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Composite Propeller for High-Speed Aircraft

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Abstract— ***Development of the aircraft with excellent parameters is very difficult. Moreover, it is necessary to optimize the power plant of the aircraft, i.e. to select an appropriate motor and propeller. The paper deals with the design and development of the prototype of a special composite propeller for the high-speed ultra-light aircraft Shark.***

Index Terms—**In-Flight Adjustable Propeller, Design of Composite Blade, Maximum Travel Speed, Propeller Production, Ultra-Light Aircraft.**

I. INTRODUCTION

The development of a propeller titled "SVRTULKA 01" for UL aircraft Shark emerged from the aircraft manufacturer SHARK.AERO Ltd. (Airport Senica, 906 31 Hlboke 406, Slovak Republic) needs.. Manufacturer tried to install different types of aircraft propellers from different producers in the world. According to the designation of the aircraft for tourist high-speed flights, the preferred propeller should be efficient at high speeds. Therefore, the in-flight adjustable propeller is required allowing the shortest start at a small angle setting of blades. With increasing airspeed, the angle setting of blades can adjust the most favorable automatically in the regime of constant speed. Moreover, as the aircraft Shark belongs to the ultra-light (UL) aircraft category, the lowest possible weight for a complete set of propeller is required. This means the overall weight of the head of the propeller, propeller blades, regulator and the entire installation.

II. TECHNICAL PARAMETERS OF THE AIRCRAFT

There are two versions of the aircraft Shark [1]:

- Shark UL - a high-performance European UL with retractable gear, smaller wings and variable-pitch propeller.
- SportShark - a simpler LSA version with bigger wing and fixed landing gear.

Both versions with technical parameters given in the Table 1 have been designed and will be tested for a maximum take-off weight of 600 kg.

Design features **-** designed according to European UL and US Light Sport Aircraft criteria. Composite low-wing design with classic tail and tandem seating.

Structure **-** glass-fibre and carbonfibre/epoxy airframe, with PVC foam and aramid honeycomb core in sandwich panels. Monocoque fuselage with integral fin has integrated arm rests, seat backs, floors and instrument panels. Composite wing with carbon-fibre main spar and an auxiliary spar carrying flap levers and aileron hinges has 60 % of the trailing edge occupied by powerful single-slotted flaps. Wings and horizontal tail can be quickly detached for transportation or storage.

Flying controls **-** mechanically actuated control surfaces with electric trim tab on the elevator and electrically actuated flaps.

Undercarriage **-** Shark UL has tricycle type retractable undercarriage with steerable 13x4" nose wheel and 14x4" main wheels with hydraulic disc brakes. Fixed undercarriage of SportShark has composite main legs and simplified front leg.

Power plant **-** one 75 kW/100HP Rotax 912ULS flat-four engine with variable-pitch composite propeller [2]. Integral fuel tanks in wings, capacity 100 liters. Characteristics of engine performance and engine torque are shown in Fig. 1.

Accommodation **-** a completely upholstered two-seat tandem cockpit with adjustable seats has full dual controls – with side sticks on the right and throttles and flap levers on the left panels. Elevator trim tab is controlled by electric switch on the side stick. Instrument panels with standard EFIS/EMS displays for both pilots are complete with the classic fuel gauges, transceiver, transponder and GPS and secondary airspeed indicators and altimeters. The single-piece cockpit canopy opens to starboard and is supported by gas struts. Baggage space is aft of seats.

Table 1 Technical parameters of the aircraft Shark [1]

Aircraft model	Shark UL	SportShark
Wing span	7.9 m	9.2 m
Length	6.7 m	6.7 m
Wing area	9.5 m²	11.4 m²
Engine	**Rotax 912ULS - 75 kW**	
Empty weight	275 kg	300 kg
Maximum take-off weight	480 kg	600 kg
Maximum permissible speed V_{NE}	333 km/h	270 km/h
Maximum cruising speed V_H	290 km/h	222 km/h
Optimum cruising speed	250 km/h	210 km/h
Stall speed, clean	80 km/h	81 km/h
Stall speed, full flaps	64 km/h	71 km/h
Max. climb rate at the MTOW	7.2 m/s	5.8 m/s

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Fuel capacity	100 liters	
Fuel consumption economy flight	15 l/hour	15 l/hour
Maximum load factor +4/-2, max. ultimate +6/-3		

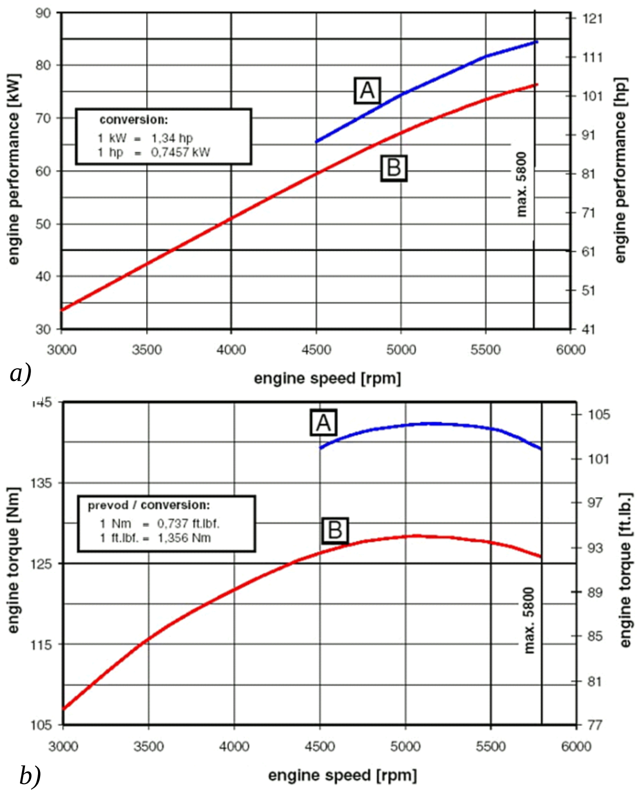

Fig. 1 Engine performance (a) and engine torque (b) as a function of engine speed [2]

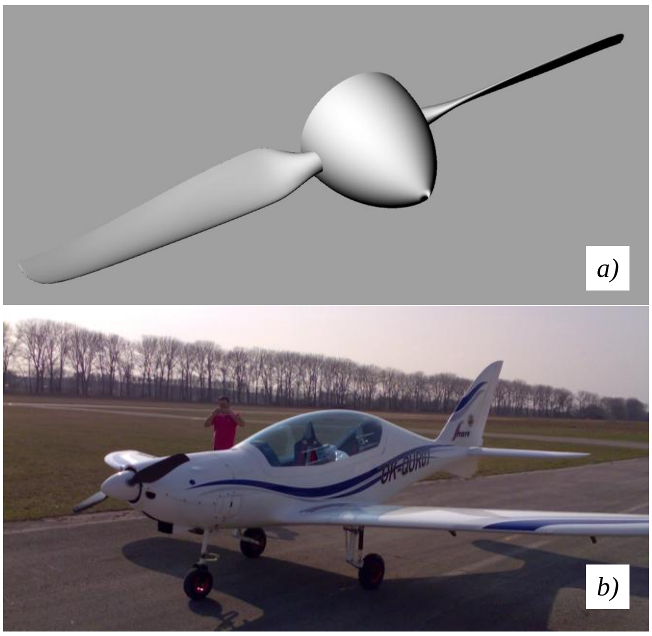

Fig. 2 3D model of the designed propeller (a) and the aircraft Shark with the propeller „SVRTULKA 01“ (b)

Due to the peculiarity of this aircraft, it was necessary to develop and optimize the entire design of the propeller from the point of maximum travel speed and corresponding engine power. Subsequently, the aerodynamic body design optimization used the following inputs: propeller diameter $D = 1.75$ m, flight speed $v = 75.0$ m/s, revolutions $n = 32.93$ 1/s, performance $N = 44.6$ kW and two blades. Aerodynamic calculation was carried out in terms of computational methods described in [3-5].

Geometric characteristics were then smoothed and optimized using the commercial software Rhinoceros [6]. A three-dimensional model of the propeller blade was also created. The model of the designed propeller and the aircraft Shark with a new propeller are illustrated in Fig. 2.

III. Propeller Production

In above mentioned 3D software Rhinoceros, the models for production of the negative and positive forms of the blades were prepared. These models were milled applying generated program code by 3D milling machine with accuracy of 50 μm. Subsequently, the positive model of propeller blade was produced using negative forms, from which the final negative molds for manufacturing of propeller blade were made (Fig. 3).

According to the load of the propeller blades, carbon fiber composite was used. The exact composition and cuts were prepared in advance using the software. Single cuts carbon fabric with plain weave from 80 g/m^2 up to 200 g/m^2 were connected using contact lamination with epoxy bitumen labeled L 285/MGS [7] (Fig. 4).

After inserting a milled core of balsa wood and applying epoxy adhesive filled with binder, both mold parts were completed by means of associated pins and screws (Fig. 5a).

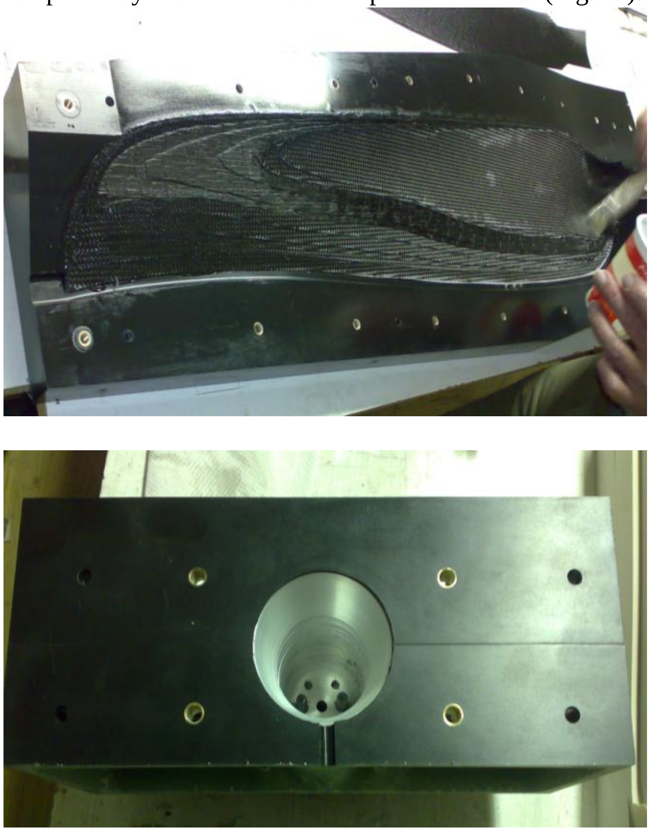

Fig. 3 Molds for the final propeller

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Fig. 4 Contact laminating layers of carbon fiber fabric

After the connection of the metallic core and screwing the forms, a paste was formed and then used to attach the core of the blades to the propeller head. Fig. 5b shows the fixture providing the settlement and affixing a metal part of the propeller hub to the core of propeller blade. Final disassembling of the form with sealed metal propeller hub is illustrated in Fig. 5c.

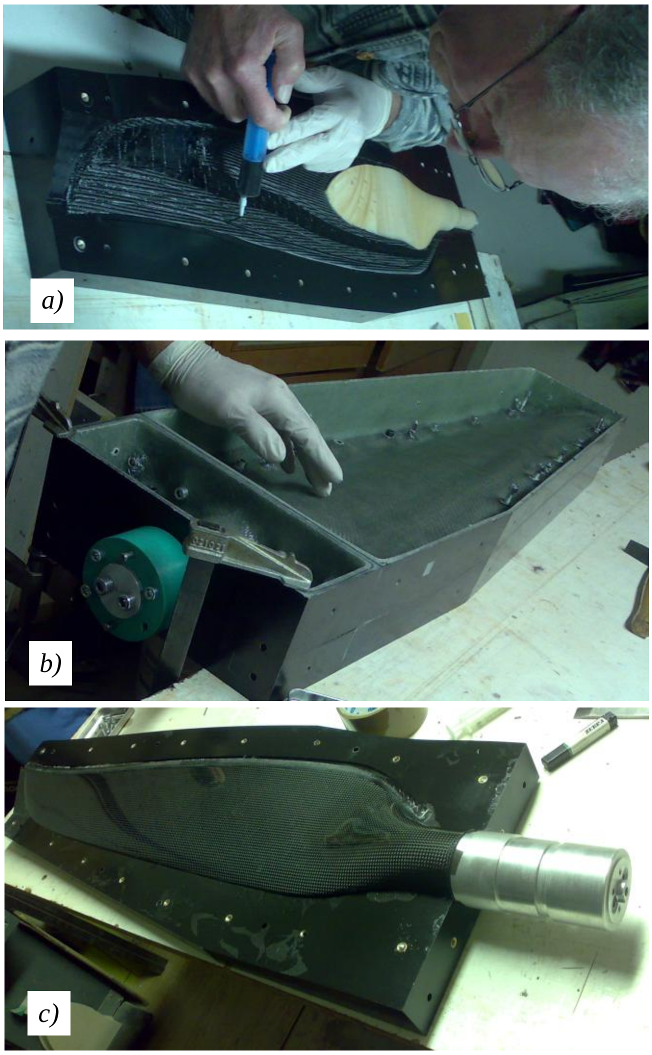

Fig. 5 Propeller production, a) combining forms, b) linking individual parts forms to the core of the blades, c) dis-assembling the form with sealed metal propeller hub

After cleaning the blade, the hub with the core and carbon composite at the perimeter is ensured secondary by high-strength bolts. The forces loading the blade are primarily ensured by adhesive joint of carbon composite parts with duralumin hub and secondary insured by two high-strength steel bolts K10. The final prototypes of the blades are shown in Fig. 6.

Fig. 7 illustrates the blades after their assembling to the propeller head. In this case, the electrically in flight adjustable double bladed propeller head by the company Woodcomp Ltd. labeled SR 3000/2W [8] was applied.

Fig. 6 Final propeller blades

Fig. 7 The propeller blades after their assembling with the propeller head Woodcomp Ltd. labeled SR 3000/2W

IV. CONCLUSION

Propeller "SVRTULKA 01" was developed for the aircraft Shark with the aim to push the limits of world speed record achieved by this aircraft. The actual speed record flights 15, 50, 100, 500 km by Mr. Eric Barberini were officially recognized by French Ultralight Association FFPLUM on 27th January 2012. The propeller was constructed according to the Regulation UL2/I.-46 of the Czech Republic, by which also the airplane Shark UL is designed and certified.

During preliminary flight tests, the level of airspeed in horizontal flight approached the speeds reached with propellers selected for mass production of aircraft. To achieve the desired objective of creating a world speed records it is necessary to resolve some deficiencies resulting from a prototype implementation and found by conducted flight tests.

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REFERENCES

[1] http://www.shark.aero.

[2] http://www.teveso.cz/letecke-motory/necertifikovane-ctyrtaktni-rotax-912-uls.php.

[3] Švrček, D.: Aerodynamic design of propeller blade with optimum circulation layout. In: MicroCAD 2009 XXIII. International Scientific Conference, 19-20 March 2009, Miskolc. - Miskolc: University of Miskolc, 2009. - ISBN 978-963-661-878-0. pp. 43-50.

[4] Švrček, D.: Výpočet aerodynamických characteristic virtual v mimonávrhovom režime. In: Aeronautical 09: International Scientific Conference. 17. September 2009, Košice. - Košice: technical University, 2009. - ISBN 978-80-553-0258-4. - pp. 1-6.

[5] Švrček, D. - Brož, V.: Aerodynamic Design of a Propeller Applied for the Aircraft ZLIN-226. In: Aerospace sciences & Aviation Technology. - ISSN 2090-0678. - ASAT-13. 13th International Conference, Cairo, Egypt, May 26-28, 2009. Abstracts of Scientific Papers. - Cairo: Military Technical College, 2009.

[6] http://www.rhino3d.com/.

[7] http://www.havel-composites.com/proddocs/techlist_01020403340tech.listL285+H500.pdf.

[8] http://www.woodcomp.cz/en/sr3000-2w.phpC. Y. Lin, M. Wu, J. A. Bloom, I. J. Cox, and M. Miller, “Rotation, scale, and translation resilient public watermarking for images,” IEEE Trans. Image Process., vol. 10, no. 5, pp. 767-782, May 2001.

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