

Numerical Investigations of Flow on the Kaplan Turbine Runner Blade Anticavitation Lip with Modified Cross Section

Vasile Cojocaru, Daniel Balint, Viorel Constantin Campian, Dorian Nedelcu and Camelia Jianu

Abstract— The cavitation phenomenon is an important cause of wear and damages of Kaplan and bulb turbines. In order to decrease the erosion rate on the blade and on the runner chamber an anticavitation lip is disposed on the suction side of the runner blade. The goal of the research presented in this paper was to observe the flow behavior for two types of geometry of Kaplan runner blade anticavitation lip. The first lip had the original dimensions from the hydropower plant. The second lip had a modified cross section and smooth edges at the extremities. Tip vortex, cavitation caverns and pressure coefficient diagrams were generated.

Keywords— anticavitation lip, cavitation, Kaplan runner blade, numerical investigations, tip vortex.

I. INTRODUCTION

THE cavitation phenomenon is an important cause of wear and damages in hydroturbines [1]. In the Romanian hydropower plants, cavitation erosion occurs mainly in Kaplan and bulb turbines (in Romania there are 107 Kaplan turbines and 11 bulb turbines). The most injured components are the runner blades and the runner chamber. On the Kaplan runner blade the erosion is more intense in the leading edge area and on the blade tip.

In order to decrease the erosion rate on the runner blade tip and on the runner chamber, an anticavitation lip is disposed on the suction side of the runner blade. The anticavitation lip has the role of overtaking the cavitation pitting which appears

The work has been co-funded by the Sectorial Operational Programme Human Resources Development 2007-2013 of the Romanian Ministry of Labour, Family and Social Protection through the Financial Agreement POSDRU/89/1.5/S/62557.

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between the runner blades and the runner chamber (the cavitation erosion moves from the periphery of the runner blades onto the lips). Using the anticavitation lip the energetic performances of the turbine are not lowered.

The goal of the research was to observe the flow behavior for two types of geometry of Kaplan runner blade anticavitation lip.

II. THE GEOMETRIC MODEL OF KAPLAN TURBINE RUNNER BLADE WITH ANTICAVITATION LIP

The CAD model (3D solid) of Kaplan runner blade was build using Autodesk Inventor [2]. The measured coordinates of the pressure side and suction side points were imported from Excel. These points were jointed in three sets of profiles using spline curves. Connecting these profiles, the suction side surface, the pressure side surface and the leading edge surface were shaped. In the next step these three surfaces were extended to a hub spherical surface and a periphery spherical surface to obtain the surfaces of the complete blade. Closed contours were created intersecting these five surfaces with radial plans. The solid model of the runner blade (Fig. 1) was generated by a loft trough these closed contours.

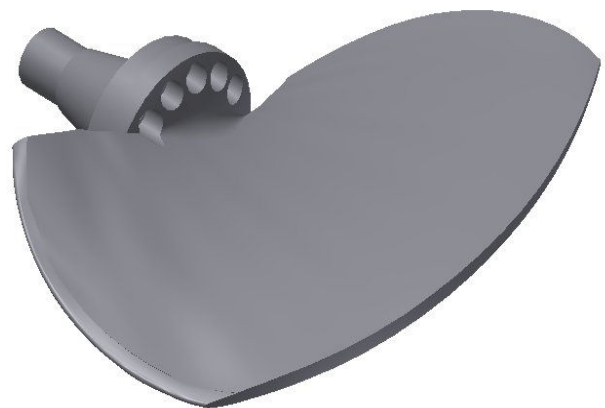


Fig. 1 The CAD model of Kaplan turbine runner blade without anticavitation lip

The anticavitation lip (Fig. 2) was added to the runner blade by a sweep of anticavitation lip cross section along a path identified by the blade tip edge. The extremities of the lip were shaped using two *Loft* commands.

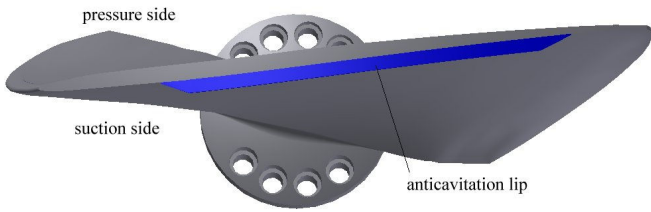


Fig. 2 The anticavitation lip

The cross section of the anticavitation lip was initially modeled at the original dimensions measured in the hydropower plant. The tip of the blade and the surface of the lip located near the runner chamber are in the same continuous cylindrical surface (Fig. 3). Thereby the width of the clearance between runner blade and runner chamber is constant.

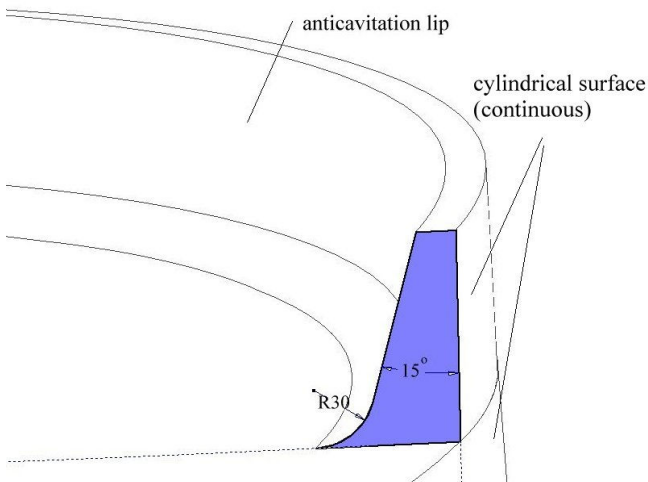


Fig. 3 The original cross section of the anticavitation lip

III. NUMERICAL ANALYSIS OF THE FLOW ON THE ORIGINAL ANTICAVITATION LIP

The numerical simulations are today an important tool in the optimization process of hydro turbines [3,4,5]. The flow analysis in the runner blade – runner chamber clearance and the investigations of tip vortex were subjects of researches regarding the turbine performances and cavitation [6,7,8,9].

In this research the numerical analysis was performed with the software TurboCAD Optim [11,12] (developed by the second author of this paper) and Ansys Fluent.

In order to calculate the vortex flow on the tip of the runner blade following steps were performed [13,14]:

- Hydrodynamic calculus of the flow in the turbine inlet;
- Hydrodynamic calculus of the flow in the turbine stator using the results from the previous step;
- Hydrodynamic calculus of the flow in the reunion domain distributor-rotor using the results from the second step;
- Isolation of an area at the tip of the runner blade to define the domain of analysis (Fig. 4): The blade was positioned on the runner. Planar profiles were obtained from the intersection of the blade tip with cylinders coaxial with the turbine. These parallels profiles were

positioned and jointed. The result was a isolated model similar with the tip of the blade;

- The limits of the domain of analysis were defined by the runner chamber surface (periodic), the rotor surface (periodic), the inlet and the outlet surfaces of the rotor related to one blade.

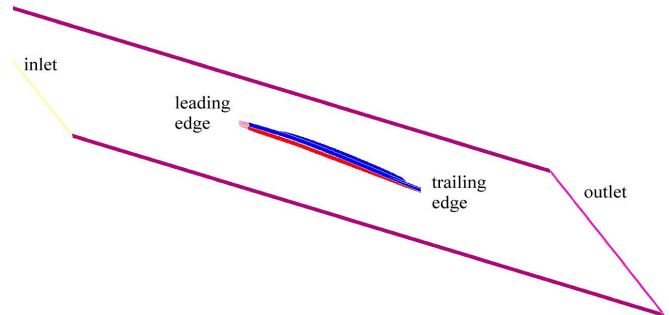


Fig. 4 The domain of analysis

The numerical analysis results for anticavitation lip with the cross section at original dimensions and shape are presented in figures 5, 6 and 7. The tip vortex (Fig. 5) detaches from the blade and the runner chamber. The cavitation erosion risk decreases due to this aspect. This is the effect of the anticavitation lip.

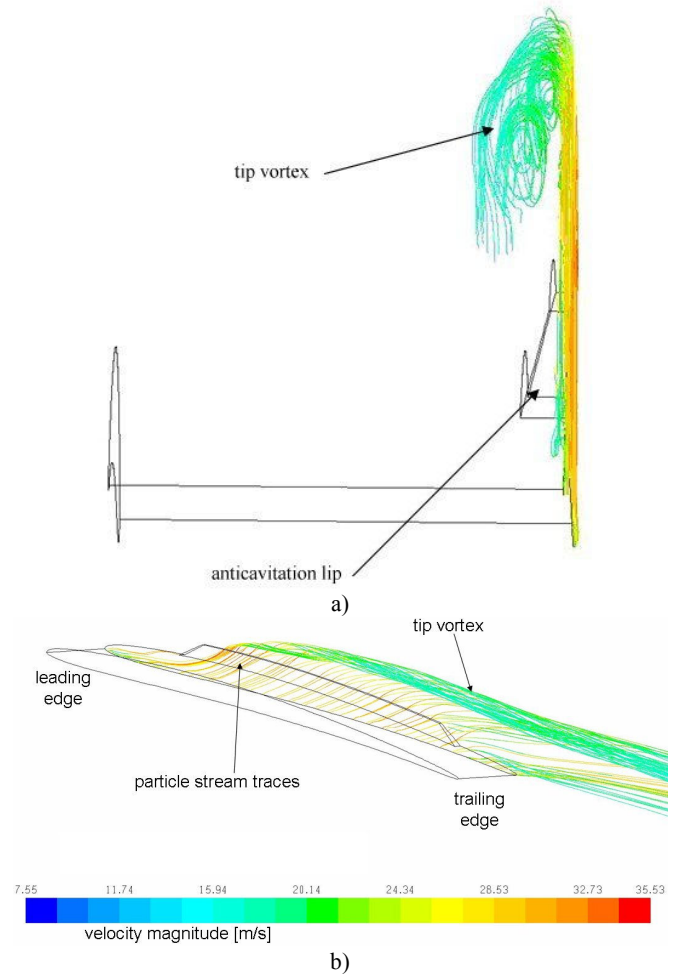


Fig. 5 The tip vortex on the anticavitation lip with original cross section a) down view, b) back view

Nevertheless, in-situ observations showed intense cavitation erosion on the anticavitation lip with this cross-section. In order to reduce this erosion new dimensions and shapes were studied for the anticavitation lip. One variant, presented in this paper, has a modified cross section and smoothed edges at the extremities of the lip. In order to define these modifications the pressure coefficient diagram and the occurrence of the cavitation caverns were plotted.

The pressure coefficient diagram (Fig. 6) shows significant variations at the extremities of the anticavitation lip. In these regions, on a short distance, the pressure coefficient ranges from about 0.2 to -0.6. This variation may facilitate the occurrence of cavitation bubbles in these areas.

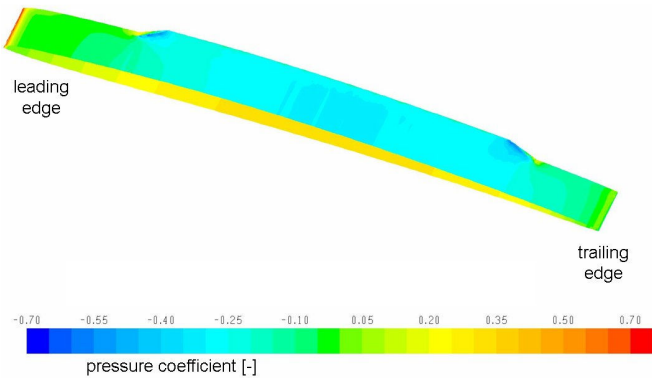


Fig. 6 The pressure coefficient variation

The numerical simulation of the cavitation caverns (Fig. 7) show also intense cavitation on the extremities of the anticavitation lip. The cause is the high gradient of the cross section on a short distance and the improper shape of the lip ends.

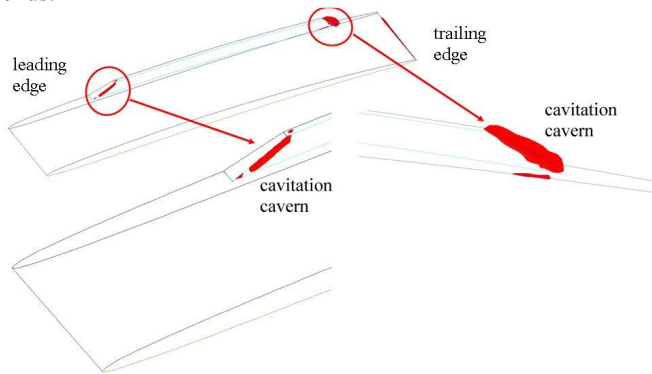


Fig. 7 The cavitation caverns

IV. NUMERICAL ANALYSIS OF THE FLOW ON ANTICAVITATION LIP WITH MODIFIED CROSS SECTION

A first solution to modify the anticavitation lip was adopted based on the analysis of the cavitation caverns and the tip vortex from the original lip. This solution includes the following modifications:

- The change of the cross section of the lip by moving the point "A" with 5 mm towards the rotor hub (Fig. 8). The clearance between the runner chamber and the blade increased in the lip area and had a conical variation. This could be a potential solution for new

lips but in situ this modification is difficult to be made due to the small space.

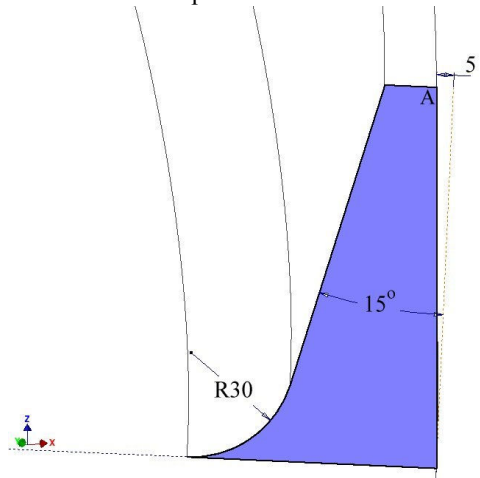


Fig. 8 The modified cross section of the anticavitation lip

- The smoothing of the two edges from the leading extremity of the lip (600 mm radius and 400 mm radius– Fig. 9.a).
- The smoothing of the two edges from the trailing extremity of the lip (400 mm radius and 200 mm radius– Fig. 9.b).

After the smoothing of the edges the extremities of the lip were closer to a hydrodynamic profile. In situ the smoothing of the edge could be realized by grinding.

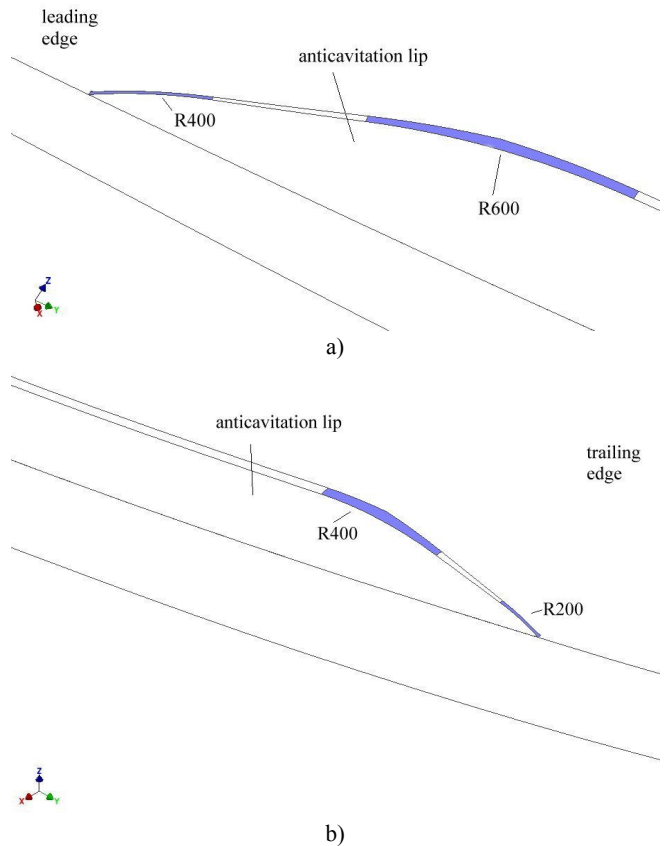


Fig. 9 The smooth edges in the leading (a) and trailing (b) of the anticavitation lip

The results of the numerical simulation made on this new lip do not show important differences compared to the original shape. However, the tip vortex (Fig. 10) is more detached from the runner chamber in the case of the lip with modified cross section. A decrease of the cavitation on the runner chamber is expected.

In the both cases a secondary vortex appeared at the extremity of the anticavitation lip in the trailing edge area. For the modified lip this secondary vortex had a divergent direction related to the main vortex. For this reason the intensity of the main vortex will be lower.

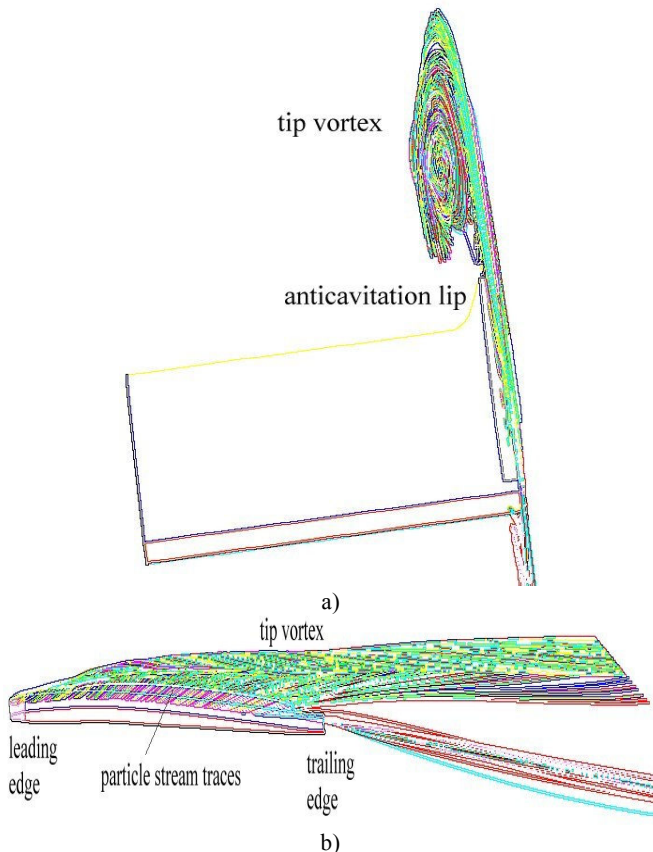


Fig. 10 The tip vortex on the of the anticavitation lip with modified cross section a) down view, b) back view

V. CONCLUSION

The numerical analysis of the flow on the original anticavitation lip of Kaplan turbine runner blade shows:

- The tip vortex detaches from the blade and the runner chamber;

- The pressure coefficient at the extremities of the lip has a significant variation from about 0.2 to -0.6;

- The cavitations caverns appear at the extremities of the lip;

On the modified anticavitation lip with tilted lateral surface a decrease of the cavitation on the runner chamber is expected.

Further researches will be made on anticavitation lip with modified hydrodynamic profile.

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