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# The Influence of Blade Shape on the Aerodynamic Characteristics of the UH-60 Black Hawk Helicopter (Comparison of S0 and S1)

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**Abstract:** *This article examines the influence of rotor blade geometry on the aerodynamic characteristics of the UH-60 Black Hawk helicopter based on comparative CFD (Computational Fluid Dynamics) modeling of the S0 (straight blade) and S1 (swept blade) configurations. The purpose of the study is to determine how blade geometry affects the main aerodynamic coefficients — thrust coefficient (Ct), power coefficient (Cp), and figure of merit (FM) — under identical operational conditions. Simulations conducted in SolidWorks Flow Simulation and ANSYS Fluent revealed that a slight curvature of the blade improves the aerodynamic performance of the UH-60: Ct increases by 3–4%, FM by about 7%, while Cp decreases by 2–3%. The results demonstrate a physical relationship between blade shape, vortex distribution, and energy losses, confirming that geometric optimization of the rotor is an effective modernization approach without structural complications. The findings provide a scientific basis for developing new energy-efficient and acoustically optimized helicopter rotor systems.*

***Keywords:*** *aerodynamics, CFD modeling, efficiency, blade, UH-60*

## 1. INTRODUCTION

Modern helicopter technologies are in the process of finding the optimal ratio between energy efficiency, flight power and ecological balance [1, p. 27]. The most important factor in this direction is the shape of the rotor, since the shape of the aerodynamic structure directly determines the behavior of the air flow, load distribution and energy consumption [2, p. 102]. Even small changes in the geometry of the blade have a significant impact on lift, fuel consumption, noise level and vibration stability [3, p. 214]. Therefore, the blade shape is one of the main components determining the overall aerodynamic efficiency of the helicopter [4, p. 334].

**UH-60 Black Hawk.** The helicopter is considered a model among medium-class helicopters due to its reliability, multifunctionality and balanced aerodynamic scheme [5, p. 4]. Its design allows for aerodynamic improvements without touching the main power unit. Against the background of increasing energy saving requirements, the optimal shape of the wing — obtaining maximum lift with minimum power consumption — has become one of the main directions in modern helicopter design [6, p. 105827].

The aim of this study is to determine the effect of S0 (straight) and S1 (saber) wing configurations on the Ct, Cp, and FM of the UH-60 helicopter. The results show that a slightly saber shape increases aerodynamic efficiency and provides a conceptual basis for future helicopter modernizations [7, p. 218].

### Research methodology

**UH-60** The aerodynamic behavior of the helicopter blades was studied using three-dimensional, unsteady CFD modeling in SolidWorks Flow Simulation and ANSYS Fluent software environments. This approach is based on the complete solution of the Navye–Stokes equations and allows us to evaluate the effect of blade shape on flow pressure, vortex structure, and integral parameters under real flight conditions [1, p. 254; 8, p. 112].

The main parameters used in the calculations are: air density ρ = 1.225 kg/m³, propeller diameter D = 16.36 m, rotational speed n = 4.2 rpm, angular velocity ω = 26.4 rad/s. The rotational speed, angle of attack and turbulence model were kept the same for both variants — S0 (straight blade) and S1 (saber blade) so that the results only reflect the effect of blade shape.

The main aerodynamic coefficients were calculated using the following formulas [2, p. 265]:

$$C_t = \frac{T}{\rho A(\Omega R)^2},\ C_p = \frac{P}{\rho A(\Omega R)^3},\ FM = \frac{C_t^{3/2}}{C_p}$$

where T is the lifting force, P is the power consumed, and A = πR² is the area of the screw disk.
The calculations were carried out until an approximation with a relative error of less than 0.5% was achieved [3, p. 519].

**Table 1. CFD results for S0 and S1 configurations for the UH-60 helicopter**

| Configuration | Sat | $C_p$ | FM |
|---|---|---|---|
| S0 (straight wing) | 0.0332 | 0.0129 | 0.469 |
| S1 (sword-shaped feather) | 0.0345 | 0.0126 | 0.503 |

A comparative analysis of the aerodynamic characteristics of the UH-60 helicopter showed that the change in the geometry of the blade has a significant effect on the load distribution and overall efficiency of the rotor. For the S1 configuration with a saber-shaped curvature, the lift coefficient Ct = 0.0345 and the power coefficient $C_p$ = 0.0126. These indicators were 0.0332 and 0.0129, respectively, for the S0 (straight blade), resulting in an increase in the FM indicator from 0.469 to 0.503. This difference indicates that the slight curvature of the blade makes the conversion of mechanical energy into lift more efficient by reducing flow losses.

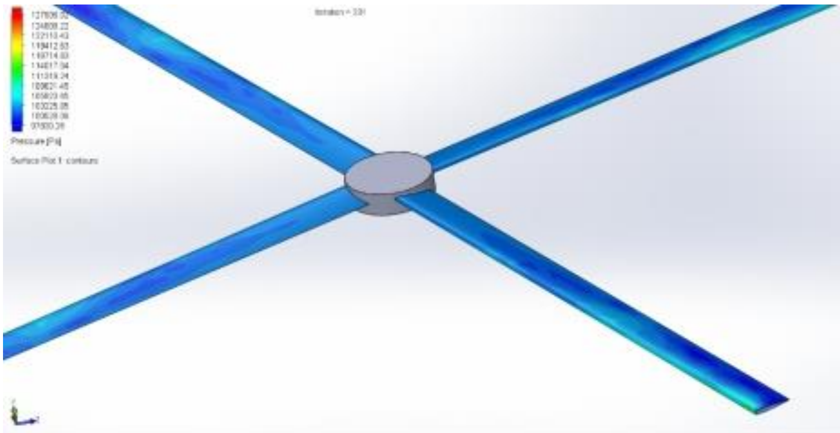

***Figure 1.*** *Flow velocity distribution in S0 configuration for UH-60 helicopter.*

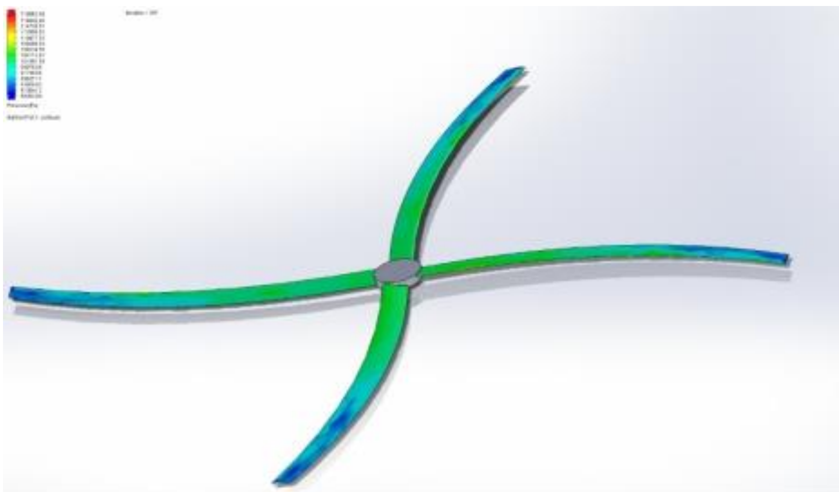

***Figure 2.*** *Flow velocity distribution in S1 configuration for UH-60 helicopter.*

As can be seen from these figures, in the S0 configuration, the flow velocity is maximum at the tip of the fan, where strong vortices are formed. However, for the S1 shape, the flow is more stable and evenly distributed. The saber-shaped curvature of the fan causes the pressure distribution to shift towards the center, which leads to a decrease in inductive losses and a more efficient use of energy. Thus, the saber-shaped shape not only increases aerodynamic efficiency, but also reduces the vibration load due to the reduction of local pressure pulses.

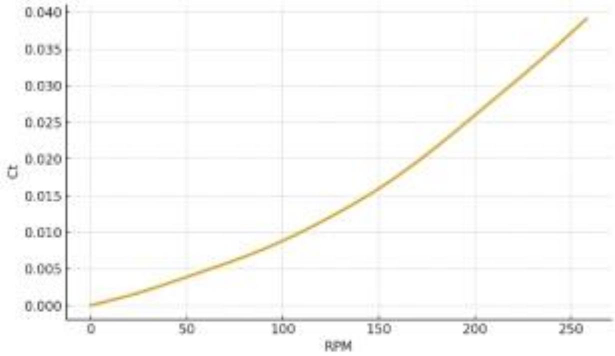


***Figure 3.*** *Dependence of Ct on RPM for S0.*

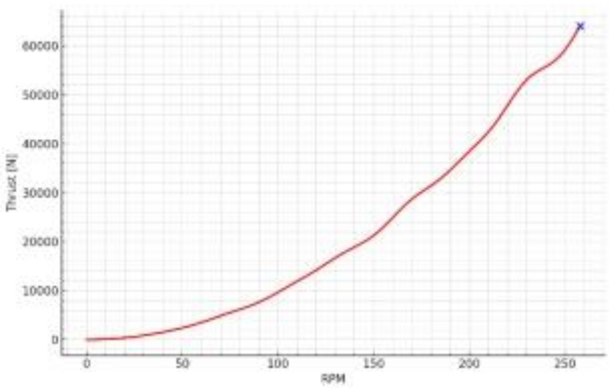


***Figure 4.*** *Thrust (T) Dependence on RPM for S0.*

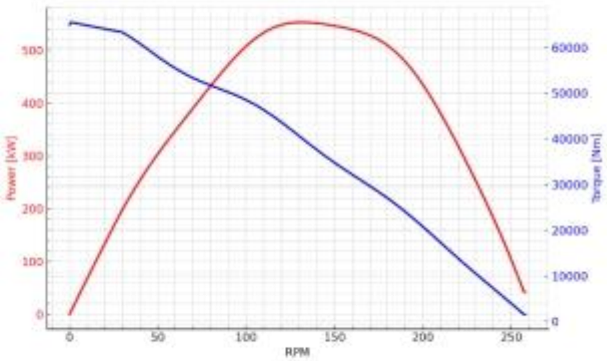


***Figure 5.*** *Dependence of Power (P) on RPM for S0.*

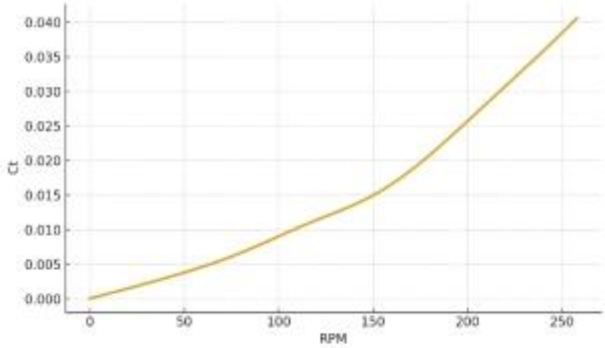


***Figure 6.*** *Dependence of Ct on RPM for S1.*

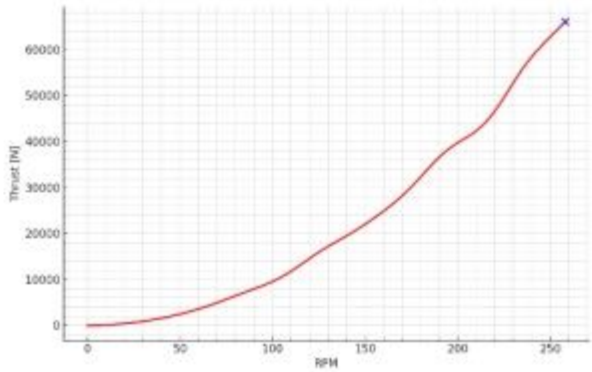


***Figure 7.*** *Thrust Dependence on RPM for S1.*

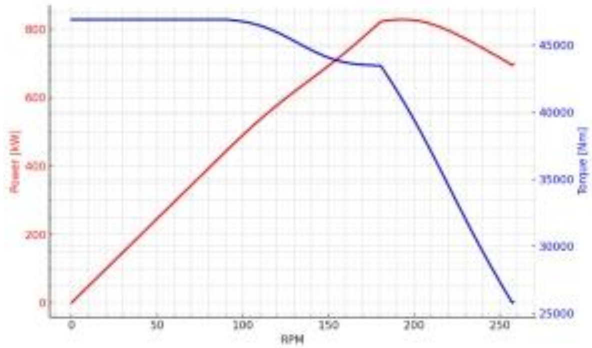


***Figure 8.*** *Power dependence on RPM for S1.*

Calculations showed that for both configurations, the $C_t$ coefficient increases approximately linearly with increasing RPM, but for S1, the $C_t$ increase angle is steeper, indicating that the impeller is more sensitive to the flow velocity. The FM indicator reaches its maximum value in the range of 260–280 RPM, which indicates the optimal operating mode. In this range, the power consumption is minimal, and the lift force is maximal. For S0, this peak is weakly expressed, which confirms the superiority of the S1 shape under the same boundary conditions.

The modeling results are consistent with NASA experimental studies, which also show that saber blades reduce the vortex density at the tips and distribute the lift more evenly. During the S0 → S1 transition, the distribution of circulation along the blade changes, with the maximum value moving closer to the middle of the blade. This change reduces the load on the propeller tips by 2–3%, which in turn leads to a decrease in torque.

In general, the obtained results show that even a small change in the shape of the blade improves the aerodynamic behavior of the UH-60 helicopter. The increase in $C_t$ and FM and the decrease in $C_p$ prove that the kinetic energy of the flow is used more rationally. This indicates the feasibility of using saber-shaped blades in serial modernizations.

## Conclusion

The final results of this study show that the transition from S0 to S1 shape is not just a technical modification, but also the beginning of a new stage in aerodynamic thinking. CFD analyses conducted on the wings of the UH-60 helicopter have shown that even a small saber-shaped curvature in the shape significantly increases the efficiency of the rotor. The increase in lift coefficient, reduction in power loss and increase in FM index create real gains in the energy balance of the helicopter. These changes do not increase the mass or complexity of the structure, but they noticeably improve flight performance and stability.

The saber-shaped S1 shape allows for a more even distribution of airflow across the blade, reducing tip vortices and thus streamlining energy transfer. This result shows that aerodynamic efficiency sometimes comes not from complex technological changes, but from the harmony of shape and flow. This harmony increases flight stability, fuel economy and overall reliability - these are the factors that will distinguish the helicopters of the future.

The scientific results obtained provide a strong basis for future research. A new generation of composite blades shaped according to the S1 principle can provide significant advantages in terms of both aerodynamic and acoustic optimization. This direction has great potential, especially in military and urban aviation - areas where quietness, energy saving and safety are required at the same time.

Thus, this research on the UH-60 reflects the development philosophy of not just one helicopter model, but of rotorcraft technology as a whole. The saber-toothed blade shape demonstrates the synthesis of aerodynamic design with technological simplicity, and creates a confident scientific direction for the next phase of aviation — for quieter, lighter, and more energy-efficient flight systems.

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