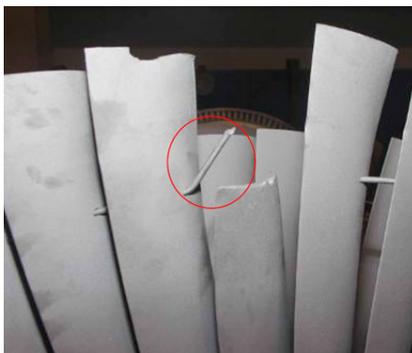


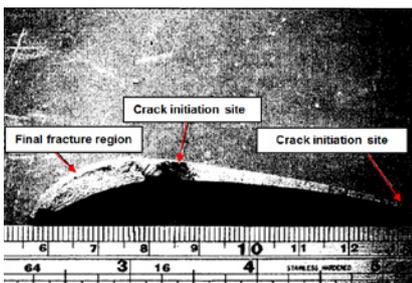
## CASE STUDY

# Lifetime Extension of Steam Turbine After Blade Failure

A 28 MW steam turbine owned by a mining company in South Sulawesi was experiencing excessive vibration. The company awarded Sulzer a contract to perform the complete inspection and repair. The field inspection revealed that one of last stage blades and the damping wire were broken. Most of the last stage blades were suffering from advanced corrosion and were covered by deposits.



Blade failure caused by vibratory fatigue



Metallurgical analysis

### The challenge

Since the turbine is the main power source for the mining operation, the loss of power availability became a critical element for the customer. It impacted the overall production of the mining operation and resulted in significant financial losses. Therefore, the repair had to be carried out under a very short time frame but the root cause had to be thoroughly analyzed first to find solutions that would prevent such a catastrophe in the future.

### The solution

Sulzer investigated several areas to find the problem and present a suitable solution.

### Blade failure causes

Blade failures on rotating equipment can result from various causes. Steam turbine blades are subject to many forces during their operational life cycle. The blade airfoils are fully exposed to high pressure, high temperature, and corrosive agents present in the steam path. Mechanical stresses during operation are other conditions that impact the service life. Based on these conditions, steam turbine blades must be manufactured based on good material selection and appropriate mechanical design.

### Metallurgical analysis to determine the primary cause of blade failure

A metallurgical analysis was performed to discover the root cause of the blade failure and prevent a recurrence. The metallurgical examination included material composition, fractography, and microstructure analysis. The material composition study provided the detailed specification of the existing blade material and served as the reference in selecting the new blade material with the same or better mechanical properties. Fractography and microstructure analysis helped engineers explain and reconstruct the failure process. It was an important element of the redesign process.

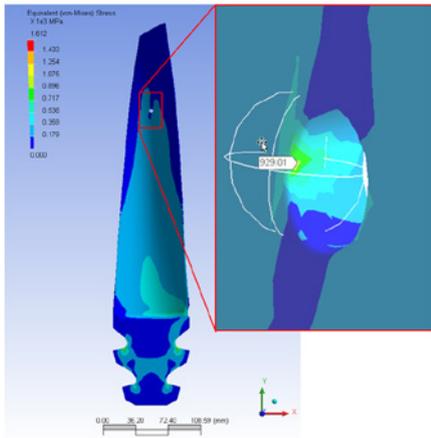
### Mechanical stress investigation

The stress analysis of the blades used finite element analysis (FEA) software. It provided information to determine the stress level on the blade due to centrifugal force. The vibration stress on the blade was also studied. The highest level of vibratory stress that a blade can nominally see in operation is that caused by the first tangential bending mode. This stress level was the reference data for the safety factor calculation.

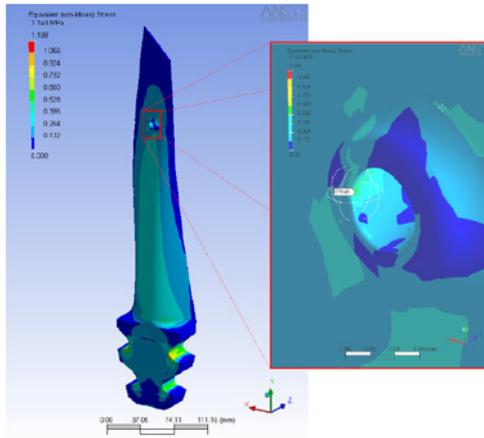
### The Sulzer difference

Sulzer can, with its many years of experience and excellent expertise, not only repair equipment but offer valuable benefits to its customers:

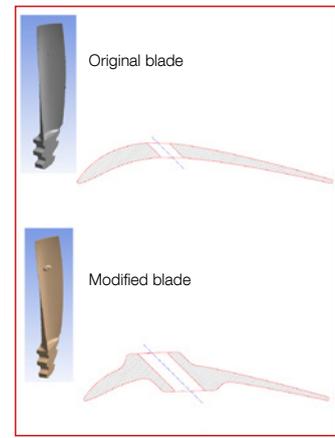
- Longer service life
- More reliability
- Higher safety factor
- Most-efficient solution
- Flexible and fast services



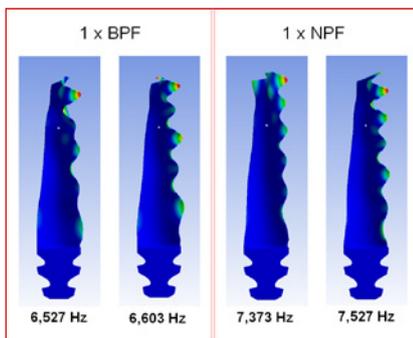
FEA on the blade



FEA of new, improved blades



New blades with improved design



Process to get proper performance

### Blade natural frequency analysis

Blade vibratory fatigue in turbomachinery is, by far, the most common form of blade failure. Although major advances have been made in blade vibration design technology, failures are still commonplace, especially when this technology is ignored. Blade vibration is one of the most complex problems to investigate in turbomachinery. Blades are primarily designed to meet aerodynamic performance goals. To achieve the proper performance, compromises must sometimes be made with regard to operation at resonance frequencies. It is impossible to design a blade that will operate without any resonance. What the designer must do is minimize the effects of the resonance encountered in operation. The data values of the analysis were then plotted on Campbell diagrams to identify significant resonance points. The natural frequencies and the frequencies of exciting forces are plotted. The coincidence of natural frequencies with the exciting forces is used as the definition of resonance.

### Customer benefit

Based on the above findings, investigation, and analysis, Sulzer concluded that blade resonance was the primary cause of the failure. Furthermore, Sulzer determined that high stress level because of centrifugal load with low safety factor at the blade hole for the damping wire as the secondary cause of the failure. Sulzer proposed several options to resolve these problems. The options then were converging to the two most efficient solutions. The solution was to increase the safety factor at the blade holes through blade modifications by adding the hole-reinforcement and increase the safety factor of the damping wire by increasing the size of the damping wire.

### Contact

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