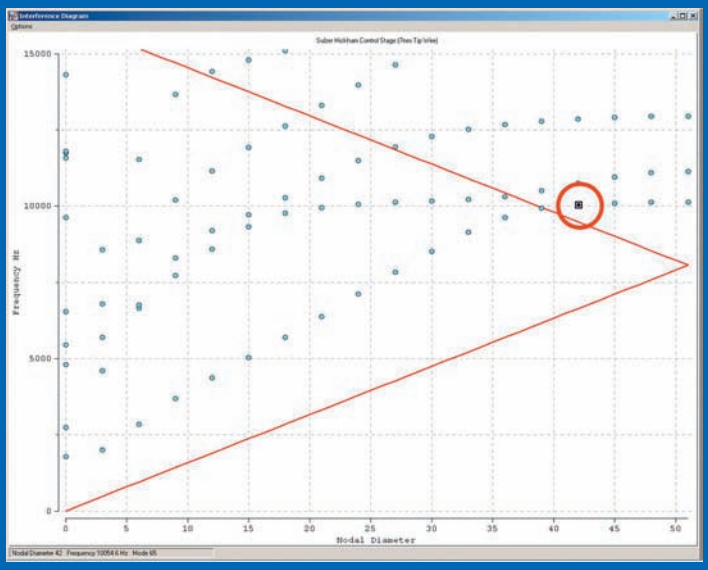

Figure 1: Interference diagram for the original design; the dominant failure mode is outlined.

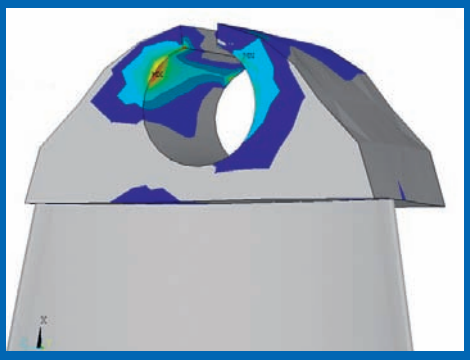

Figure 2: Stress concentration and distribution at the original design cover tips resulting in wire cracking.

Design Change Takes Care of Repeated Tie Wire Cracking on a 19 MW-Steam Turbine

Four failures and three previous modifications convinced the owner of this 19 MW-steam turbine, located at a waste power plant, that a radical design change, based on thorough analysis, was required to solve the recurrent problems and this was achieved by blade modification.

The actual order for the design change on the 19 MW-steam turbine was received by Sulzer Repco, who then formed a global team, together with Sulzer Hickham USA and Sulzer Elbar. Each partner has its specific expertize localized in a center of excellence and each contributed to the end result.

The engineers at Sulzer Hickham USA performed the analysis for the design change. The approach taken to prevent future failures was to first identify the type of failure in order to understand what design changes should be made. This was done by evaluating the harmonics and nodal shapes of the blade by finite element analysis.

The stresses occurring were computed, taking into account the specific operational conditions, such as speed, nozzle configuration and steam conditions. As shown in the interference diagram (Figure 1) the dominant failure mode found for the original shroud design is a resonant condition of the tangential mode with the nozzle passing frequency.

The stress distribution related to the dominant failure mode is given in Figure 2. The high stress distribution coincides with the observed failures. The best available solution identified for solving this problem was to join the shrouds together in packets.

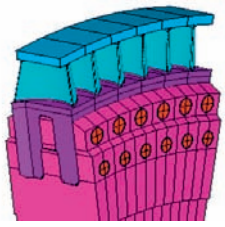

Figure 3: 3-dimensional model of the blade package.

The new design as shown in Figure 3 has reduced the stress load by more than 25% and, equally importantly, has increased the safety margin to the resonance frequency.

The extensive analysis shows that joining of the individual blades to packets results in improved dynamic behavior. Since the blade roots were already machined to final dimensions, the acceptable joining technique should of course not lead to unacceptable distortion. Furthermore, the mechanical strength should be as high as possible. Out of all available techniques, laser fusion welding was proved to be the most promising technique.

This is where the expertize of Sulzer Elbar came in. Acceptance testing of the welding procedure was carried out in house. This comprised a full metallurgical and mechanical assessment of the welds and heat treatments. Figure 4 shows the microstructure of the through weld after heat treatment.

Re-engineered blades.

To guarantee sound dimensions and minimize distortion, dedicated tooling was constructed together with Sulzer Repco. The outer shrouds of 6 blades were welded by laser welding as indicated in Figure 5. The depth of the through weld was 5 mm.

After welding, the parts were heat treated and inspected by crack inspections and X-ray. No defects were found.

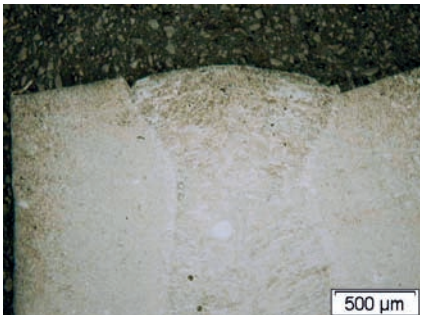

Figure 4: Microstructure of the through weld.

Figure 5: Blade packets after welding.

The final installation of the blade pacets with custom developed tooling was carried out by Sulzer Repco.

All analysis, processes and product developments were carried out in house and within a time period of seven weeks. Because of good coordination the total operation was completed concurrently with the blade manufacturing and contributed to the lowest possible intervention time.

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