Francis Turbine Runner Design on the Basis of Loss Analysis

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Long Abstract

Introduction

On the basis of one dimensional loss analysis, it is effective to design a Francis turbine runner. There are friction, incidence, mixing, swirl, bend and secondary flow loss in the turbine passage. Therefore, how to reduce the loss distribution on the flow passage is an important step in the turbine performance improvement. In this study, a Francis turbine runner has been designed according the loss distribution. Three meridional plane shapes are selected to investigate the loss distribution on the runner passage and runner design. The results show that there is the significant effect of the meridional plane shape on reducing runner passage loss. The smooth shroud curve also plays a role of reducing the loss on the runner passage.

1. Turbine Model and Numerical Method

In this study, a Francis turbine model with specific speed N_s=130 m-kW to investigate the loss distribution on the runner passage and runner design. The inlet diameter of the runner is D_1=0.547m, the outlet diameter of that is D_e=0.5m and the number of runner blade is Z=14. In addition, the number of guide vane and stay vane is Z_g=Z_s=16, and the height of guide vane is B=0.103m. The design point of the Francis turbine is at H=64.2m for the effective head, Q=1.21 m^3/s for the water flow rate and N=914 min^{-1} for the rotational speed.

Figure 1 shows the three different meridional plane shapes for the loss analysis. The curvature of Shape 1 crown curve is larger than that of Shapes 2 and 3. Moreover, the D_4 of the Shape 1 is larger than the others, which means that the runner outlet area of the Shape 1 is larger than that of the others. The L_e length of Shape 1 also is longer than that of the others. The meridional plane of the Shapes 2 and 3 is similar, and only the shroud shape of the Shape 3 is changed to be smooth. The shroud of Shape 2 is combined by circle and straight line.

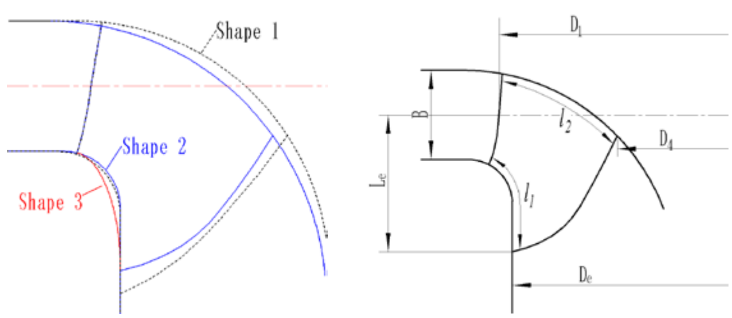

Figure 1. Meridional plane shapes

2. Results and Discussion

In order to investigate the loss distribution on the runner passage by those three meridional plane shapes, the other parameters should be kept same. The exit angles from runner passage are kept same at 90°, whose case has the best efficiency point and the loss in the draft tube can be reduced [1-3]. Therefore, in order to comparison to loss distribution by those three meridional plane shapes, the exit angles from crown to shroud have been controlled to around 90° as shown in Fig. 2. Figure 3 shows the efficiency curve by the meridional plane shapes. The efficiency of Shape 3 achieves the best efficiency point. However, the efficiency of Shape 1 is the lowest one. Too larger runner outlet area reduces the efficiency significantly. Figure 4 shows the loss analysis on the component passage. It can be see that the loss in the runner passage is the highest, which achieves more than 3%. The loss at the stay vane guide and vane passage achieves around 2%. Moreover, there is minimum loss which occurs at the draft tube, and achieves around 0.2%. As the shapes of stay vane, guide vane and draft tube passage are same for the three different meridional plane shapes, the loss distributes similar at those three components. Too larger runner outlet area increases the loss at runner passage drastically. Moreover, the shroud with smoothly distributional curve plays a role of reducing the loss at the runner passage effectively. Figure 5 shows the cavitation analysis. The inception cavitation occurs at the trailing edge of blade. However, the air volume fraction is only lower than 0.4%. This means there is not real cavitation in the runner passage.

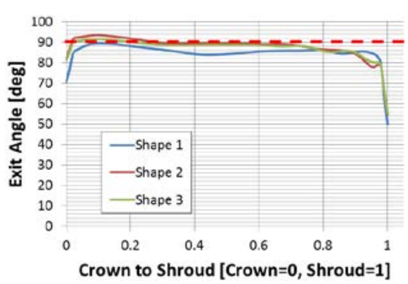

Figure 2. Exit angle from runner passage.

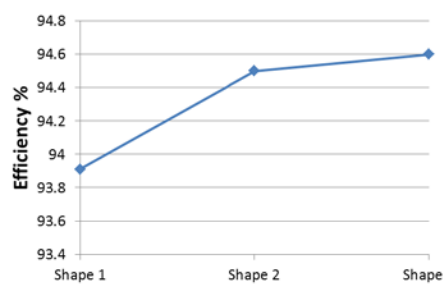

Figure 3. Efficiency curve

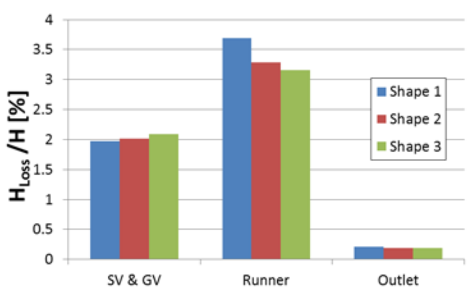

Figure 4. Loss analysis in the flow passage.

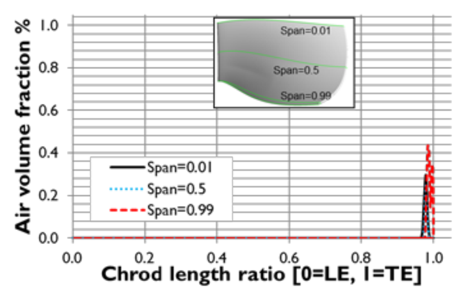

Figure 5. Cavitation analysis result

Acknowledgement

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