Transient Loadings – They may be the Peak Loadings!

If you are experiencing problems in a process, it could be the result of detrimental transient forcing function. Often in a process, data is taken and averaged over a matter of minutes or even hours, which renders such cause undetectable. You may need to capture the field data on a millisecond basis to help a qualified team determine the root cause.

Designing static and rotating equipment often begins with a specifications sheet that lists the performance expectations and requirements. However, startup or shutdown requirements are rarely listed. For static equipment, this could include heat up rates or sequencing of process feeds to the equipment. For rotating equipment, ramping conditions through critical speeds may have been omitted. Many times, during the startup of a plant, opportunities for relatively high transient loadings are present. Let's discuss a few examples to "hone in" on some design considerations.

First, let's consider the heat up rate of thick-walled reactors and heat exchangers. When these components heat up, localized thermal gradients produce stresses. If the firing rate of the equipment is too quick, the thermal gradient induced can cause detrimental stress to the vessel. You may wonder how this can happen if the peak temperature is not reached. The key is the transient heat transfer. The firing rate will be dependent on the process fluid conditions, geometry, and materials. Frequently, the surface on the "hot side" will heat up quickly and the outer surfaces will remain colder due to thermal lag. As a result, the transient thermal gradient can be higher than steady state.

Next, let's take the startup of rotating equipment. When bringing a system on line, a compressor or turbine is commonly "false loaded," during which time performance issues may exist that can affect the equipment. For example, dynamic stresses during startup can be higher than normal. Also, for compressors, transient loads may exist resulting in the loss of cooling on intercoolers. Sometimes, the process fluid properties change during startup due to yield achieved, which can also lead to response changes in the equipment. In addition, polymer equipment often has polymer-lubricated bearings that interact with heat, speed, and differential pressure which can affect the bearing performance.

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Most of the startup issues discussed are not analyzed during the process and detailed design phase of the plant. In the past, many of these situations were too difficult to analyze, so trial and error, as well as experience, were used to determine startup procedures. This is no longer the case for many applications. Whereas, in the past, transient process and mechanical analysis were very rare, they are now conducted on a regular basis. The advent of faster computers, better numerical methods, and economical solution methodologies have made this possible.

Given the above, below are some recommended solution methodologies:

Startup analysis of static equipment methodology:

1. Develop a finite element (FE) model of the equipment;
2. Calculate the transient heat transfer film coefficients (film coefficient versus time);
3. Perform a transient heat transfer FE analysis;
4. Perform a transient stress FE analysis.

Simulation of intercooler failure for a compressor methodology:

1. Set up parameters of compressor performance model;
2. Evaluate the transient heat transfer in the intercooler;
3. Forward step the compressor performance model in time simulating the loss of cooling.

Remember the peak stresses are not always the steady state stresses. Don't let it "bite" you. New methodologies and tools can tell you what you need to know to operate your equipment safely and reliably.

Cliff's Notes:

KnightHawk is frequently contracted to perform root cause failure analysis in cases with limited data when the root cause is incredibly difficult, and seemingly impossible, to determine. To do this work, KnightHawk typically performs a Phase 1 engineering assessment. Phase 1 is generally a lump sum cost. Phase 2 contains the detailed work required to determine the root cause. KnightHawk has perfected a root cause methodology involving multidiscipline analysis. To complement our process and further serve you, we also have a metallurgical and materials lab which can inspect any failed parts to aid in characterizing the failure. In addition, we have a field services group to assess vibration, dynamic pressure, flow and acoustics. We are truly your "One Stop Shop" for all your Engineering Solutions needs.

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