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FLOW VISUALIZATION IN CONTROL VALVE WITH PROFILING CONE

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Abstract: *The results from aerodynamic research on the model control valve with profiling cone of steam turbine ŠKODA are presented. Experimental work was realized in the research laboratory CKTI Sankt Petersburg. Pressure pulsations under cone in a big range of operational parameters were measured. Measurements were realized by means of optical interferometry.*

Keywords: ***valve, profiling cone, visualization.***

1. Introduction

The result of the requirements to build turbines operated under constantly increasing admission pressures and higher unit ratings is the necessity to steer the momentary power of the turbine via control valves with relief. After the rather limited success of the application of licence to a relief valve for the 1000 MW turbine, the topics of operational reliability and shape of the control valve cone have received systematic attention. Individual variants of the potential valve designs are subject to thorough testing at various laboratory stands. Among the highly useful benefit is the possibility to visualise the flow inside the valves that is realised by CKTI in St. Petersburg under the supervision of ŠKODA POWER (Feldberg 2005). Calculations of flow inside the valves are useful as well (Matas 2004).

Numerous experiments have indicated that designs using a single central relief port are not suitable. New publications (Zarjankin & Simonov 2005) recommend that the cone use a perforated wall. In the valve for the 1000 MW turbine, the perforated ring – damper assisted in the suppression of extreme pressure pulsation during startup at high pressure loss with elevated local values of Mach numbers. A disadvantage of the damper is that it is present also at rated operating conditions. This disadvantage could be removed by controlled steam discharge through the perforated wall of the cone.

The CKTI laboratory has carried out tests to verify the shaped valve cone with relief holes. The needs of the visualisation process required that a desk model of the valve cone be prepared, including the holes. Visualisations were realised using the shadowing method in a Töpler machine and using a Mach – Zehnder interferometer. Pressure pulses are evaluated according to the change in the local optical signal.

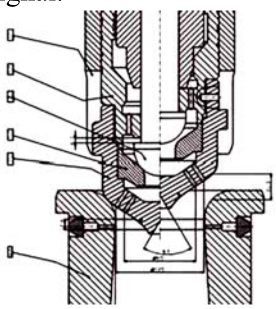

Figure 1: Actual rendering of a cone in a relief valve

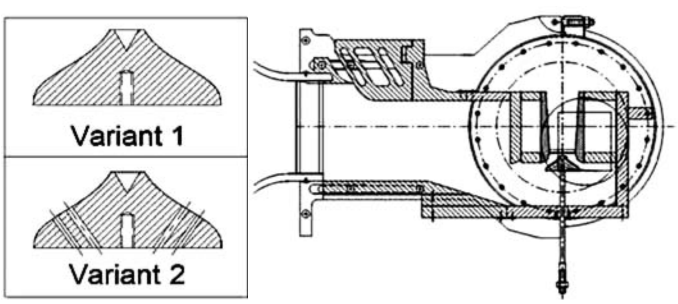

Figure 2: Model of a valve featuring a shaped cone and relief port

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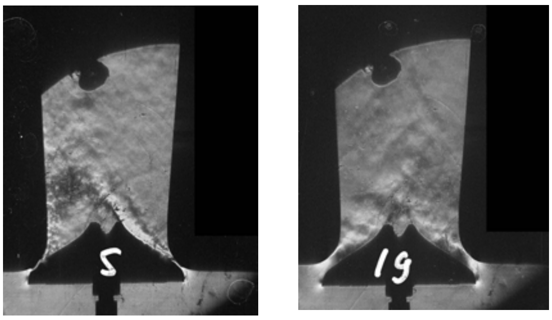
2. Design of Experiment and Valve Model

The design of the valve assumed for verification by experiment is shown in Figure 1. The model for visualisation of flow requires the transition and 3D realisation of the part of interest into a 2D system. For that reason, the number of holes in the model was reduced to preserve the proportional flow area relevant to the neck area. The model of the cone has been simplified against the original part – see Figure 2. Pressure above the cone is assumed equal to that at the valve intake port.

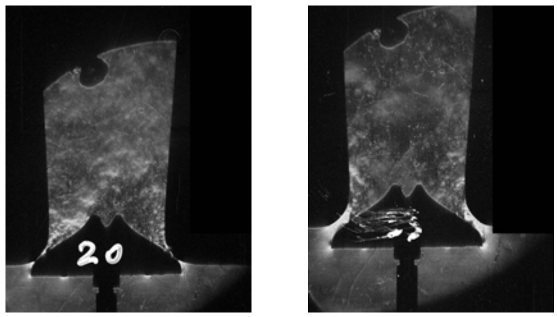
3. Flow Visualisation

Visualisation of flow using the shadow method has been realised for a wide variety of operating modes. Figure 5 provides an overview of two pressure ratios and lift for variant 1 (cone without perforation). Low lift and low pressure ratio delivers irregular distribution of flow fields. At one side of the cone, separated flow occurs while at the other side of the cone, flow attraction to the cone prevails. The effects of the relief holes can also be inferred from a series of images of flow fields in Figure 6. Relief holes promote stabilisation of flow fields in separating the flow from the cone. The flow lines from the holes possess an ejection effect that leads to partial intake of steam from the environment.



$h/D_0=0.02$, $p_2/p_0=0.35$ $h/D_0=0.11$, $P_2/P_0=0.87$

Figure 3: Visualisation of flow under the cone without perforation (Variant 1)



$h/D_0=0.01$, $P_2/P_0=0.35$ $h/D_0=0.09$, $P_2/P_0=0.75$

Figure 4: Visualisation of flow under the cone with perforation (Variant 2)

4. Measuring of Pressure Pulses

Interferometric measuring enables the assessment of velocity fields, Mach numbers, and changes in pressure pulsation in the location of interest.

5. Conclusions

Flow under the shaped cone of the control valve may, under certain pressure conditions and at low lift, be unstable with differential flow arrangement on the opposite sides of the cone.

Cone perforation assists in stabilising the flow in the diffuser and under the cone. It also provides symmetrical flow field in the surroundings of the cone. The velocities become balanced in the neck of the diffuser. Flow separation from the cone is evident.

Pressure pulsation ranging from 2 to 10% is present in a non-relief cone. Maximum pulsation occurs in the area under the cone where the flow from both sides of the cone amalgamates. Cone perforation assists in damping the pressure pulsation. The damping ratio amounts to 10 to 15 in the low frequency range.

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