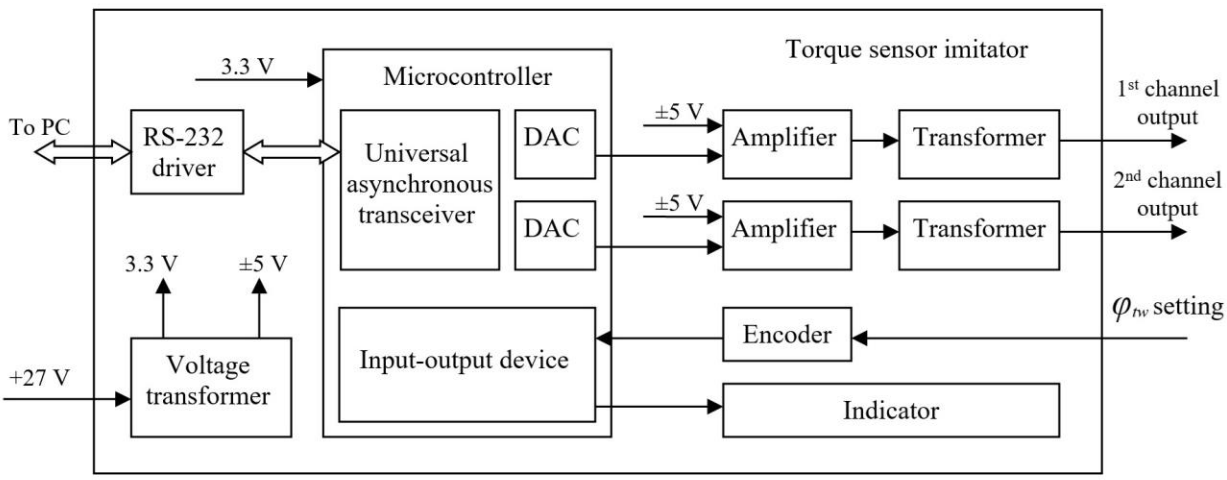

Fig. 2. Block diagram of the developed two-channel imitator

4. The developed torque meter imitator was verified during the testing of the RDC-450M-117V regulator as part of the TV3-117VMA-SBM1V engine.

Authors' contributions: problem statement – **A. G. Buryachenko**; information sources review – **A. G. Buryachenko;** development of basic solutions – **D. S. Burunov**; implementation of solutions – **V. O. Vasyukovich**; experimental studies and analysis of their results – **V. O. Vasyukovich, A. G. Buryachenko**.

Conflict of Interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

Use of Artificial Intelligence

The authors confirm that they did not use artificial intelligence methods while creating the presented work.

All authors have read and agreed with the published version of the manuscript.

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МЕТРОЛОГІЧНЕ ЗАБЕЗПЕЧЕННЯ ВИМІРЮВАЛЬНИХ КАНАЛІВ БОРТОВИХ РЕГУЛЯТОРІВ

А. Г. Буряченко, Д. С. Бурунов, В. О. Васюкович

Предметом дослідження стала розробка компактного, зручного у використанні імітатора вимірювача крутного моменту на вільному валу турбіни для метрологічного забезпечення розробки та виробництва

РДЦ-450М-117В – цифрового бортового регулятора двигуна ТВ3-117ВМА-СБМ1В. ***Метою роботи*** була розробка імітатора вимірювача крутного моменту на основі інформації про характеристики реального вимірювача крутного моменту авіаційного двигуна, але без його механічної частини, досить великої та складної у виготовленні та використанні при виготовленні регуляторів. Справа в тому, що справжній вимірювач крутного моменту двигуна (сигнал якого потрібно було імітувати) є комбінацією спеціального вільного вихідного валу турбіни (вимірювального валу) з двома індукторами на ньому і датчика швидкості обертання ротора (з частотним вихідним сигналом). ***Завдання***, що стояли перед розробниками, полягали в дослідженні принципу роботи реального вимірювача крутного моменту та його характеристик, в першу чергу характеристик вихідного сигналу, та розробки електронного пристрою, що забезпечує відтворення такого ж сигналу. ***Методи***: теоретичне та експериментальне дослідження характеристик вимірювача реального крутного моменту двигуна на стендах ВАТ «Мотор Січ», обробка експериментальних даних (осцилограм датчика швидкості обертання ротора) методом кількісного аналізу. ***Результати***. Розроблено конструкторську документацію та програмне забезпечення для імітатора вимірювача крутного моменту та виготовлено імітатор. Це компактний, зручний у використанні двоканальний електронний імітатор, що забезпечує калібрування та перевірку вимірювальних каналів регулятора РДЦ-450М-117В і здатний працювати в автономному режимі під керуванням оператора або у складі стенда-імітатора двигуна (або підключаючись до ПК із встановленою математичною моделлю двигуна) під автоматичним керуванням за математичною моделлю двигуна. ***Наукова новизна*** отриманих результатів: детально досліджено вихідний сигнал вимірювача крутного моменту двигуна і реалізований в компактному електронному імітаторі, що не потребує механічної частини, аналогічної реальному вимірювальному валу з двома індукторами на ньому і датчиком швидкості обертання ротора. ***Практичне значення***. У рамках метрологічного забезпечення розробки та виробництва регуляторів авіаційних двигунів розроблено новий компактний, зручний у використанні двоканальний електронний імітатор вимірювача крутного моменту на вільному валу турбіни. Розроблений імітатор вимірювача крутного моменту забезпечує заводські випробування регуляторів двигуна. Імітатор веріфікований при випробуваннях регулятора РДЦ-450М-117В у складі двигуна ТВ3-117ВМА-СБМ1В

Ключові слова: комплектуючі вироби авіаційної техніки; регулятор двигуна; канал вимірювання крутного моменту.

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