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AN INFLUENCE OF PUSHER PROPELLER COVER ON ITS PERFORMANCE – A CONCEPT OF WIND TUNNEL INVESTIGATION

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Abstract

The paper describes a concept of wind tunnel investigation of the influence of the pusher propeller cover on its performance. The pusher propeller is one of the most popular types of the airplane propulsion, especially in light sport aircrafts and in the UAVs (Unmanned Aerial Vehicles). Its main advantages is that the engine with the pusher propeller does not affect the visibility from the cockpit and allows for placing an electronic equipment (for example, a camera) in the front part of the UAV's fuselage. One of main disadvantages of pusher propeller is that it is partially covered by the fuselage and the wings of the airplane, thus the slipstream is distorted. This distortion may reduce the propeller thrust and efficiency. It may also cause vibrations of the propeller blades. This fact is well known, however it is difficult to find any quantitative information about reduction of the propeller performance. Taking it into account, it is worth to treat this subject and show a way to enhance the propeller performance. The wind tunnel tests, which concept has been described in the paper, will include measurements of total aerodynamic loads acting on the investigated object and on the propeller. Measurement of velocity distribution in the slipstream (by pressure measurement and by laser anemometry) will be included as well.

Keywords: *aircraft engineering, air propulsion, pusher propeller, wind tunnel tests*

1. Introduction

A pusher propeller is a propeller mounted behind engine so that drive shaft is in compression [9]. It has been applied as an aircraft propulsion since early days of aviation – for example, in the Wright Flyer, flown in 1903. Nowadays it is a popular type of single-engine (rarely multi-engine) airplane propulsion. It may be applied especially in light aircraft, which are one of specialties of Institute of Aviation [18, 19]. Some examples of aircrafts powered by the pusher propeller are presented in Fig. 1-3.

Advantages of this propulsion, according to [8], is:

- Unobstructed forward view,
- Reduced cabin noise,
- Normal force aft of the centre of gravity increases stability,
- Turbulent high-speed wake does not flow over a fuselage or a nacelle, and, at least theoretically, will result in less drag,
- The streamtube will energize the flow in front of propeller and suppress flow separation on the body, even at high angle of attack.

One of the most important disadvantage of pusher propellers is that *the fuselage ahead of the propeller may distort flow inside the streamtube, causing asymmetric disc loading and increased blade stresses. This distortion may affect the propeller's performance* [8]. A propeller efficiency may be reduced by up to 15% for the pusher propeller, while the efficiency of a tractor propeller decreases only by 10% (see Fig. 4). The plot presented in Fig. 4 includes an axisymmetric nacelle only. It should be noted that the pusher propellers usually have small diameter, because of construction constrains and due to small distance from the ground during take-off and landing, when the angle of attack is high. In this case the influence of the fuselage is significant.

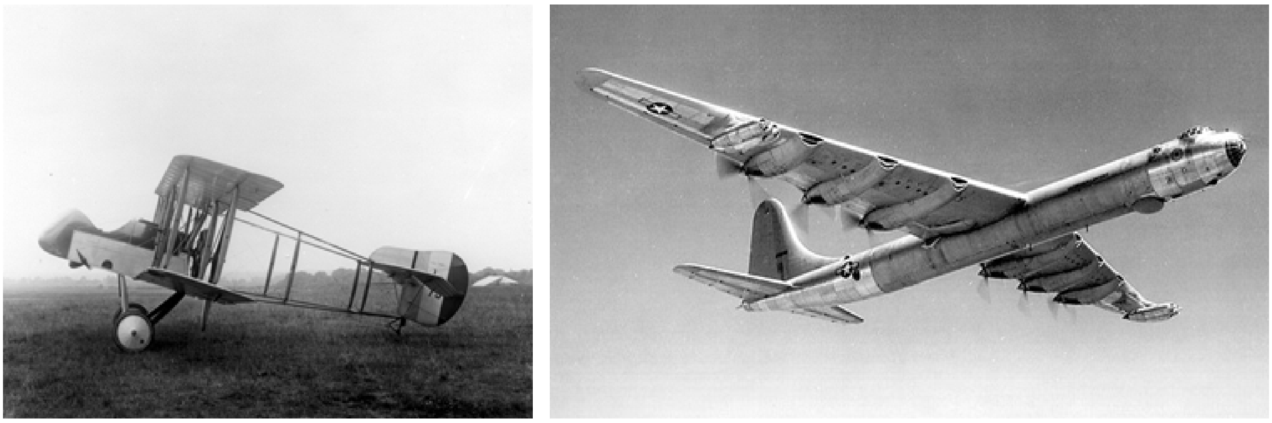

Fig. 1. Airco DH.2 fighter, 1915 (left), Convair B-36 Peacemaker bomber, 1946 (right) [21, 22]

Fig. 2. Lake Buccaneer amphibian, 1950 (left), SZD-45 Ogar motor glider, 1973 (right) [23, 24]

Fig. 3. Rutan VariEze light aircraft, 1975 (left), MQ-1 Predator UAV, 1994 (right) [25, 26]

In Fig. 5 and 6 a distribution of velocity magnitude in the slipstream of the pusher propeller and ducted fan (respectively) has been presented. It is a result of CFD calculations of the joined-wing UAV, ILX-32 MOSUPS [6, 7, 11]. As it can be observed, a part of the propeller slipstream (placed behind the fuselage) has reduced velocity. It means that an axial force acting on the propeller in this part is reduced, which results from the law of conservation of momentum.

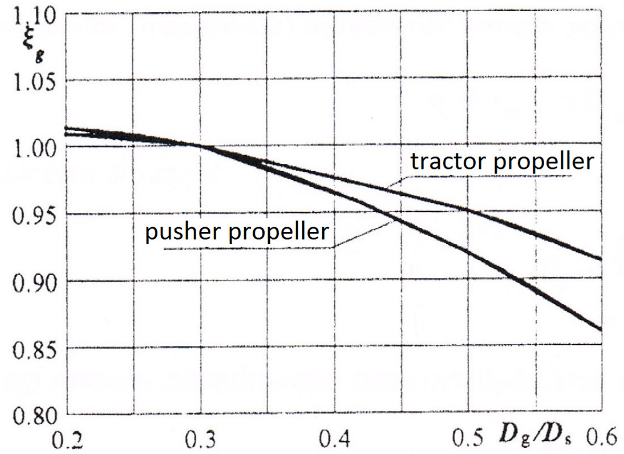

Fig. 4. Correction factor of tractor and pusher propeller efficiency 10, 20]

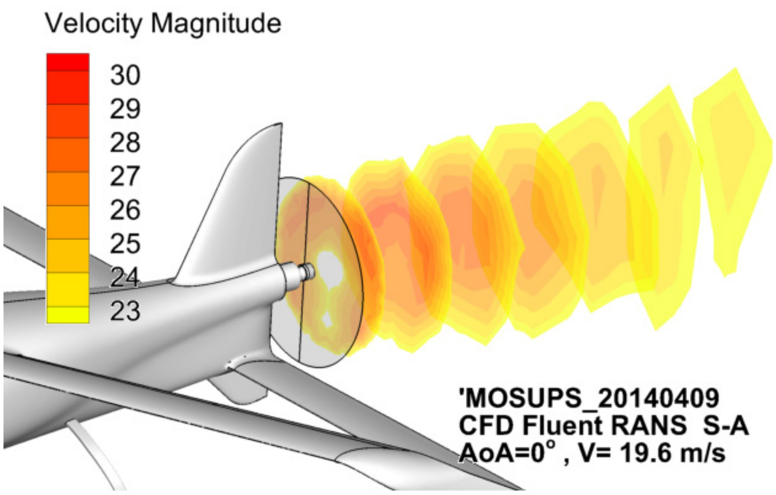

Fig. 5. A distribution of velocity magnitude in the slipstream of the pusher propeller

2. A goal of the investigation

To the author´s best knowledge, very few publications can be found in the literature that discuss an influence of the airframe on conditions of the pusher propeller work. It seems that some universal guides in this field would be helpful to improve performance of the pusher-configuration airplanes or to reduce an effort of airframe designers.

The investigation, described in the paper, should allow for finding an impact of some basic parameters, which defines flight conditions and a fuselage geometry, on the propeller performance. These parameters may be, for example:

– advance ratio,
– angle of attack of the propeller,
– cross-section area of the fuselage,
– shape of the fuselage aft part.

3. Investigation concept

The object of the investigation is a nacelle, shaped as an aft part of a pusher-configuration aircraft. A shape of the front part of the object is modelled to avoid flow separation on it. This approach utilizes the experience from the wind tunnel tests of ILX-32 MOSUPS propulsion [2-4, 13]. In that case, the propulsion was investigated in presence of the rear part of fuselage and the root part of aft wing (Fig. 7).

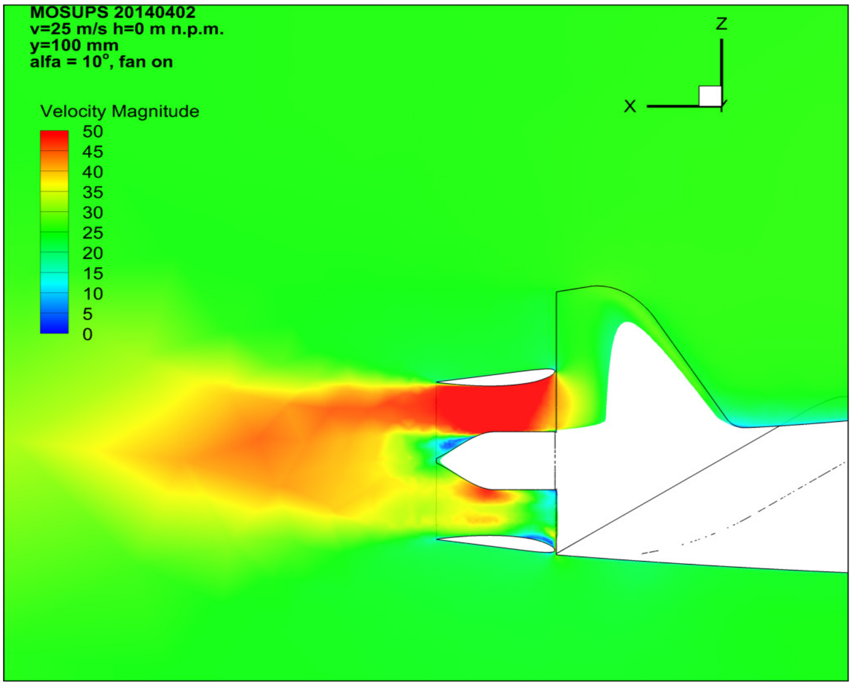

Fig. 6. A distribution of velocity magnitude in the slipstream of the pusher ducted fan

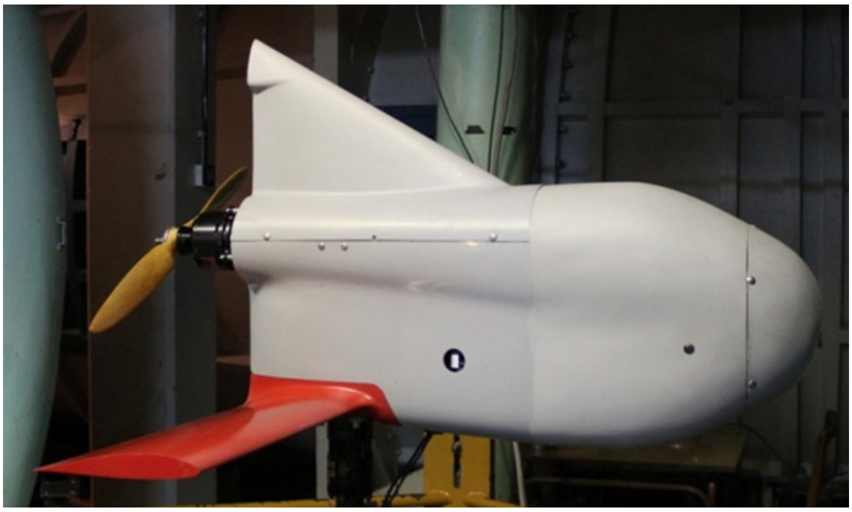

Fig. 7. The pusher propeller of ILX-32 MOSUPS investigated in the wind tunnel

The investigated object is modular and its skin is interchangeable to facilitate investigation for various shapes and areas of the nacelle. The skin is mounted to the core, which is a fixing for a motor with a battery and a controller. The measurement equipment is mounted to the core as well.

The thrust of the propeller will be measured in two ways. First is a strain-gage balance mounted to the object, which measures the effective thrust (including the nacelle drag force). Second way is strain-gages fixed to the engine mount, which measures the thrust force. This approach is recommended to obtain a change of the aerodynamic drag of the nacelle, caused by a propeller [15]. A suction on the front side of the propeller disc may prevent to the flow separation phenomenon [5]. To analyze this effect, a static pressure distribution on the nacelle surface is measured.

The velocity distribution in the slipstream is measured with the PIV (Particle Image Velocimetry) method, which is a modern technique of measurement and visualization of the flow velocity field [1, 13, 16, 17]. To make the measurement, seeding particles must be atomized in the flow. Droplets of the seeding are illuminated with lightsheet (i.e. a laser light, formed in a thin sheet by the lenses) and photographed by a camera. In the post-processing phase the measured velocity field is obtained by determination of the particles displacements during the time interval Δt. The PIV system and its application in the T-1 wind tunnel is described i.a. in [13, 16, 17].

The velocity distribution measured using PIV indicates areas, where the energy losses are greatest. It allows for identifying, which elements of the airframe are a source of the propeller performance loss. Moreover a velocity distribution may be used to calculate a momentum change, i.e. a thrust force.

The PIV measurements are completed and verified by measurements of the total pressure in the slipstream. A high-speed measurement of the velocity using CTA anemometer is foreseen. It allows for taking into account that the flow velocity changes with high frequency and in its wide range: peaks caused by the vortices on the blade tip may achieve even 10% or more [14, 15]. Additionally, the rotational speed of the propeller, voltage and amperage of a current which supplies the motor, are measured.

The investigation is conducted in the T-1 wind tunnel in Institute of Aviation, which is a closed-circuit, open test section wind tunnel. The test section diameter is 1.5 m and the flow speed ranges from 12 up to 45 m/s. The tunnel is using a 55 kW electric motor and a four-bladed constant speed fan. The speed is controlled by changing the angle of blades (for higher changes) and vent flaps (for precise control of the speed) [3, 12].

4. Conclusion

A performance of the pusher propeller may be significantly reduced (up to 15%) due to the presence of the fuselage, nacelle or other airframe elements. The thrust reduction is connected with a slipstream velocity loss. The investigation described in this paper allows for assessing an impact of various parameters, which are used in definition of a fuselage geometry and flight conditions. Results of the investigation will be used for create an aerodynamic database, which will improve a performance of aircrafts powered by the pusher propeller. This database should also ease a design and optimisation process of these aircrafts.

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