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STRAIN GAUGE MEASUREMENT OF PROPELLER BLADE VIBRATION DURING OPERATION ON AIRCRAFT DIESEL ENGINE

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1. Introduction

The propeller propulsion unit is still the most effective way to drive light sport and tourist aircraft for which high initial thrust, steep climbing, minimum fuel consumption and low operational costs are requested. The limit is no very high flight velocities, in comparison with jet business planes. Such airplanes equipped with a reciprocating spark ignition engine have been developed to perfection practically during all century of history of flying. But another pressure on reducing of consumption and emissions has been still exerted. The innovative using of a reciprocating engine based on diesel cycle is one of possible way. The fuel for this kind of engines is kerosene oil – in comparison with common aviation gasoline (AvGas) the low consumption means longer range of flight and other substantial advantage is its availability on each airports practically because the same fuel is used for jet airplanes. For these reasons various attempts with diesel engines has been performed for all history of aviation, but on the field of so called general aviation they have not been very successful. Of course, there are some disadvantages and problematical aspects. It is well-known that these types of engines generate higher levels of torque oscillation on the shaft during their operation in comparison with the AVGAS engines and this fact has to be respected during design of the propulsion unit. Especially for maintenance of contemporary levels of reliability and safety it is necessary to regard the mentioned factors during choice of an appropriate propeller, let us say the propeller should be designed specially.

The Aerospace research and test establishment (VZLU) has took part in an innovative project focused on design of such specific aircraft propeller. Next to the demand on a structure capable to withstand the increased levels of vibratory excitation, the aerodynamics of the propeller will be optimized for the diesel conditions of operation, i.e. lower rotational speed. The other advantage of such solution will lead to lower noise of the propulsion unit, because the contribution of aerodynamic noise of the propeller is often more than half of the total output of aircraft noise.

The French engine SMA SR305 is an air and oil cooled flat four-cylinder aircraft engine, operating on the four-stroke diesel cycle with direct fuel injection into the cylinder. It is supplied with air by a turbocharger via an intercooler. The operation is controlled by an electronic system of the Engine Control Unit nowadays, of course. A propeller is direct driven and its maximal rotational speed is limited up to 2200 RPM. The 230E engine version was certified by EASA and FAA in 2010.

The Horizon 2020 / Clean Sky 2 project is aimed to verification of behavior of the engine – propeller dynamic system with the main target to design a propeller together with appropriate solutions. The leader of the consortium of participants for this project is the company Woodcomp Propellers. As the first step the vibration survey of a common propeller type mounted on the SR305 engine was assumed.

2. Methods of measurement

Strain gauges are the only one method of realization of measurement on the rotating propeller in practice. Recently, some attempts of use of optical means of measurement have been done, but these experiments are still under development, usually on the ground operation only because of extent devices. The main advantage is a complex vibration scan of all propeller blades. While the strain gauges provide loading data only from small areas of their grids and so their number

depending on purpose of measurement can be considerable.

The key part of the measuring chain is a device for transmission of measured signals from rotating part to a stationary base. In the past, contact slip-rings were used. Nowadays, wireless telemetry systems are preferred because of their high noise immunity. Another reason is the measurement on the single-engined aircraft equipped with a tractor propeller can be realized, as there was an invincible problem in former time. Digital data acquisition devices must provide an appropriate rate of sampling, because various components of the propeller oscillation can be in the range up to 1000 Hz. VZLU uses a Kraus MT-32 system.

3. Tests and evaluation

The Woodcomp KW-15 type is three-bladed propeller with hydro-mechanical control of blade angle settings for constant-speed operation. It is intended for typical engine applications in general aviation: The AVGAS engines of Lycoming or Continental with power up to 300 HP and rotational speeds up to 2700 RPM. The prototype has been retained as the firm testing propeller equipped with strain gauges for ever and so it was used as an initial propeller for the first testing of the SR305 diesel engine. The vibration survey measured on the propeller blades was performed on the Woodcomp ground testing station – a special bench embedded in a wind tunnel.

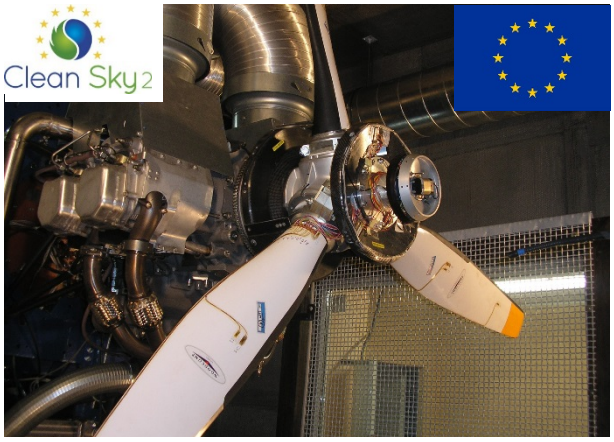

Fig. 1. KW-15 propeller equipped with strain gauges and mounted on SR305 diesel engine during tests.

The evaluation of the measured signals contains both over-all values of strain oscillation (Fig. 2) and spectral decomposition of the signals to verify levels of vibration frequency components caused by various exciting effects with their typical frequencies. So called Campbell diagram serves to detect possibility of resonances.

4. Conclusion

The measurements and their evaluations described shortly above are routine operations for the VZLU Aircraft Propeller Testing Laboratory in principle, but working on the new kind of engine characterized by different behavior is an appealing challenge.

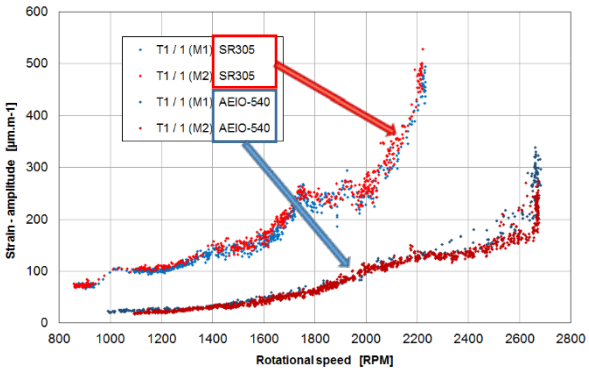

Fig. 2. Comparison of dynamic loading measured in T1 strain gauge position on the blade root for operation on diesel SR305 and Lycoming AEIO-540 engines.

The results of the measurement of propeller blade vibration on diesel SR305 engine was compared with the operation of the same propeller on a six-cylinder spark-ignition engine of Lycoming AEIO-540 type. The comparison with a four-cylinder AVGAS engine with similarly close power (as the tested SR305 engine) would be more interesting, but unfortunately, there are no relevant data in our database.

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