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When rotating equipment can rub you wrong

You have just started your new job as senior rotating equipment reliability engineer at a major production facility that involves rotating equipment. You have just joined the morning meeting on your first day and all you hear about is that the TE-101 is up and running, and everyone is hopeful that this time it will run the planned three years without an unscheduled outage. Without wanting to sound too ignorant, you whisper to the engineer next to you and ask what this is all about, and he tells you it involves a turboexpander used in the process of a major ethylene production facility. The turboexpander is used in a product purification unit that is essential to plant operation. When this unit goes down, the plant goes down. The next Sunday morning the unit goes down, and you get your first emergency call out to the plant. Upon reaching the plant you find that TE-101 has wrecked again, and the spare from the previous wreck is in the shop.

While on site you start collecting and reviewing history. There are several key points that you observe right away. Before the failure, process conditions change, causing a different load condition in the turboexpander. The original equipment manufacturer reviewed this data as well and concluded there should be no problems since the unit was operating well within the design limits. Previous rotordynamics work indicated a small imbalance, but that was to be expected with the machine loading and unloading. In every case there was no warning of the pending failure. This would eliminate aerodynamic excitation, build up of the impeller or degradation of the impeller. Bearing temperatures would remain within normal limits and would not exhibit any issues of concern. The impeller was investigated, and there was no evidence of foreign particle damage or liquid carryover.

The cause of the failure was due to a rub that occurred between the impeller and the shroud. Clearances are tight in the turboexpander to obtain desired efficiencies and performance. As the impeller spins at normally very high rpm, the clearances are tighter due to the centrifugal load. During a process change it is possible for the temperatures to vary several hundred degrees. Due to the thermal lag between the housing and the impeller, it is possible for clearances to close up and lead to a failure.

An approach to avoid these failures and make sure the equipment functions properly across all operating ranges is as follows:

1. Perform a process analysis of the unit concerning all steady state and transient conditions of the turboexpander.
2. Utilize computational fluid dynamics to model the impeller to look at local temperatures and determine the possibility of any liquid formation.
3. Based on design clearances, perform a finite element heat transfer analysis of the turboexpander to evaluate the clearances. The model should consider the "spin up" conditions to obtain the final location and configuration of the impeller. The analysis would have to be a transient heat transfer analysis to include the thermal lag in the system.
4. It is important that the turboexpander handle all the fluid states that come from the process. In some cases there may be ice formation or dust particles that can cause issues if not considered in the design.
5. The rotordynamics of the system are important, with rotor stiffness a major consideration. The rotor should also be designed to handle some imbalance due to solids buildup. Remarkable thrust conditions must also be handled by a robust design.
6. A good seal design appropriate for the application must be considered. Make sure the materials are compatible to handle temperature transients as discussed in this article.
7. Develop and incorporate the necessary instrumentation to address the reliability issues of the machine.

Turboexpanders are basic in design and are not that complex in structure. However, like many pieces of rotating equipment, the details of both process and mechanical design are what affects a successful outcome in operation. A qualified professional engineer competent in rotating equipment should be involved with troubleshooting and implementation of any fix of this equipment.

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