

After Catastrophic Failure

Revival of a 50-MW Steam Turbine

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Following a severe steam turbine failure, Sulzer Hickham (a subsidiary of Sulzer Turbomachinery Services) provided a cost-effective rebuilt of the turbine rotor and internals. Various elements were redesigned and upgraded during this repair, and start-up assistance was provided. The unit was rebuilt and restarted in record time, and the end user was fully satisfied.

▶ In late 2000, Sulzer Hickham received an order to repair a 1943-vintage, 50-MW steam turbine (Fig. 1). Its configuration consists of a 20-stage, tandem compound double-flow machine with inlet conditions of 60 bar (850 psi) at 500°C (900°F), exhausting to a surface condenser.

A Hopeless Case?

This was the third catastrophic thrust bearing failure since the high-pressure (HP) rotor was renewed in the mid-1980s. The latest failure resulted in severe damage to the rotor and diaphragms. The OEM had declined to repair the HP rotor, and they recommended that the rotor be replaced. In fact,

serious consideration had been given by the end user's upper management to dispose of this machinery train. This potential action was predicated on the unreliable operating history of this unit, the high OEM repair costs, and excessive maintenance costs required to keep the unit running. A final evaluation of the economics of the situation dictated that reviving the machine would be cost-effective if sufficient actions could be implemented that would prevent such failures in the future.

Comprehensive Repair

Sulzer Hickham's engineering personnel inspected the machine and its components, and developed an

all-encompassing repair plan that included root cause failure analysis, a rotor dynamics study, reliability upgrades, and "Hickham-At-Speed" (HAS) balancing in a three-bearing configuration at full speed of 3600 rpm. To prevent future catastrophic failures, a state-of-the-art machinery protection scheme was devised. The end results of these studies included the design and installation of an upgraded thrust and number-one journal bearing, the installation of an improved lube oil filtration system, an electronic governor control system, and a complete Bentley Nevada 3500 series machinery protection system per API 670 (a standard of the American Petroleum Institute). Operating procedures were also developed for the machine and were issued to the end user.

Field service work was performed by Sulzer Hickham to repair the oil

circulating pumps, correct leaks on the main stop valve, and perform various activities to flush and clean up the oil system. The generator bearings were replaced, and new hydrogen seals were installed. In addition, the turbine control valve assembly and camshafts were properly assembled with new bearings. The valve linkages were connected to the main servo, and all valves were fully stroked and tested.

The major turbine repairs were performed on an expedited basis at the Sulzer Hickham shops in La Porte, Texas, USA. This included the welding restoration of four integral turbine disks, the integral thrust collar on the HP rotor, and the replacement of 18 rows of turbine blades and shroud bands. Two of the large, cast iron, low-pressure (LP) diaphragms, which had been condemned during the bid phase by competing shops,

were restored using mechanical inserts designed by Sulzer Hickham. Two HP diaphragms also required inserting, and all remaining diaphragms required significant dressing and/or weld repairs due to rotor rubs.

Vibrations Reduced

During the initial design and historical reviews, Sulzer Hickham learned that a period of almost four years was required by the OEM to get the machine to run when the HP rotor was renewed in the mid-1980s. The reasons for this were not fully appreciated until the start-up attempts in early July 2001. During this start-up, Sulzer Hickham's technical services personnel were on site to monitor and record the vibration, axial position, differential expansion and case expansion transducer signals, along with bearing babbitt temperatures. From that data, it became obvious that the HP rotor was very temperature-sensitive. Variations in the inlet steam conditions would often result in excessive deflection of the HP turbine shaft. In fact, changes in parameters such as turbine growth rate, front standard elevation, exhaust vacuum, or generator load would significantly alter the rotor vibration response.

Special Damper Bearing

In addition, at operating speed, the machine was very close to a critical speed. To further complicate the issue, the surface condenser was rigidly attached to the turbine and was located beneath the number-two bearing, which was inside the LP exhaust hood and surrounded by exhaust steam. This caused the number-two bearing

1 After having experienced three serious bearing failures, this 50-MW steam turbine has been repaired by Sulzer Hickham.



elevation (and consequent bearing loads) to vary during start-up due to temperature transients. The HP standard is supported by a 100 cm (40") tall flex-leg and is subject to radiant heat from the casing, so it also resulted in elevation variances at the number-one bearing. The elevation changes of the number-one and -two bearings dramatically affected the vibratory response of the HP rotor. Because of the combination of these factors, initial attempts to counter the shaft deflection with field balance weights were unsuccessful.

In an effort to improve the linearity of the rotor response, and therefore permit field balancing, a new Squeeze Film Damper bearing for the HP front standard was designed and supplied by Bearings Plus, Inc., on an expedited basis. Figure 2 outlines the configuration of this patented SFD bearing assembly. In operation, the scroll sections are filled with lube oil, and this provides additional flexibility and damping to the number-one bearing.



3 The rebuilt turbine has been running satisfactorily since August 2001.

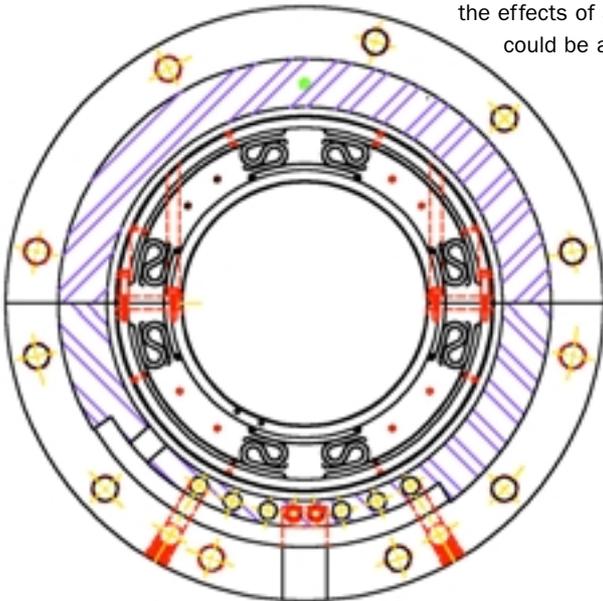
Customer Fully Satisfied

The new bearing functioned as expected, and permitted the shaft deflection problem to be brought under control with balance weights. The machine was put online at full load in mid-August 2001 and has run satisfactorily ever since (Fig. 3). During this time period, several nuisance trips have occurred, and in every case, the unit was successfully restarted. The plant operating personnel, some

with over 20 years experience on this machine, commented that the turbine had never run so smoothly.

The combination of the latest technology and experienced Sulzer Hickham personnel allowed the start-up phase of the machine to be reduced to a small fraction of that required in the mid-1980s, and resulted in a reliable long-term source of power generation for the plant. ◀

2 By the use of a special damper bearing, the effects of a critical speed could be alleviated.



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