Performance under Pressure

CCI turbine bypass valve

CCI substantially reduced warranty repair costs by using fluids simulation to upgrade the design of its control valves.

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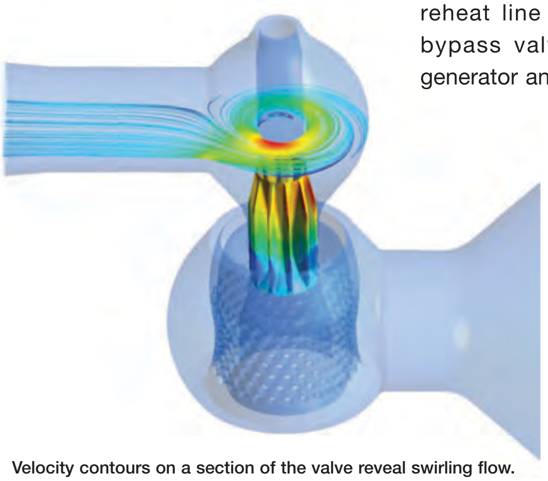
Traditionally, power plants spent the majority of their time running at fixed loads and subcritical conditions (under 220 bar). In today's tough business environment, plants are often running with a variable load to match fluctuating power demand, and to boost plant efficiency, operators are operating at supercritical conditions. Consequently, turbine bypass valves are cycled more frequently and at higher temperatures. The result is that the valves now undergo much more thermal and mechanical loading than in the past.

To meet today's demanding environment, Control Components Inc. (CCI) in India needed to upgrade the design of its turbine bypass valves. Simulation with fluid dynamics software from ANSYS made it possible for CCI engineers to visualize flow inside the valve, and to estimate hydraulic and thermal loading on the valve's pressure boundary components. Once a good understanding of the flow physics was established, finding a solution became easy.

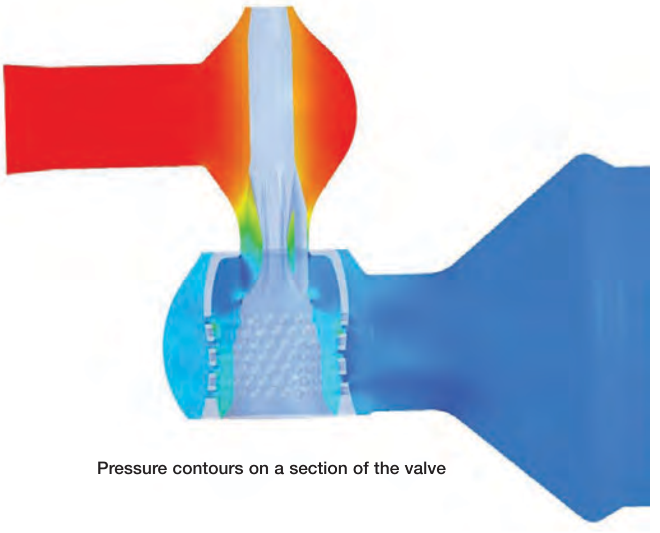


Velocity contours on a section of the valve reveal swirling flow.

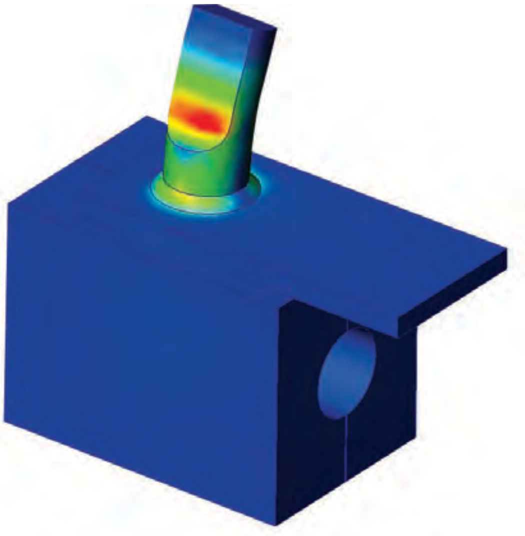
Control Components Inc. is the world's leading supplier of severe service control valves and silencers. Its turbine bypass valves route high-pressure, high-temperature steam around the turbine (HP, IP and LP) from the main steam line to the cold reheat line or condenser. Turbine bypass valves enable the steam generator and turbine to be operated independently during startup and shutdown as well as when the load is changed. The turbine bypass valve must produce an extremely high (200 bar) pressure reduction in fluid due to process condition requirements in the downstream. The valve must also provide temperature control by adding water to the steam to reduce its specific enthalpy, a process called desuperheating that reduces the steam's capacity to do mechanical work and to release heat.

To address the harsh operating conditions, CCI engineers faced several difficult technical challenges. The ability to perform physical testing was limited due to the expense of setting up a physical test that duplicates an operating power plant's extremely high pressures and temperatures. And even when such a test could be performed, only limited information could be obtained. Detailed process conditions cannot be observed reliably inside the valve, or even at its inlet and outlet.

In addition, desuperheating is a very complex phenomenon to simulate. In most fluid dynamics problems, it is sufficient to assume that a fluid has a constant density or obeys the ideal gas law. But the pressure drops are so high in turbine bypass applications that steam must be represented as a real gas — rather than as an ideal gas — to accurately predict the temperature distribution in the valve. ANSYS CFX fluid dynamics software offers a built-in real-gas



Pressure contours on a section of the valve



Stress contours on anti-rotation pin

equations model that provides accurate predictions under these critical conditions. The real-gas equations also provide accurate prediction of flows with phase change.

The engineering team's first challenge was to determine the flow field at the inlet to the valve. While inlet flow, temperature and pressure can easily be measured, in the past it was never possible to determine the actual velocity distribution over the cross section of the pipe feeding the valve inlet. The inlet piping bends in various directions to accommodate the layout, and this results in a relatively non-uniform velocity profile at the valve inlet, which can have a major impact on valve performance. To address this, the inlet piping was modeled separately, and the export boundary condition option in ANSYS CFX was used to export the inlet flow field to the valve model.

CCI engineers began the process of simulating the control valve by using a SolidWorks® solid model of the existing design. The valve geometry is complex, with multiple stages to absorb the enormous pressure drop involved in the application. The first stage needed to be simulated to a high degree of accuracy because it included the greatest amount of thermal cycling.

Next, CCI engineers used ANSYS ICEM CFD meshing software to create a finer hex mesh of the critical first stage. The flow across the turbine bypass valve divides into two parts: the pressure drop region and the desuperheating region.

Transient simulation revealed that the flow conditions inside the valve were far different from what had been imagined.

Engineers easily transferred the pressure loading and its equivalent torque from the fluids simulation to ANSYS Mechanical software and performed a structural analysis of key valve components. This information was used to design structurally stronger components that can be installed in a simple field retrofit to existing valves.

Simulation made it possible to quickly upgrade the turbine bypass valve in a few weeks, compared to the six to 12 months that would have been required using conventional methods. The result was a substantial reduction in engineering costs.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