UDC 629.735

L.G. Markovska, K.V. Balalaieva
(National Aviation University, Ukraine)

Possibilities of increasing the efficiency of UAVs by improving the characteristics of propellers

The paper examines promising technical solutions aimed at improving the characteristics of UAV propellers in order to increase the efficiency of UAVs.

Introduction.

As technology advances and UAV applications expand, new requirements and standards for their operation arise. The aerodynamic characteristics of propellers must meet these new requirements, which may include increased efficiency, reduced noise, and improved stability. Research in this area allows propellers to be adapted to new conditions and standards, ensuring their competitiveness and compliance with modern needs.

Current state of the problem.

Rotating propeller blades capture air and throw it in the direction opposite to the movement. A low-pressure zone is formed in front of the propeller, and a high-pressure zone is formed behind the propeller. Rotation of the propeller blades results in the air masses thrown out by it acquiring simultaneous movements in circular and radial directions, which is what uses the main energy supplied to the propeller [1].

The issue of increasing the efficiency of UAV propellers has been little studied. But even the experimental data available [2] is sufficient to understand that the losses in the propellers are quite large. This implies the need for research related to improving the aerodynamics of the propellers (see Fig. 1)

Load Testing Data									
Ambient Temperature			18℃		Voltage			DC Power Supplier	
Item No.	Voltage (V)	Prop	Throttle	Current (A)	Power (W)	Thrust (G)	RPM	Efficiency (G/W)	Operating Temperature (℃)
P60 KV170	48	T-motor 20*6CF	50%	5.4	259.20	2116	4152	8.16	55
			55%	6.4	307.20	2371	4425	7.72	
			60%	7.7	369.60	2762	4709	7.47	
			65%	9.3	446.40	3125	5014	7.00	
			75%	13.2	633.60	4002	5626	6.32	
			85%	17.3	830.40	4821	6177	5.81	
			100%	25.4	1219.20	6246	6992	5.12	
		T-motor 22*6.6CF	50%	6.6	316.8	2801	3703	8.84	85
			55%	8.6	412.8	3312	4005	8.02	
			60%	9.9	475.2	3763	4289	7.92	
			65%	12.4	595.2	4356	4575	7.32	
			75%	17.1	820.8	5372	5091	6.54	
			85%	23.2	1113.6	6582	5635	5.91	
			100%	34	1632	8414	6374	5.16	

Fig. 1. Results of testing the P60 engine with the KV170 propeller

From the experience of using propellers in "big aviation": the efficiency of modern propellers can reach 82...86% [3]. This is achieved by carefully improving the aerodynamic characteristics of propellers for the purposes of "big aviation".

Promising technical solutions that can improve the characteristics of propellers:

1. Optimization of the propeller blade profiling.
2. Optimization of the installation angles, geometric and aerodynamic twist of the propeller blade.
3. Use of saber-shaped blades. A multi-blade propeller with thin saber-shaped blades allows you to shift the onset of a wave crisis, and thereby increase the maximum flight speed.
4. The location of the propeller in an aerodynamic ring is a fairly promising technical solution, since it allows you to reduce the final flow around the blades, reduce noise and increase safety when rotating the propeller. However, the weight of the ring is a limiting factor for the widespread use of such a design solution in aviation. Increasing the weight of a UAV without compromising its use and durability is usually within 20-50% of its initial weight. Further increase has a negative impact on all aspects of the use of the UAV, worsens its technical condition [3].
5. The guide vanes are made in the form of a system of fixed blades (stator), allowing to straighten the air flow obtained twisted after the propeller, and thereby increasing the axial component of the flow velocity, which in turn directly increases the thrust by up to 10% [4].

The aerodynamics of the propellers has a direct impact on the efficiency and performance of the UAV. Improving the aerodynamic characteristics can lead to a significant increase in lift, a decrease in air resistance and an increase in overall thrust. This allows the UAV to be more effective in performing tasks such as flight duration, loading and maneuverability. For example, reducing aerodynamic drag can reduce energy consumption and extend the battery life of the device [5].

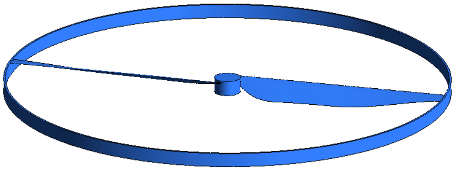
The aerodynamic performance of propellers has a direct impact on the flight stability of a UAV. Poor aerodynamic performance can result in vibration, shaking, and instability, making it difficult to control the aircraft. Improving propeller aerodynamics can help reduce these issues, providing a smoother, more stable flight, which is critical for precision missions and safe operations.

The aerodynamic performance of propellers affects the noise level generated during their operation. Improving aerodynamic performance can help reduce noise, which is especially important for quiet applications, such as civil and defense surveillance missions or operations in populated areas. Reducing noise can also reduce the likelihood of UAV detection and improve stealth.

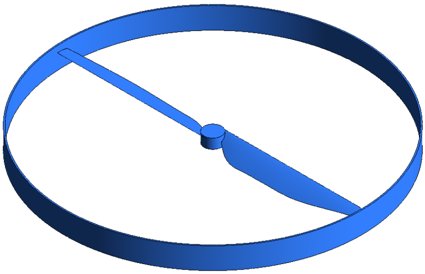
Propeller efficiency has a direct impact on UAV power consumption. Improving aerodynamics can reduce the energy cost of maintaining a UAV’s flight, allowing for longer flight times or smaller and lighter batteries. This allows for more payload to be carried by the UAV. UAV safety and reliability.

Improving the aerodynamic characteristics of propellers also affects the safety and reliability of UAVs. Structural reliability and flight stability can reduce the risk of accidents and failures, which is critical for operational safety, especially in difficult conditions or when performing dangerous missions.

The paper studies the change in acoustic radiation in the near field for a propeller in a ring. The effect of changing the ring parameters, namely its height, was studied. The ring leads to an increase in thrust and a decrease in noise. However, the ring parameters affect the manifestation of these effects to a greater or lesser extent. In terms of weight, the lower the ring height, the lighter it is. The paper considers a propeller with a minimum ring height and a ring height increased by 5 mm above and 5 mm below the propeller. Three-dimensional models of the propellers under study are shown in Fig. 2.



a



b

Fig. 2. Three-dimensional models of the propellers in ring:
a - propeller with a minimum ring height; b - propeller with a ring height increased by 10 mm

The acoustic radiation of the propellers was calculated based on the results of modeling the flow around the propellers in the ring. The calculation results showed that the ring, which has a greater height, more effectively reduces noise in the near field. The difference in the acoustic pressure level was 1.2 dB.

Conclusion

All this indicates that improving the aerodynamic characteristics of UAV propellers is extremely relevant for modern research. This not only ensures increased efficiency and performance of the devices, but also opens up new possibilities for their application, promotes innovation, and meets growing market requirements and standards.

References

1. Сметанін Ю. О. Аеродинаміка. Енциклопедія Сучасної України [Електронний ресурс]. Редкол. : І. М. Дзюба, А. І. Жуковський, М. Г. Железняк

[та ін.] ; НАН України, НТШ. К. : Інститут енциклопедичних досліджень НАН України 2001. Режим доступу : https://esu.com.ua/article-42702

2. Муравйов О.В., Довбиш І.О., Галаган Р.М., Богдан Г.А., Момот А.С. Перспективи розвитку технологій та підвищення рівня автономності БПЛА. Вчені записки ТНУ імені В.І. Вернадського. Серія: Технічні науки Том 34 (73) № 2 2023. Режим доступу: https://doi.org/10.32782/2663-5941/2023.2.1/32

3. Kovačević, A., Svorcan, J., Hasan, M.S., Ivanov, T. and Jovanović, M. (), Optimal propeller blade design, computation, manufacturing and experimental testing. Aircraft Engineering and Aerospace Technology. 2021, Vol. 93, No. 8, pp. 1323-1332. Режим доступу: https://doi.org/10.1108/AEAT-03-2021-0091

4. Якименко А.В., Ковбаса С.М. Тягові характеристики гвинтомоторної групи на основі безколекторного двигуна MT 2213-935 KV та пропелера 10x4.5. Міжнародний науково-технічний журнал "Сучасні проблеми електроенерготехніки та автоматики", 2015. Режим доступу: http://jour.fea.kpi.ua/article/view/68733/63820

5. Hang Zhu Aerodynamic Performance of Propellers for Multirotor Unmanned Aerial Vehicles: Measurement, Analysis, and Experiment. Shock and Vibration, 2021. Режим доступу: https://doi.org/10.1155/2021/9538647