Experimental Flow Analysis of LP Exhaust Hood for a Steam Turbine

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1. Introduction

The flow structure and performance of exhaust hood for LP (low-pressure) steam turbine (SMART-P, 65MW) used for the generation of fresh-water were investigated experimentally. Due to general arrangement of the downward condenser, the discharging flow from the LSB (last stage blade) turns 90 degree from axial direction to radial direction. Therefore, aerodynamic design of the exhaust hood is essential to ensure the desirable pressure recovery performance of the exhaust hood. Detailed understanding of flow behavior within the exhaust hood, especially pressure distribution inside the exhaust hood and velocity distribution through the flow passage is important to estimate the kinetic energy loss and aerodynamic performance.

The recent advancements for the analysis of a turbine exhaust hood have been mainly achieved by CFD approaches. Tindell et al. [1] analyzed an LP turbine exhaust hood using simulation program (PARC). Xu et al. [2] studied 3-D flow in the same exhaust hood model numerically and found a larger passage vortex with high intensity in the flow, reducing the static pressure recovery. Sloldov [3], Dejean et al. [4] and Linhart & Hoznedl [5] also simulated 3-D flow and predicted the performance of an exhaust hood numerically.

However, there are relatively a few experimental investigations because of considerable difficulties in measuring the complex internal flow inside the exhaust hood. More reliable and sufficient experimental data for the flow within the exhaust hood are required for validation of numerical predictions.

The objective of this study is to investigate the complex flow behavior inside an exhaust hood model of a low-pressure steam turbine by pressure and PIV (particle image velocimetry) measurements. These experimental results can be used as comparison data for the validation of numerical simulation.

2. Experimental Apparatus and Methods

The exhaust hood model was installed at the end of an open loop wind tunnel and the working fluid is air. The front view is shown in Fig. 1 and pressure taps location is indicated in Fig. 2. The LSB exit plane and the condenser neck flange define the entrance and the exit of the exhaust hood, respectively. The bearing cone forms the inner boundary of the annular discharge flow, and the steam guide constitutes the outer boundary. Geometry ratio of the tested model to the prototype is 1: 4.088. In order to carry out flow visualization, the whole exhaust hood model was made of transparent acryl. Pressure and PIV measurements have been done to investigate the performance of exhaust hood model.

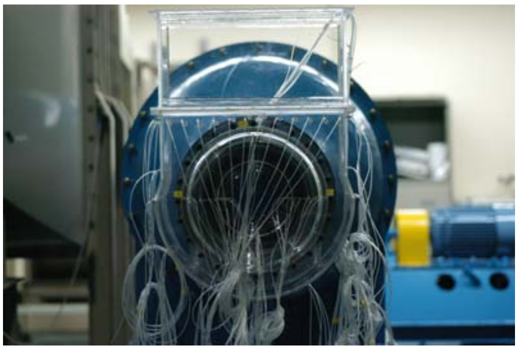


Fig. 1. Exhaust hood model of LP steam turbine

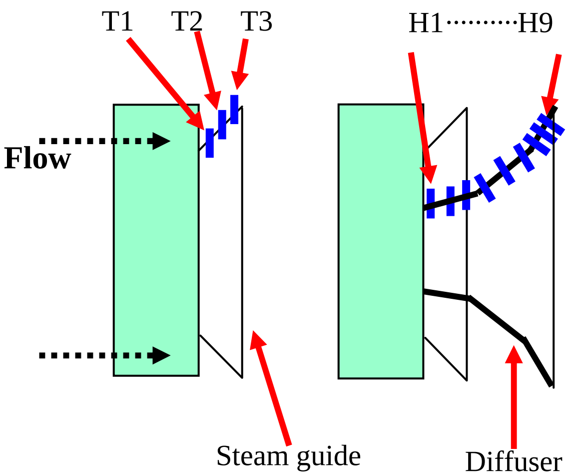


Fig. 2. Location of pressure taps at the steam guide vane and diffuser.

3. Results and Discussion

3.1 Pressure Measurements

The loss of the LP exhaust hood was estimated by the hood loss coefficient or the static pressure recovery coefficient (SPRC). In this study, the energy loss of the hood model was estimated by measuring the SPRC. The SPRC indicates the rate of static pressure change from the LSB to the condenser neck flange of an exhaust hood. SPRC was calculated by using the following equation.

$$C_{PR} = \frac{P_{S_F} - P_{S_{ANN}}}{P_{T_{ANN}} - P_{S_{ANN}}} \qquad (1)$$

Where P_{SANN} and P_{TANN} implies the static pressure and the total pressure at the exit of the LSB, respectively.

Additionally, P_{SF} is the static pressure at the condenser neck flange. The mean pressure and SPRC values were measured at the inflow velocity of 60 m/s (Fig. 3). The negative SPRC indicates the loss of pressure due to flow separation near the steam guide vane, the complex vortex structure at the collector, non-uniform velocity distribution at the outlet of hood and etc.

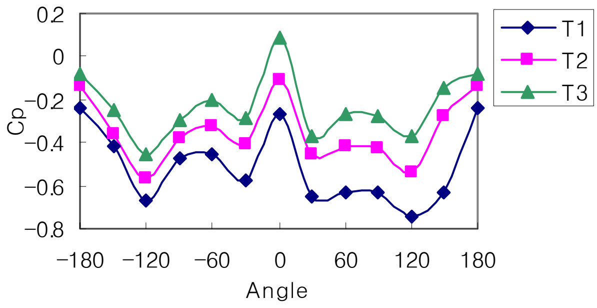
3.2 PIV Velocity Field Measurements

As shown in Fig. 4, a counter-clockwise strong vortex forms in the corner region between the top of steam guide vane and the butterfly vane, due to severe flow separation of 'backward step expansion'. Although it is restricted in the corner and its dimension is small, the vertical motion in its core is remarkably high and the horseshoe shape vortex has very strong intensity. Hence, this horse shape vortex seems to consume large amount of kinetic energy.

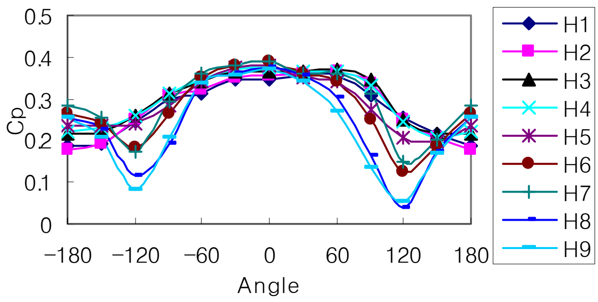
4. Conclusion

The 3-D vortical flow inside the exhaust hood was visualized quantitatively under the simulated inflow condition at a design condition in order to investigate the flow structure inside the exhaust hood and obtain reliable data for improving flow path design. The steam guide vane and the bearing cone should be designed carefully in order to control these vortical flow structures and achieve favorable hood performance.

Pressure measurements were also performed to estimate the pressure recovery performance of the exhaust hood. The large pressure fluctuating may result from flow separation at the tip of steam guide vane, the main source of pressure loss of the exhaust hood. Pressure measurements and flow visualization were very helpful for precise estimation of exhaust hood performance and optimization of exhaust hood design.



(a) At the steam guide vane



(b) At the diffuser

Fig. 3. Distribution of static pressure coefficient at the steam guide and diffuser

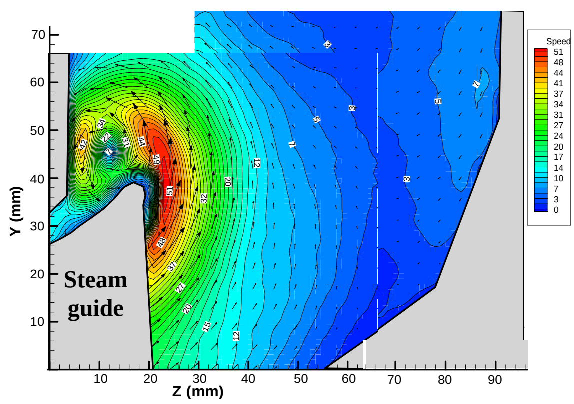


Fig. 4. Velocity distribution measured at the vertical center plane.

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