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Effect of Seat Shape on Control Valve for Large Steam Turbines

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1. Introduction

Among various valves that control the steam flow to the turbine, the control valve is certainly the most significant. The steam flow rate is determined by the area formed by the stem disk and the seat of the control valve. While the ideal control valve linearly controls the steam mass flow rate with its stem lift, the real control valve has various flow characteristic curves pursuant to the stem lift. Thus, flow characteristic curves are needed to precisely design the control valves manufactured for the operating conditions of power plants. VELO (Valve Engineered Layout Operation) experimentally determines the characteristic curves for the flow control in the steam power plants. The Widows' Creek type control valve is the reference model and air is selected as the working fluid. Previous experimental flow coefficients for the high opening of the control valve and the region of high pressure ratios were found to be lower than those of the reference but essentially identical in the low opening and the region of low pressure ratios. VELO is newly performed to particularly check on any change in the flow coefficient depending on the length of a pipe section attached to the valve exit [1-3]. According to the VELO test results, however, the flow coefficient in the region mentioned does not change and a difference is recently found in terms of modelling the valve and the seat. It is thus revealed that the seat of the scaled down valve in VELO is different from reference. In order to make sure whether the seat shape will increase the flow coefficients or not, the seat of the valve in VELO is remodeled and analyzed by utilizing the commercial computational fluid dynamics.

2. Experiment

There are two models of VELO which are 2:1 and 4:1 scaled valves. The results for the 2:1 scaled model exhibited a narrower region than those for the 4:1 scaled model because of the lower air blower capacity [4]. VELO, however, showed that both the linearly scaled down models yield almost the same flow coefficients. Thus only the 4:1 scaled valve model was used in VELO.

2.1. Test procedure

It is preferable to measure real mass flow rate at different ratios of the stem lift length versus the seat diameter in test. Then the flow characteristic curves at each pressure ratio of the outlet static pressure versus the inlet total pressure can be obtained. It is, however, difficult to keep the pressure ratio constant at various measuring points. Rather, it turns out to be easier to measure volume flow rate, temperature, and pressure by changing volume flow rate at the constant disk stem lift.

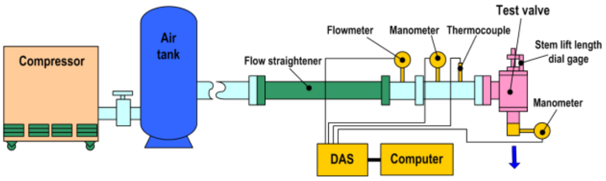

Fig. 1. Test apparatus

This results in a difference between the input and output pressures. Thus the air pressure ratio is changed according to the position of the valve stem. As a result, one may obtain flow characteristic points at each pressure ratio and the constant ratio of the stem lift length versus the seat diameter. The position of sensors and other equipments for VELO is depicted in Fig. 1.

2.2. Result of test with and without pipe extension

The VELO test with the extended pipe yielded the characteristic curves plotted in Fig. 2 and it shows that the flow coefficients are decreased by adding the exit long pipe.

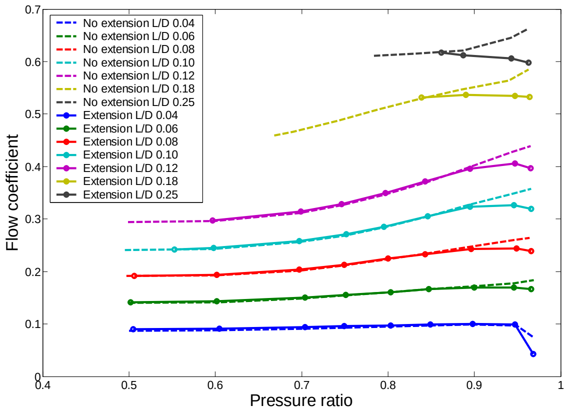

Fig. 2. Effect of a long pipe

3. Different shapes of valve seat

A difference was recently found in terms of modelling the valve and the seat through the comparison of two-dimensional drawings produced by Doosan Heavy Industries and Construction Co., Ltd. as demonstrated in Fig. 3.

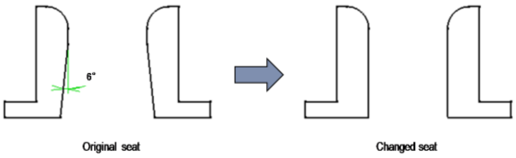

Fig. 3. Valve seat shape

The discrepancy between the GE and DHIC flow coefficients may be attributed to the modified seat from the original one.

4. Computational fluid dynamic analysis

The numerical analysis of VELO was previously performed by utilizing a CFD code, FLUENT. It resulted in the disability of obtaining the flow coefficients by using the commercial CFD code [5] but another CFD code was chosen to check on a tendency to increase the mass flow rate by reforming the seat shape. ANSYS Design Modeler was used for three-dimensional computer aided design of the flow domain following reference and it was directly imported to the computational flow analysis code, CFX® 11.0 [6].

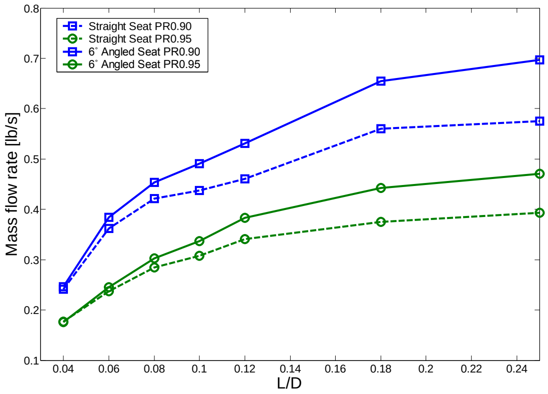

Fig. 4. CFX-Post result

Fig. 4 presents that the mass flow rate increased by altering the straight seat shape into 6° angled one.

5. Conclusion

The test results revealed that the flow coefficients are not necessarily affected by the pipe extension at the exit. In addition, the test using different length pipes turned out that the effect of pipe extension, which would increase the flow coefficients, was a wrong assumption. The difference was found in terms of modelling the valve and the seat. Thus the commercial CFD code was utilized to look into the influence of the valve seat shape in advance. As a result, it might be said that the mass flow rate of the air would increase if the seat shape changed to reference, which is 6° angled. Further, it is necessary to remodel the seat shape of the test valve to improve in the flow coefficients. This analysis will be extended to check on the effect of pipe extension and another test will be performed by making valves of different seat shapes.

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