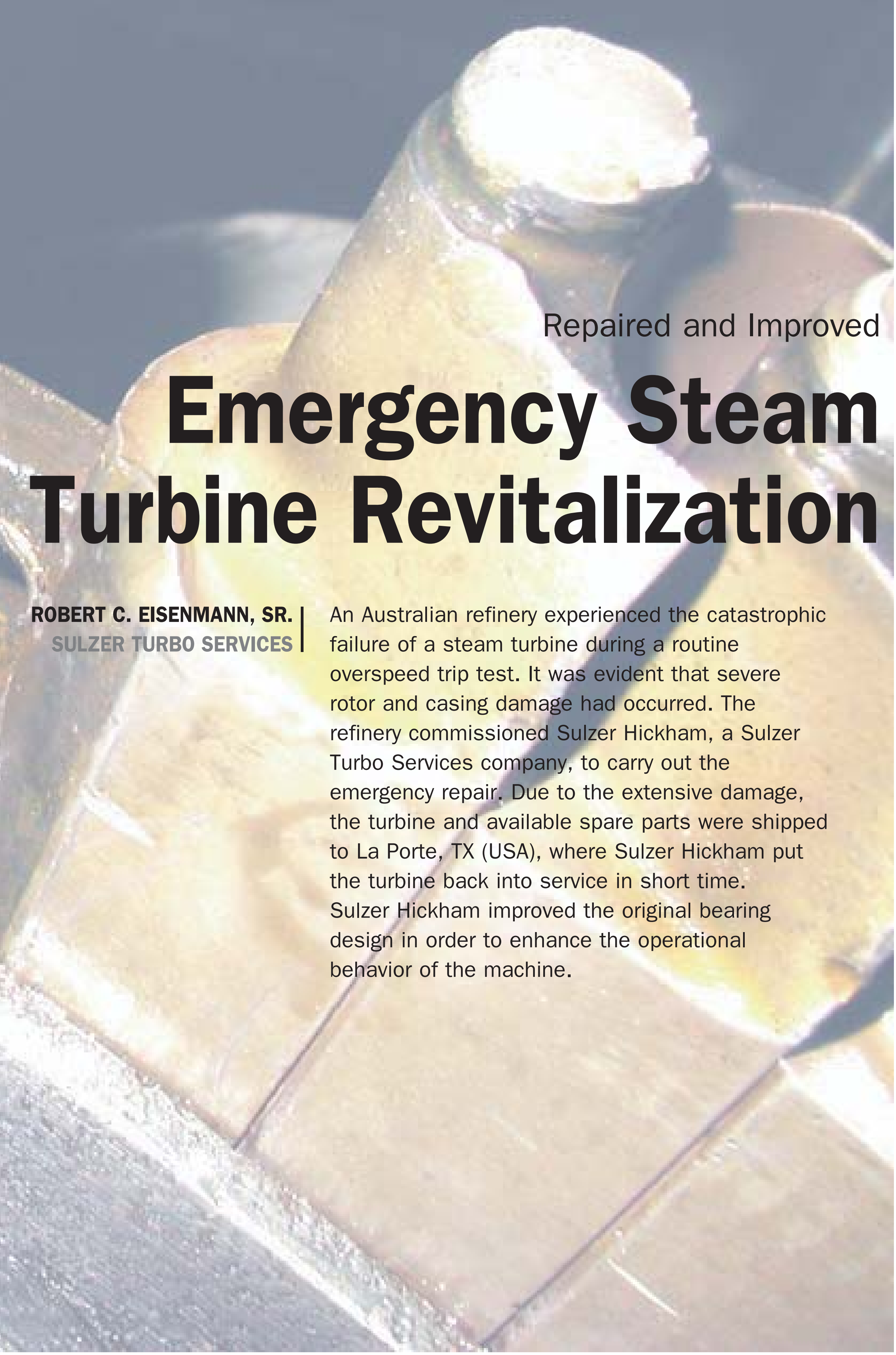


Repaired and Improved

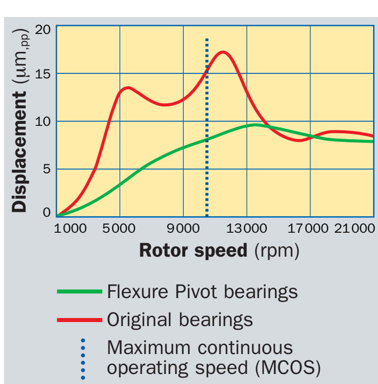
Emergency Steam Turbine Revitalization

ROBERT C. EISENMANN, SR.
SULZER TURBO SERVICES

An Australian refinery experienced the catastrophic failure of a steam turbine during a routine overspeed trip test. It was evident that severe rotor and casing damage had occurred. The refinery commissioned Sulzer Hickham, a Sulzer Turbo Services company, to carry out the emergency repair. Due to the extensive damage, the turbine and available spare parts were shipped to La Porte, TX (USA), where Sulzer Hickham put the turbine back into service in short time. Sulzer Hickham improved the original bearing design in order to enhance the operational behavior of the machine.

1 Steam turbine blade and shroud failure. Sulzer Turbo Services repaired this steam turbine from an Australian refinery in just 10 days.

This high-pressure turbine has a maximum continuous operating speed (MCOS) of 10,450 rpm and a desired over-speed trip point of 11,400 rpm. During a maintenance shutdown, the spare turbine rotor was installed. Following reassembly, the uncoupled turbine was ramped up to 10,000 rpm with no evidence of distress. According to established procedures, the governor was overridden mechanically to reach overspeed. During this operation, speed increased rapidly from 10,000 rpm to 15,400 rpm, and the turbine emitted a loud bang. The unit was shut down and disassembled for mechanical inspection, which revealed serious damage to casing, rotor, and blades (Fig. 1).



2 The calculated rotor response of original and Flexure Pivot™ bearings shows reduced displacement with the new bearings.

Flexure Pivot™ is patented by KMC, and licensed by Bearings Plus Inc. Houston, TX

Analysis of Rotor Dynamics

This turbine has a history of vibration problems. For the past 20 years, a tuned mass damper had been attached to the exhaust bearing housing to maintain peak-to-peak shaft vibration amplitudes between 50 and 75 $\mu m_{,pp}$ (2.0 and 3.0 $mil_{,pp}$, 1 mil = 0.001 inch). Visual inspection revealed pressure dams in the top halves of both bearings, and the bottom bearing halves were purposely relieved of Babbitt. Obviously, the machine was susceptible to some type of instability, and the sleeve bearings had been modified to address this problem. Because of this observation, Sulzer Hickham developed an analytical rotor model and carried out a rotor dynamic analysis (RDA), which showed that it was necessary to modify the journal bearings.

The turbine was originally equipped with liner-type sleeve bearings, which are suitable for lower-speed machines, but which lack the rigidity and dimensional stability necessary for high-speed turbomachinery. The RDA revealed a marginal design of the original sleeve bearings. The first critical speed was calculated to be 5500 rpm, which is very close to one-half of operating speed. The second critical speed was calculated to be 11,500 rpm, which is only 10% above MCOS. Any degradation in bearing stiffness would move the second critical down into the operating-speed range (Fig. 2). The RDA clearly identified a 4-pad, tilting-pad bearing as the best bearing configuration. The size of the turbine bearing housings, however, did not allow for the installation of a traditional tilting-pad bearing with rocker arms. It was therefore necessary to minimize the bearing outer diameter, which led to the choice of the Flexure Pivot™ design (Fig. 3).

Improved Bearing Design

The Flexure Pivot bearing is a one-piece construction without any potential for assembly errors, wearing of parts, or flutter of unloaded pads. This configuration effectively suppressed the first critical speed response and increased the second critical to 13,500 rpm (29% separation margin). Synchronous vibration amplitudes were reduced, and stability was improved considerably. In addition, bearing loads at operating speed were reduced by 48% compared with the original bearings. Overall, the Flexure Pivot bearings provided a major improvement to the response of this 50-year-old turbine rotor.

Further examination of rotor behavior and potential bearing housing response was conducted by using the Flexure Pivot bearings. Within the parameters examined, there was no further justification for keeping the 20-year-old tuned mass damper. Sulzer Hickham recommended removing this mechanical device from the exhaust-end bearing housing.

Mechanical Repairs

Because the failed rotor had sustained severe blade and shroud damage, using the previously operating rotor was the only short-term solution. The journals in this rotor were coated with tungsten carbide and ground to size. The shaft coupling fit and both seal areas were coated with Inconel 718 and then ground to size. The rotor was balanced, and the shaft sur-

3 The Flexure Pivot journal bearing provides a zero-tolerance for the bearing assembly stack-up dimensions due to its tight machining tolerances.

faces were burnished for new proximity probes. In addition, Sulzer Enpro repaired the oil relay governor and servo, and an improved overspeed trip mechanism was installed.

Instrumentation Upgrades

Besides the obvious mechanical repairs, the customer requested a fully engineered suite of 10 proximity probes. The set included dual thrust probes, X–Y probes at each journal, a keyphasor, and a slotted wheel observed by 3 speed-sensing probes for triple-redundant overspeed measurement capability.

This installation proved to be a challenge due to the limited space available at both ends of the turbine. The X–Y radial probes at the exhaust bearing housing were mounted with only minor modifications to the turbine. The governor-end probes, however, required the manufacture of an instrument hub to accommodate the dual thrust probes, the 3 timing probes, and the once-per-turn keyphasor (Fig. 4). Now, all transducer signal cables are terminated outside of the governor casing, and all coaxial cables are sealed appropriately (Fig. 5).

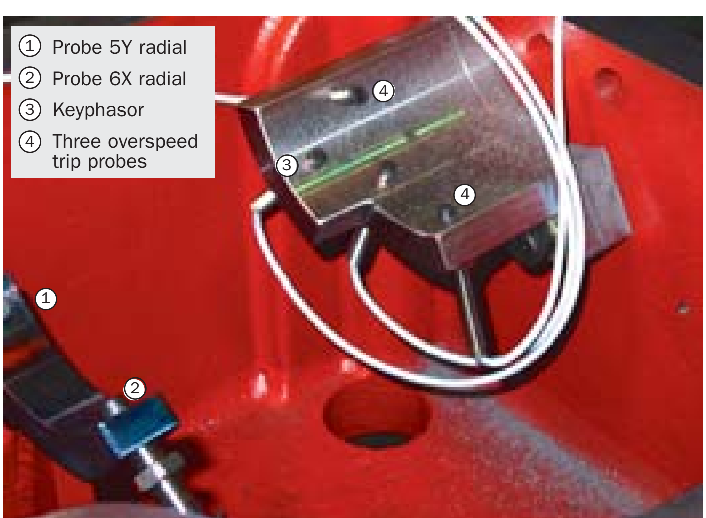
Successful Startup

The complete package of mechanical repairs, rotor-dynamic analysis, and bearing optimization, followed by bearing mechanical design and manufacturing, fully engineered installation of 10 proximity probes, plus governor overhaul, reassembly, and final shipment was accomplished in 10 calendar days. Field installation and startup were very successful, with shaft vibration amplitudes of less than 20 $\mu m_{,pp}$ (0.8 $Mil_{,pp}$) at all locations. Due to the mechanical upgrades to this turbine, service life will be extended significantly and long-term maintenance costs will be reduced. To minimize future downtime, Sulzer is currently manufacturing a complete spare rotor assembly for this turbine. Overall, the personnel at the Australian refinery was exceptionally pleased with this work by Sulzer Turbo Services. ◀

Contact

Sulzer Hickham Inc.
Robert. C. Eisenmann, Sr.
11518 Old La Porte Road
La Porte, TX 77571
USA
Phone +1 713 567 27 91
Fax +1 713 567 28 44
bob.eisenmann@sulzer.com

4 The radial vibration probes at the governor end are mounted in a special bracket designed and manufactured by Sulzer Hickham.



5 In the governor housing, proper spacing is maintained between probes to eliminate any potential of cross talk.