Sulzer Turbo Services

Case Study

Design Changes Resulting in Lifetime Extension of Gas Turbine Rotor Blades

Sulzer Elbar was given the order to overhaul gas turbine engine sets of an European manufactured 165MW heavy duty gas turbine. The refurbishment included the repair all gas turbine blades, vanes and combustors. The parts had been operated in a base load operation, fired with oil containing sulphur.

An incoming inspection revealed that among others, the shrouded rotor blades had suffered from creep deflection. Based on the measured deflections, the blades, as shown in figure 1, exceeded the repair specifications and were therefore rejected for further operation.

Fig 1:Creep deflection of shrouded blades.

Due to a combination of the high centrifugal stresses and the operating temperature, creep deflection of the shroud and ballooning develops over time. At a particular degree of deformation, creep damage can no longer be recoverable by heat treatments; hot isostatic pressing or other methods.

Even though the creep damage could not be restored by conventional techniques, Sulzer Elbar engineering started discussions on what it might take to salvage the blades.

After many hours of discussions and brainstorming sessions, Sulzer Elbar developed a potential solution that was discussed with the client. The proposed solution was to remove the defective material (the entire shroud), add material to increase the tip length and modify the existing shroud.
(Fig. 2)

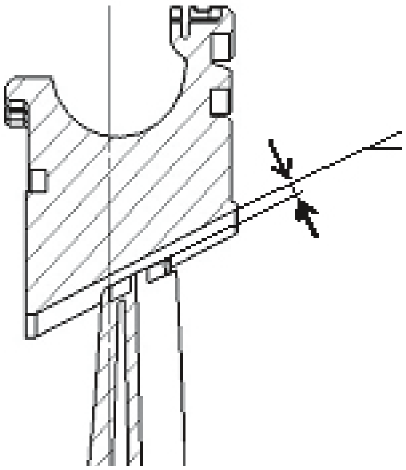

Fig 2: Blade design change from a shrouded to a squealer tip design.

After discussion with our customer, both parties agreed to initiate a project to examine the feasibility of the design. A dedicated engineering team was formed to validate the design. The main objectives were to investigate if the design change would result in a gas turbine efficiency loss or an increase of the operational risks.

FEM analysis was carried out to calculate the mechanical stresses and to simulate the dynamic behavior of the non shrouded design. The natural frequency of the blade should not interfere with the rotational speed.

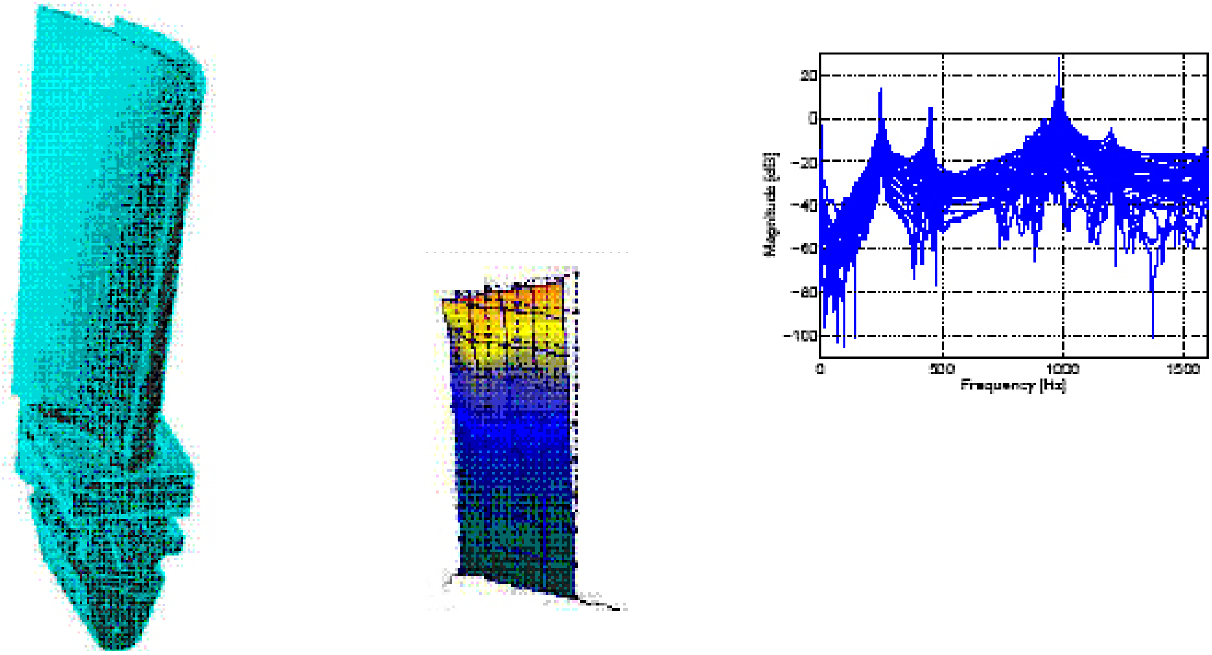

Fig 3: Dynamic analyses of the modified design.

The results of the FEM modelling were verified by experiments, including modal analyses. A good correlation was found between the calculated and measured natural frequencies (Fig. 3). Dynamic analyses of the calculations showed that the blades needed to be modified and trimmed to a particular frequency range. After modification all results of the conceptual design phase were discussed with the customer.

All parties agreed to proceed with the manufacturing phase of the blades and mating shroud blocks. Detailed manufacturing specifications and design details had been developed and agreed upon. For the modification of the blade several in-house technologies were used. The main step was the removal of the tip shroud by wire EDM, powder laser weld built up of the blade squeeler tip and autogeneous laser welding (joining) of the tip cap. For this particular application, all these techniques have been qualified. The quality was assured by X-ray and die penetrant inspections. The frequency of the blades was checked and parts were tuned to adhere to the set frequency specifications. An MCrAlY coating was applied to the blade surface to protect against hot corrosion.

Since the blade tip was changed from a shrouded to a squealer tip design, the mating shroud block also needed to be changed. A new shroud block had to be designed, interchangeable with the original design. The design and manufacturing specifications and qualifications were developed. Casting and machining of the new parts was carried out to Sulzer Elbar’s own specification.

Fig 4: Boroscope inspection after 3000 EOH.

Since the efficiency of the gas turbine is highly sensitive to the clearance between the blade tip and the shroud block, engineering examined potential abradable coatings that could withstand the corrosive environment. Furthermore, it was important that no smearing between the blade tip and heat shield could occur, resulting in built up of material at the shroud.

A ceramic coating was selected with a good hot corrosion resistance and low wetability. The “cold clearance” between blade tip and shroud block was specified to allow a limited contact between the blade tip and the shroud during first start up. Due to the physical properties of the ceramic coating (e.g. low wetability and high hardness), the ceramic coating would act as a grinding stone resulting in the smallest possible clearance.

All parts were manufactured within nine months after the design was approved. After successful installation in the gas turbine, parts operated efficiently. No change in gas turbine performance was noted.

A dedicated boroscope inspection programme was carried out to minimize operational risk as much as possible.

After a full operational cycle, the parts have been removed and will be available for refurbishment and operation. Since the life limiting section of the part has been removed (the shroud), at least another operational cycle is expected. This will result in an additional reduction of costs of ownership. Essential for this success was the cooperation between the end customer and the service provider. A transparent decision making process was the key. Evidently the in-house design and manufacturing knowledge and skills contributed to this result.

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