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# Numerical Analysis of Flow in Kaplan Turbine Runner Blades Anticavitation Lip with Modified Hydrodynamic Profile

*In order to increase the lifetime of runner blades of Kaplan turbines damaged by cavitation erosion, an anticavitation lip is attached to the periphery of the runner blades on the suction side. The anticavitation lip overtakes the cavitation pitting which appears between the runner blades and the runner chamber. A blade with the original anticavitation lip was modeled using CAE. The numerical simulations showed the tip vortex position and the source of the cavitation erosion. Using these data, a modified profile of the anticavitation lip was designed.*

***Keywords***: *anticavitation lip, cavitation erosion, Kaplan turbine, runner blade, CAE.*

## 1. Introduction

In the Kaplan turbines, cavitation erosion affects mainly the runner blades and the runner chamber. The cavitation which appears inside the gap between the runner blades and the runner chamber (tip clearance cavitation) is caused by the difference of pressure between the suction side and the pressure side [1]. The anticavitation lips, disposed on the suction side of the runner blades, have the role of overtaking the cavitation pitting which appears between the runner blades and the runner chamber. The cavitation erosion moves from the periphery of the runner blades onto the lips [2, 3].

The researches presented in this paper were focused on the study of the influence of anticavitation lip profile on the intensity of cavitation erosion.

The CAD model of the blade with anticavitation lip (figure 1) was built in Autodesk Inventor using the steps described in [2]. The cross section and the profile of the anticavitation lip were initially modeled at the original dimensions from the hydropower plant. The numerical simulation was performed in Ansys-Fluent and TurboCAD Optim [4].

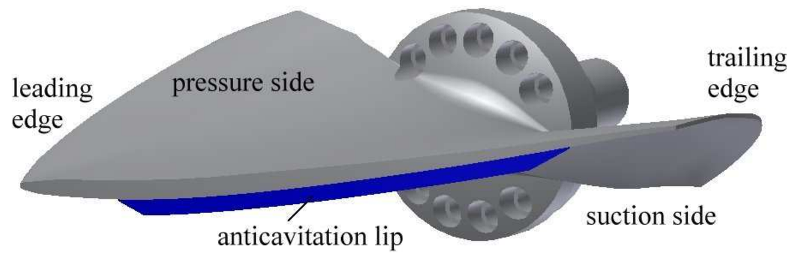



**Figure 1.** Kaplan runner blade with original anticavitation lip

The limits of the domain of analysis were defined by the runner chamber surface (wall), the rotor surface (wall), the inlet and the outlet surfaces of the rotor related to one blade. Hydrodynamic calculus of the flow in turbine inlet, turbine stator and distributor-rotor were performed and connected in order to define the boundary conditions for the domain of analysis.

## 2. Anticavitation lip with modified profile

The original profile of the anticavitation lip has the tips angled at ~45°. The results of the numerical simulations for this profile show the occurrence of cavitation caverns on the lip tips (figure 2).

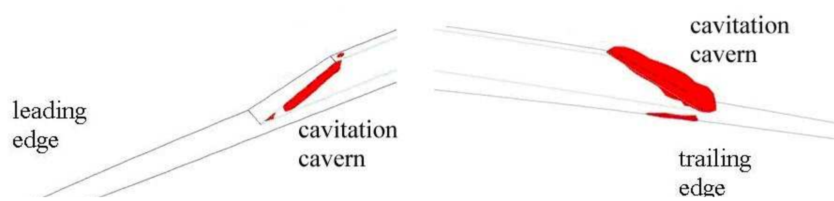



**Figure 2.** Cavitations caverns on the tips of the anticavitation lip

The modified lip was designed to reduce the cavitation caverns. An elliptical profile was chosen (figure 3) to define the limit of the lip. This ellipse had the semimajor axis equal to the lip length at the intersection with the blade. The semiminor axis of the ellipse is equal to the high of the original lip.

The charts of cavitation caverns provide rapid information related to the caverns position but, for an accurate evaluation of the cavitation phenomenon, the variation of pressure coefficient must be studied. Also the vortex charts show the shape and the direction of the tip vortex.

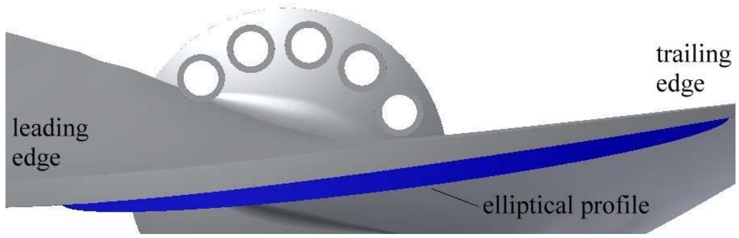



**Figure 3.** Modified anticavitation lip with elliptical profile

The pressure coefficient [5] is defined by:

$$c_{\mathrm{p}} = \frac{p - p_{ref}}{\rho \cdot g \cdot H} \qquad (1)$$

Where: $p$ – pressure in the analyzed point;
$p_{ref}$ – reference pressure at the outlet of the turbine;
$\rho$ – water density;
$g$ – gravitational acceleration;
$H$ – head of the turbine.

The pressure coefficient variation along the original anticavitation lip, at 50 mm far from the blade – runner chamber clearance, shows a high jump at the lip tips. At the leading edge area the pressure coefficient on the suction side (figure 4) varies from 0.05 to -0.425 on a distance of ~0.05 m. Similar in the trailing edge area the pressure coefficient varies from -0.36 to 0.025 on a distance of 0.07m [6].

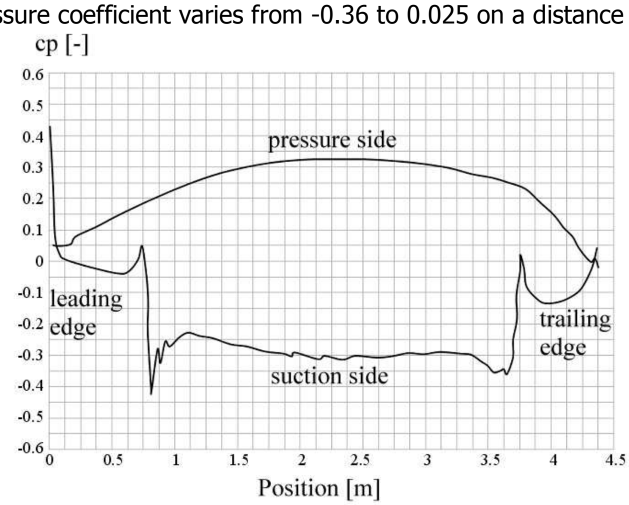
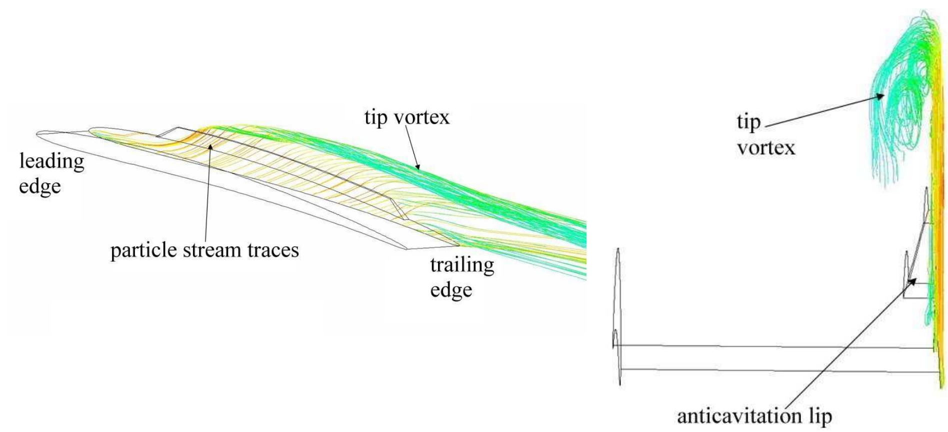



**Figure 4.** The pressure coefficient (cp) variation along the original anticavitation lip. Section at 50 mm far from the blade tip




a) b)

**Figure 5.** The tip vortex on the original anticavitation lip: a) down view, b) back view

For the modified anticavitation lip the pressure variation was represented for three distances far from blade tip: 50 mm, 100 mm and 150 mm (figure 6). The effect of the anticavitation lip decreases with the increase of this distance.

At 50 mm far from blade tip the pressure coefficient variation along the modified anticavitation lip shows smaller jumps at the lip tips. At the leading edge area the pressure coefficient on the suction side varies from -0.05 to -0.35 on a distance of ~0.15 m. In the trailing edge area the pressure coefficient varies from -0.12 to 0.14 on a distance of 0.25 m. The pressure has bigger values in several isolated points.

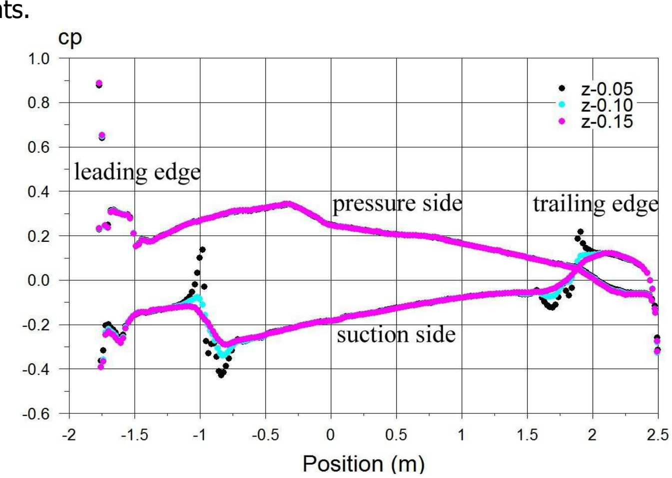
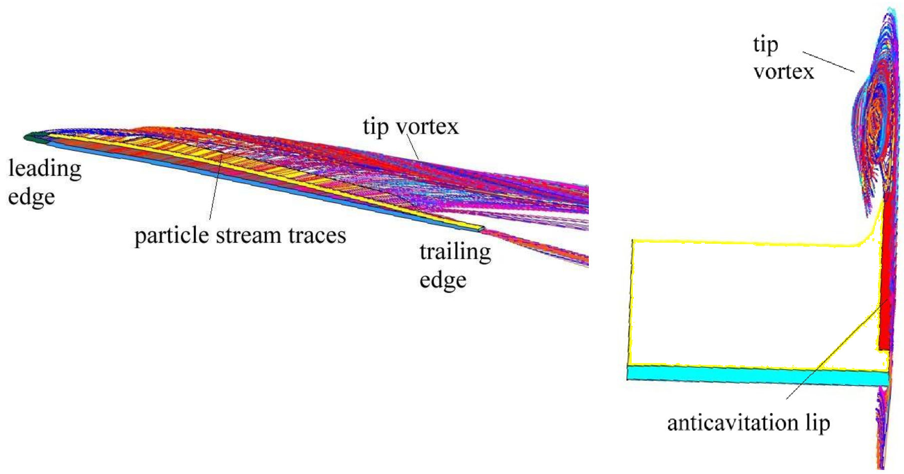



**Figure 6.** The pressure coefficient (cp) variation along the modified anticavitation lip. Sections at 50 mm, 100 mm and 150 mm far from the blade tip

The tip vortex is detached from the blade suction side for both cases (figure 5 – original lip, figure 7 – modified lip). This is the effect of the anticavitation lip.
For the modified lip the tip vortex is also separated in two components: a main vortex on the whole length of the lip and a secondary vortex at the trailing edge area. This separation decreases the intensity of the main vortex.




a) b)

**Figure 7.** The tip vortex on the modified anticavitation lip: a) down view, b) back view

## 3. Conclusion

The results of numerical simulations on the Kaplan turbine runner blade with original and modified anticavitation lip show a decrease of the pressure variation at the tips of the lip in the second case. This decrease is shown by the limit values of the pressure coefficient and by the gradient of the variation. Also, for the lip with modified profile, the tip vortex is separated in two components (a secondary vortex appears in the trailing edge area). Due to these aspects a decrease of the cavitation erosion is expected.

## Acknowledgements

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