DEPARTMENT OF AVIATION ENGINES
AEROSPACE FACULTY
NATIONAL AVIATION UNIVERSITY

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PhD Thesis

METHOD OF REDUCING HUB LOSSES OF PUSHER AIR PROPELLERS WITH TANDEM BLADES OF SMALL UAV

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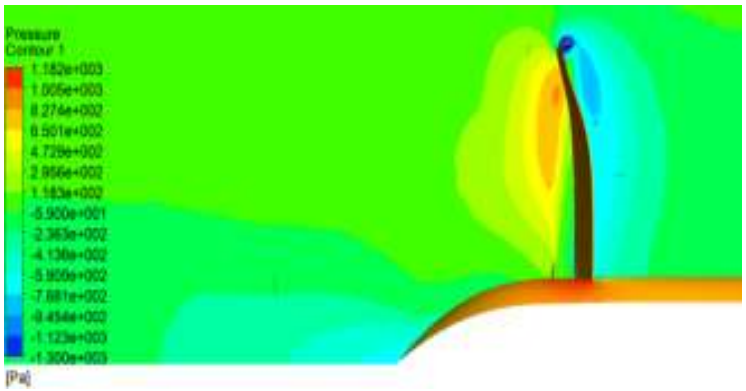
JUSTIFICATION RELEVANCE AND RESEARCH PROBLEMS

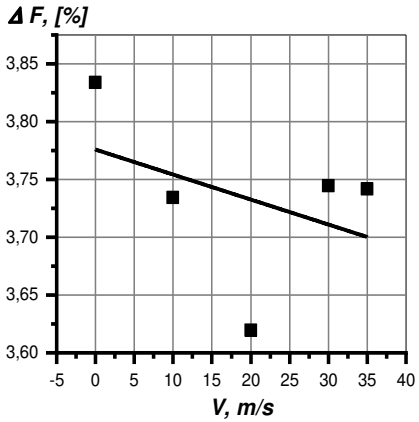
FOR SMALL SISE UAV VERY IMPOTANT →
- Decreasing geometrical size of propeller (diameter)
- Increasing efficiency of propeller

BENEFITS OF TANDEM BLADE →
- Increasing aerodynamic loading of propeller blades
- Decreasing geometrical size of propeller (diameter)

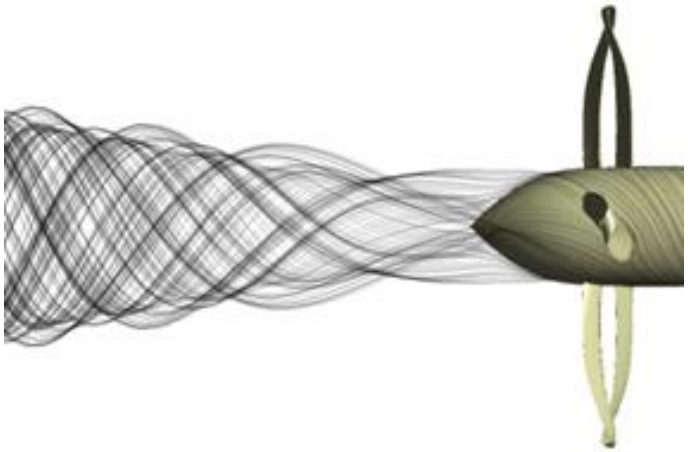
DISADVANTAGES OF TANDEM BLADE →
- Increasing level of tip and hub loses
- Increasing generating noise level (for unclosed blade)
- Difficult the blade pitch change mechanism



Contour of pressure distribution



Axial force losses



Structure of hub vortex

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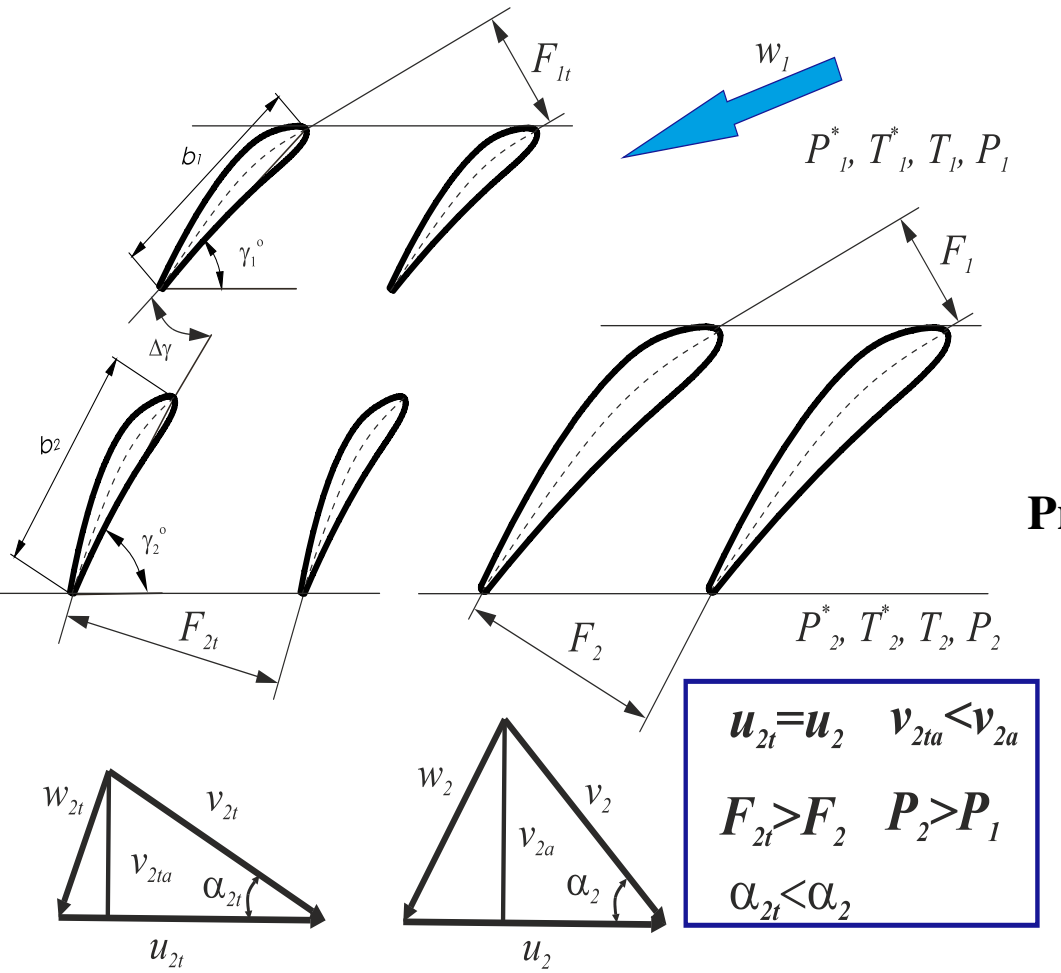
THE MAIN CAUSES OF THE HUB VORTEX INITIATION

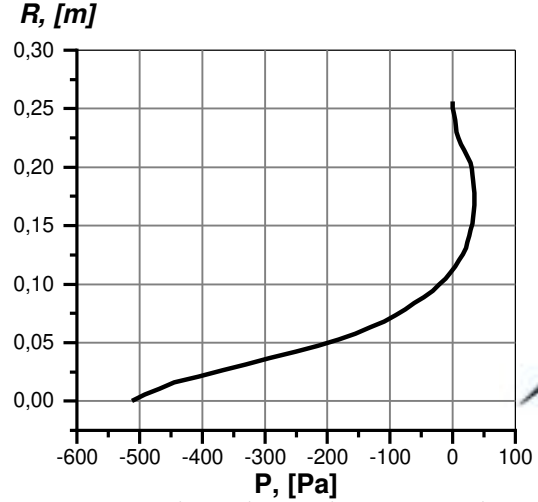


$u_{2t}=u_2$ $\quad v_{2ta}<v_{2a}$

$F_{2t}>F_2$ $\quad P_2>P_1$

$\alpha_{2t}<\alpha_2$

Velocity triangle behind tandem and single blade rows propeller



Pressure distribution behind propeller hub

$$\frac{dp}{d\bar{r}} = \rho\frac{w_t^2}{\bar{r}}$$

pressure distribution in the radial direction

$$p_0 = p_\infty - \rho\int_0^\infty \frac{w_t^2}{\bar{r}}dr$$

pressure at the center of vortex

$$p(r) = p_0 - \rho\int_0^r \frac{w_t^2}{\bar{r}}dr$$

pressure in the radial direction

$$T_h = \frac{2\pi}{S_h}\int_0^{r_h} rp(r)dr$$

negative thrust of the hub and spinner

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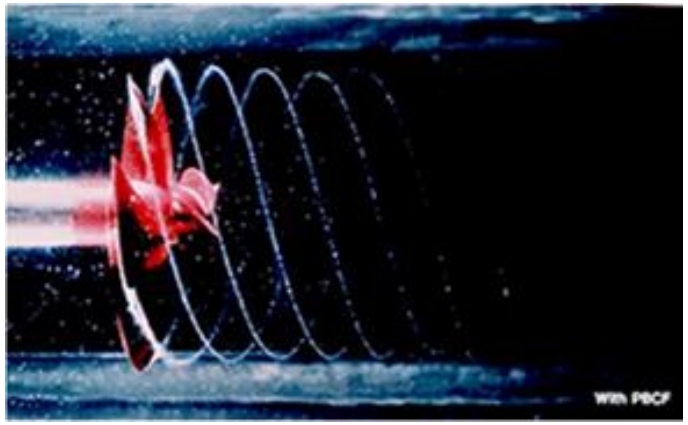
THE MAIN WAYS TO REDUCE HUB VORTEX INTENSITY

Vortex flow behind the propeller

before installation of PBCF



after installation of PBCF

Propeller with Boss Cap Fins

Rim driven fan

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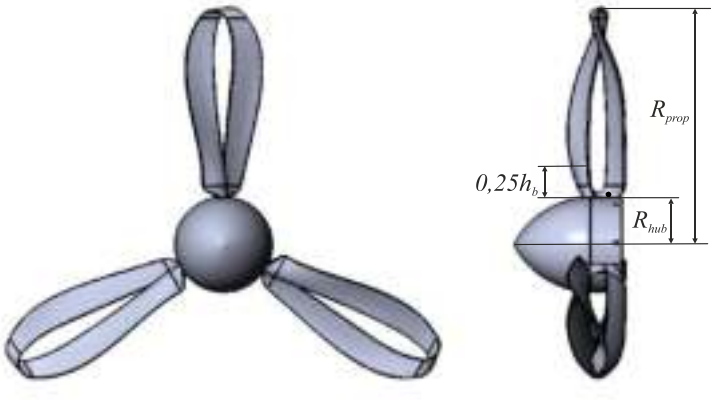
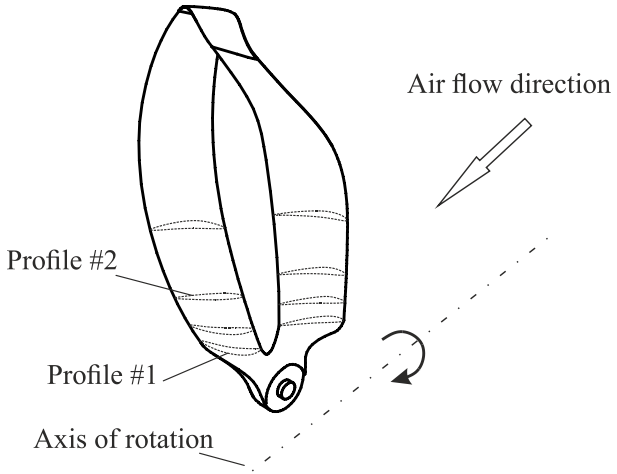
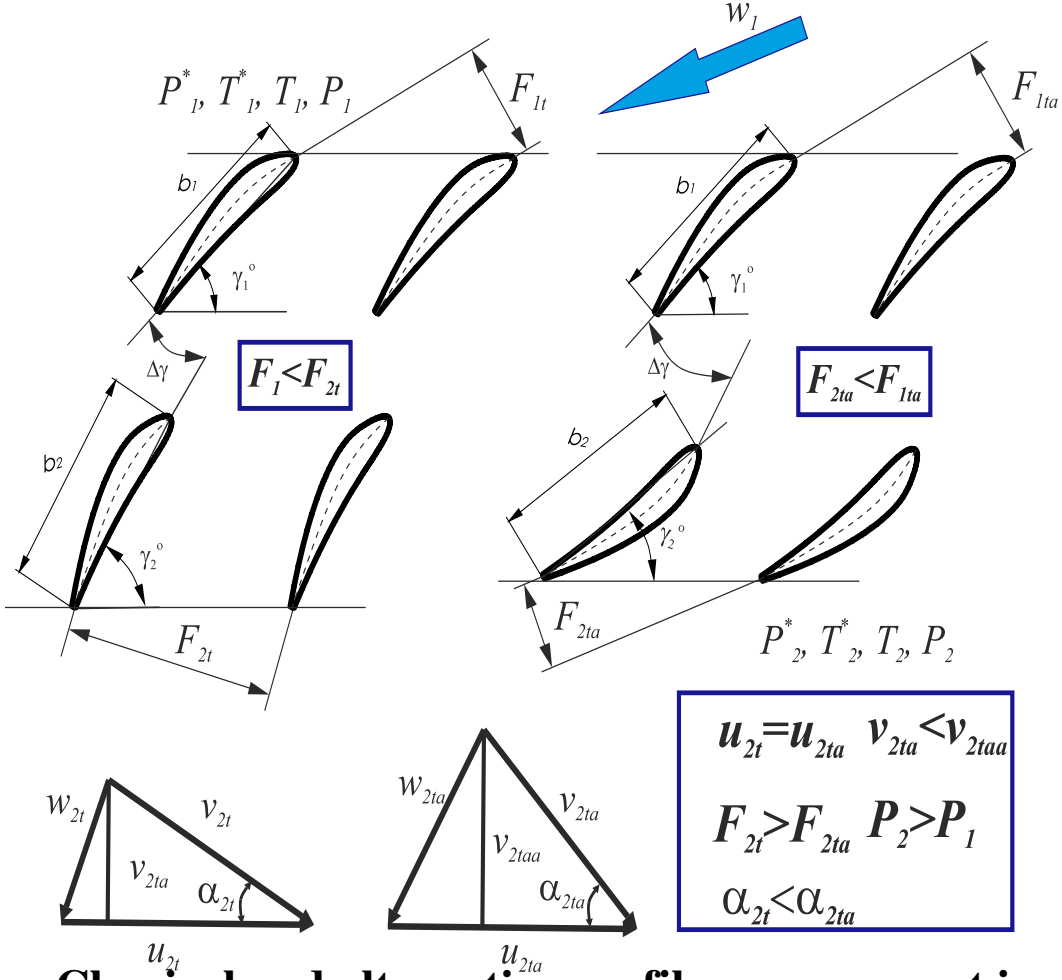
METHOD OF HUB VORTEX INTENSITY REDUCING



Object of investigation



The tandem propeller blade with alternative profiles arrangement



Classical and alternative profile arrangement in hub section of tandem propeller blade

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METHODOLOGY OF TANDEM PROPELLER CHARACTERISTICS EXPERIMENTAL RESEARCH

Prop diameter - 406 mm
Hub diameter - 80 mm
RPM - 5000 rev/min
Blade number - 3

Advance ratio

$$J = \frac{V_\infty}{nD}$$

Trust coefficient

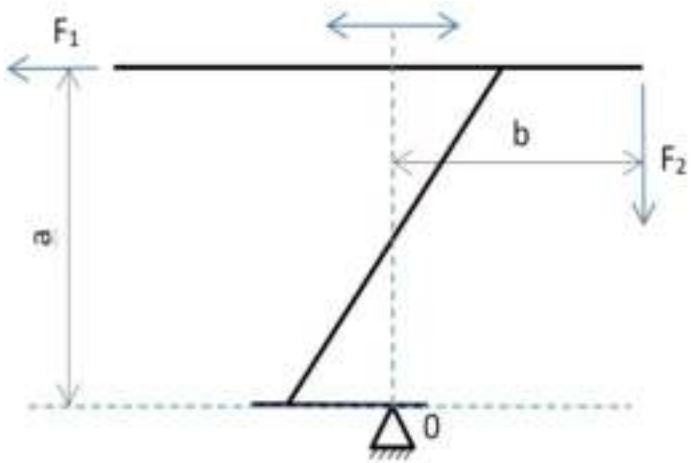
$$C_T = \frac{T_x}{\rho_\infty n^2 D^4}$$

Power coefficient

$$C_P = \frac{P_{shaft}}{\rho_\infty n^3 D^5}$$

Efficiency

$$\eta = \frac{T_x V_\infty}{P_{shaft}}$$



Chem of force balance

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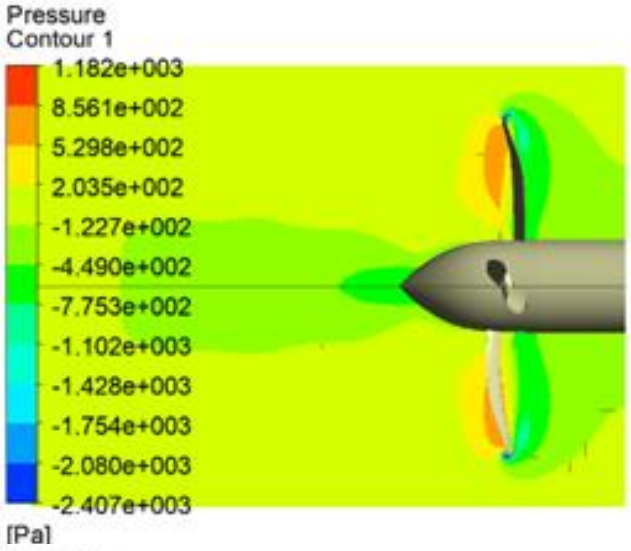
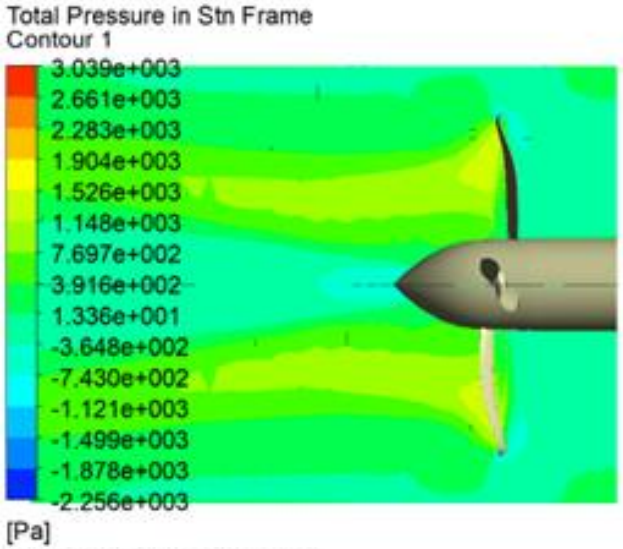
RESULTS OF TANDEM PROPELLER INVESTIGATIONS BEFOR MODIFICATION

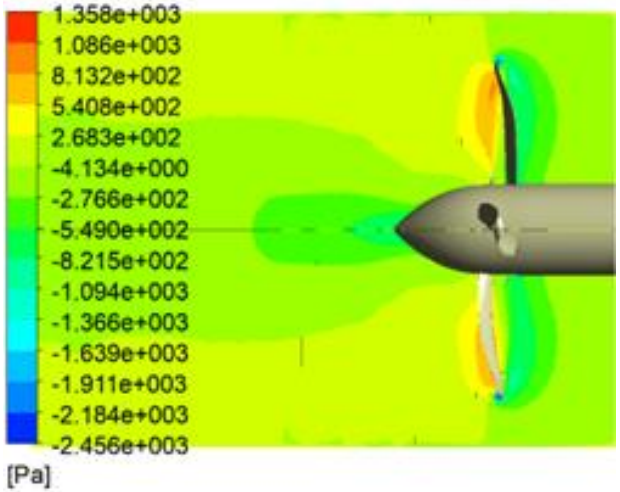
Contour of pressure and total pressure distribution in the meridional section of propeller

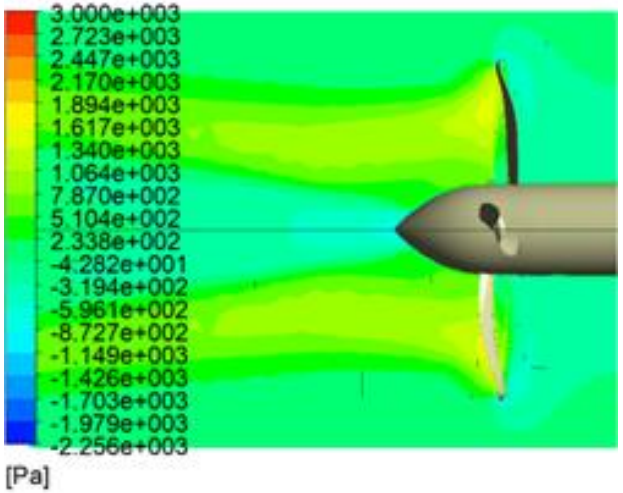
$\Delta\gamma=0°$





$\Delta\gamma=15°$





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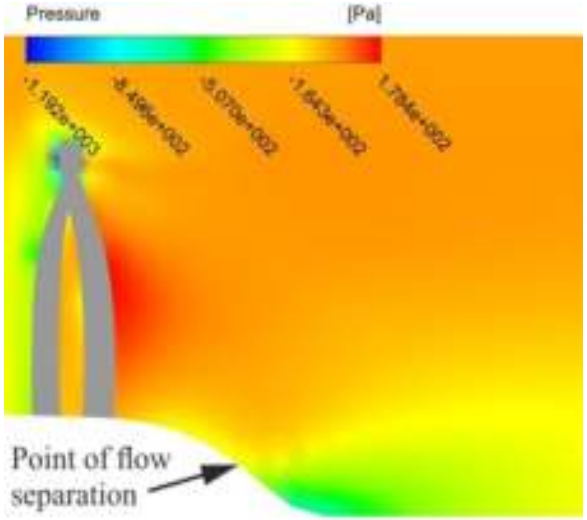
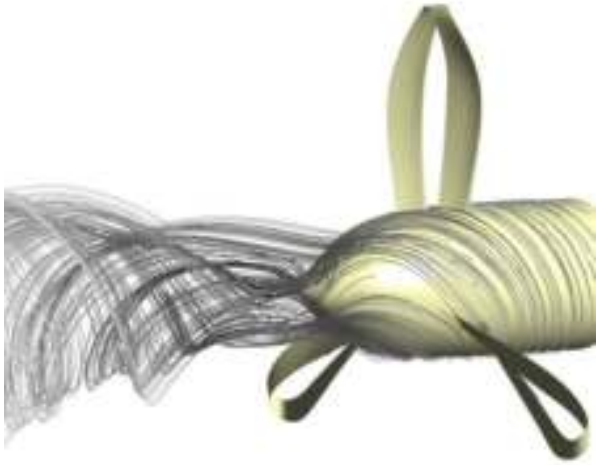
CHARACTERISTICS OF TANDEM PROPELLER AFTER MODIFICATION AND OPTIMIZATION PROFILE ARRANGEMENT

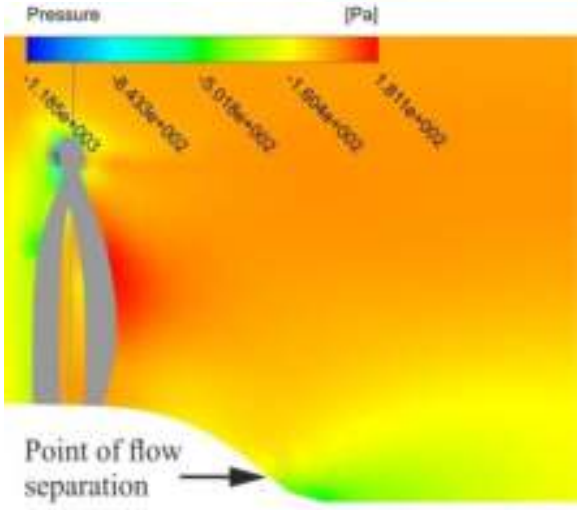
Contour of pressure distribution and hub vortex shape of tandem propeller at $V_\infty = 0 m/s$

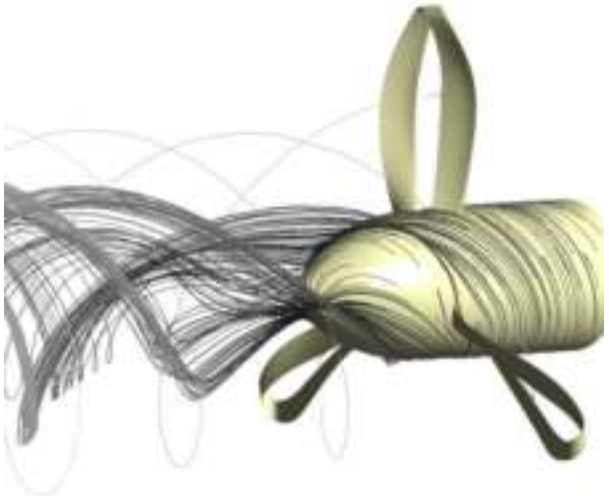
Before modification





After modification

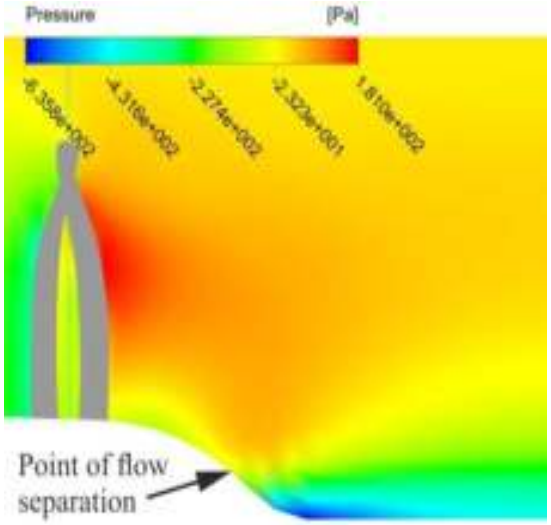


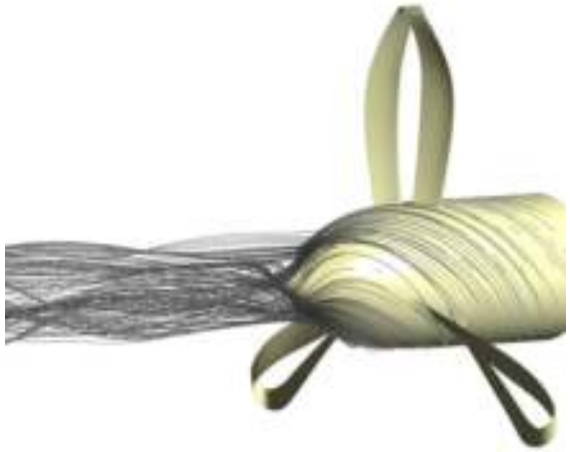


CHARACTERISTICS OF TANDEM PROPELLER AFTER MODIFICATION AND OPTIMIZATION PROFILE ARRANGEMENT

Contour of pressure distribution and hub vortex shape of tandem propeller at $V_\infty = 25 m/s$

Before modification





After modification