

# Case Study

## Final Stage Blade Modification Extending Lifecycle

In early August 2007 Sulzer Hickham Indonesia was contracted by an international nickel production company located in South Sulawesi to perform a complete inspection and repair on their 28 MW steam turbine rotor. The unit was reported as having excessive vibration. Further field inspections found that one of last stage blades and the damping wire were broken. The customer requested Sulzer Hickham Indonesia to investigate the root cause of the failure and modify the blade to extend the lifecycle.

The last stage blade is a fir-tree free standing blade type with a 4 mm damping wire. The investigation started by collecting the historical information and continued with subsequent analyses:

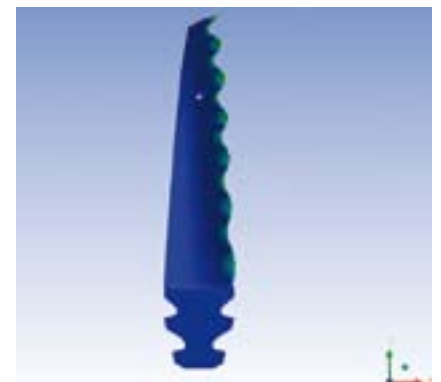
- Preliminary examination of the failed part
- Metallurgical analysis including chemical analysis, macroscopic and microscopic examination and fractography analysis
- Mechanical stress analysis
- Blade natural frequency testing and analysis

The chemical analysis result indicated that the blade material was X20CrMo13, and the damping wire material was identified as titanium Ti-6Al-4V. Fractography analysis deter-

mined two crack initiations located at the blade hole for damping wire and trailing edge. To support the evidences found on metallurgical analysis, stress analysis was then performed. This determined the stress level on the blade and damping wire due to centrifugal force. This analysis was conducted using finite element software. The blade was scanned and measured using portable CMM to define the blade profile prior to modeling in finite element program. The result indicated the maximum stress at airfoil at blade hole for damping wire area is beyond the yield strength of the blade material, and was consistent with the finding on the metallurgical examination.

The stress level on the damping wire was analyzed using line elements. A certain section of the wire was modeled and symmetrical constraints were applied to represent the actual condition of the wire. The analysis result showed that the damping wire has a safety factor of 1.25. This safety factor value is marginal and can lead

to failure. The damping wire strength may have been reduced by corrosion, galling, and erosion. This would lower the safety factor significantly.



Finite element analysis of the blade.

Modal analysis was also conducted to determine the natural frequencies of the blade. The blades natural frequencies were analyzed numerically by using finite element method. This model was also used for stress analysis. To verify the model and analysis result, the blade natural frequencies were tested using a frequency analyzer equipment. The blade frequency testing was done by clamping the blade at its root area. First testing was performed by analyzing the natural

frequency of the blade only, without damping wire. The effect of the damping wire to the blade was simulated on the second test. The result indicated that no significant difference in natural frequencies between the first (without damping wire) and second testing (with damping wire). This proves that damping wires would not alter the natural frequencies.

The result of both tests on the blades showed that there is no significant differences with the numerical analysis result by finite element method. This indicates that the natural frequencies obtained can be used for further analysis. The natural frequencies of the analysis was then plotted on Campbell diagrams, to identify significant resonance points. Campbell diagrams depicts turbine speed on the horizontal axis and frequency on the vertical axis. The natural frequencies and the frequencies of exciting forces were plotted. The coincidence of natural frequencies with the exciting forces is used as the definition of resonance. The data was next analyzed at blade pass frequency (BPF) and nozzle pass frequency (NPF). Some intersections were noted.

In order to know the mode shape

of the blade in the intersection frequencies, the post-processing of the numerical analysis at these frequencies were chosen. Based on the anal-

the natural frequencies from resonant as well as increasing the blade safety factor to counter indicated problem and eliminate all risks.

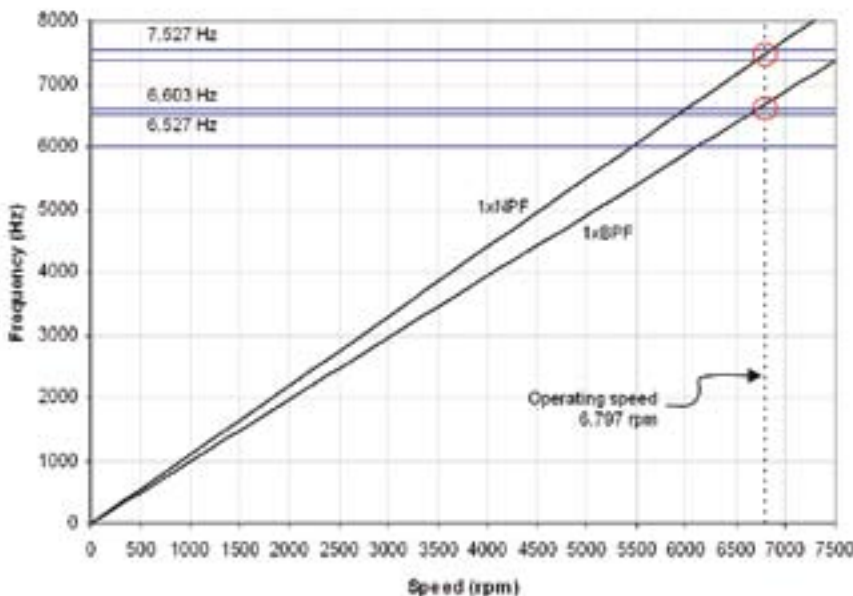


Incoming condition of the last stage blades.

yses results, it was concluded that the root cause of the failure was the low safety factor of the damping wire. Once the damping wire failed, the blades were no longer damped and the amplitude of resonance became high enough to start initiating the crack at the trailing edge. A proposal was made to enlarge the damping wire size and blade redesign to shift

The final redesign came to damping wire size enlargement and adding reinforcement at blade hole for damping wire. The finite element analysis of the modified blades and new size of damping wire were conducted to see how significant the stress level would be reduced. The analysis result indicated the stress level at blade air-foil at blade hole for damping wire decreases 38% and the new size of the damping wire had 34% of the stress level of the original one. The natural frequency analysis also indicated no significant change in natural frequencies.

The final design of modified blade was then forwarded to the blade manufacturer for blades production. The new blades were then moment weighed and installed in the unit. The unit is now running at full capacity without any problems.



Campbell Diagram.

Hepy Hanipa  
PT Sulzer Hickham Indonesia