BULLETIN

Carrier Corporation

Carrier
A United Technologies Company

North American Operations

Number: C9922 Date: 11/22/99 Supersedes: N/A Date:
Title: 19XL AND 19XR IMPELLER BLADE BREAKAGE
Category: *GENERAL* Termination Date:
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Models Affected: CAC: 19XL, 19XR centrifugal chillers
BDP:

We have been made aware that a very small number of centrifugal compressor machines operating in R134a have had failures of the impeller. The specific failure mode seen is that the tip of one or more of the impeller blades break off. This bulletin will summarize what we have determined about the root cause of the problem and its solution.

Symptoms

The impeller will become considerably more noisy in normal operation. Lift characteristics may change, which can lead to surging conditions under conditions in which machine operation should be normal based on a comparison to the selection program. In a severe case, unbalance in the impeller leads to bearing damage, with associated symptoms.

When the impeller is removed from the machine promptly, only one or a small number of impeller blades will be damaged (figure 1). Once a single blade separates, the blade will bounce around inside the compressor causing secondary damage, which are typically dents to the neighboring blades. This secondary damage often masks the actual blade which first broke, requiring detailed lab analysis to find the root cause. It will not be possible to determine the root cause mechanism in the field on these failed impellers, they must be returned to CSS Service Engineering for analysis..

Root Cause

Blade breakage occurs when the blade material is not strong enough to survive the forces placed on it. Analysis of the crack surfaces of failed blades by the Carrier materials laboratory indicates that the failure mechanism is from a single load event, or a small number of load events. The forces in question are pressure forces on the blade. The origin of these forces is in a phenomenon called rotating stall, often called mini-surge, the background of which is discussed below. Rotating stall requires job site conditions in which relatively high lift conditions predominate, but surge is not present. The pressure forces work on the blades and body of the centrifugal impeller. In some cases, it appears that the blade has hit the shroud, the force of which causes the blade to snap backwards and break off. In other cases, the pressure forces may work directly on the blade to snap it off.

Mail Keys: 2.33A, 2.33B, 2.33D, 2.40, 2.40A, 2.40B, 2.40D, 2.40M, 2.46A, 5.25G

In summary, the main factors influencing the failure mode are: design strength of the individual impeller blades, job site conditions leading to rotating stall, and the material properties of the blades.

Rotating Stall

In full surge, the entire flow through the compressor will reverse direction. This violent motion leads to large vibrations and large swing of amps. In practice, looking at the PIC screen or with an amp meter, large variation (>30%) in amps is seen. Our controls attempt to keep the compressor from operating in surge, and shut down the machine so that it won't operate in surge for additional periods.

In contrast, rotating stall is a phenomenon in which only a small number of the centrifugal compressor passages have reversed flow. One might visualize this as a bubble of reversed flow through which the compressor is rotating. In practice, this bubble rotates around the impeller and interacts with it, so that pressure traces show oscillations between approximately 5 and 30 hz, when the impeller is operating at 15,000 rpm (250 hz). Measurements with an amp meter or evaluation of the amp load with the PIC will not reveal significant fluctuations (<10%). The sound of the machine will not be smooth, but will not have the low frequency noises and severe vibrations associated with surge. Centrifugal compressors are designed to operate in rotating stall without damage.

Population Effected

By correlating the design strength of the blades with the observed field population of failed impellers, the conclusion was drawn that the impeller breakage phenomenon is almost completely confined to the following sizes:

19XL - impellers with the size code 49*, where "*" represents a number 1-9
19XR - impellers with the size code 38*, and 20*, where "*" represents a number 1-9

Factory Preventive Action

While individual impeller breakage cases might be correlated with inferior material properties, the preventative action was planned with the desire to have the machine capable of operation in rotating stall for an indefinite period of time. Since the impeller blade looks like a cantilever beam in side view, the important strength property of such a beam is the blade length to width ratio (see figure 2). The design change which was made was to thicken the blades of certain impeller sizes so that the blade length to width ratio was smaller than a number determined empirically to have survived in 19XL and 19XR applications. These impellers are commonly referred to as "thick bladed" impellers, even though it is not the absolute thickness which is important. The factory has been using 19XL thick bladed impellers since 9/97, the 19XR3 has been using thick bladed impellers since 1/99, and the 19XR2 impellers are currently in the process of changing to thick bladed designs with implementation scheduled for 1Q/00.

Corrective Action

In the field, if a failure occurs, replace the impeller blade with a thick bladed design. Inspect the diffuser and bearings and replace as necessary. Check a new version of the selection program before replacement to make sure that the thick bladed impeller design can perform the duty required as small changes in performance were noted upon the redesign. Contact Service Engineering for any required support.

Job site conditions impact the susceptibility of the compressor to the problem. Most job sites do not have the conditions required for rotating stall and thus the impeller will never break. Supporting this statement is the observation that very few machines fail which have survived a season of operation. Thus, it is not recommended that impellers on job sites without a failed impeller be replaced.

For job sites that have had an impeller failure of this kind, it is known that job site conditions exist which can promote this failure mechanism. Contact service engineering for specific recommendations about the failed machine and any other machines at a job site. For machines that might be effected by this failure mechanism, which are on the same loop as a failed machine, proactive action may be recommended.

Figure 1 - picture of an impeller with a small number of broken blades
Figure 1A - impeller with broken blade
Figure 2 - side view of the impeller showing the length to width ratio

Figure 1 - picture of an impeller with a small number of broken blades

Figure 1A

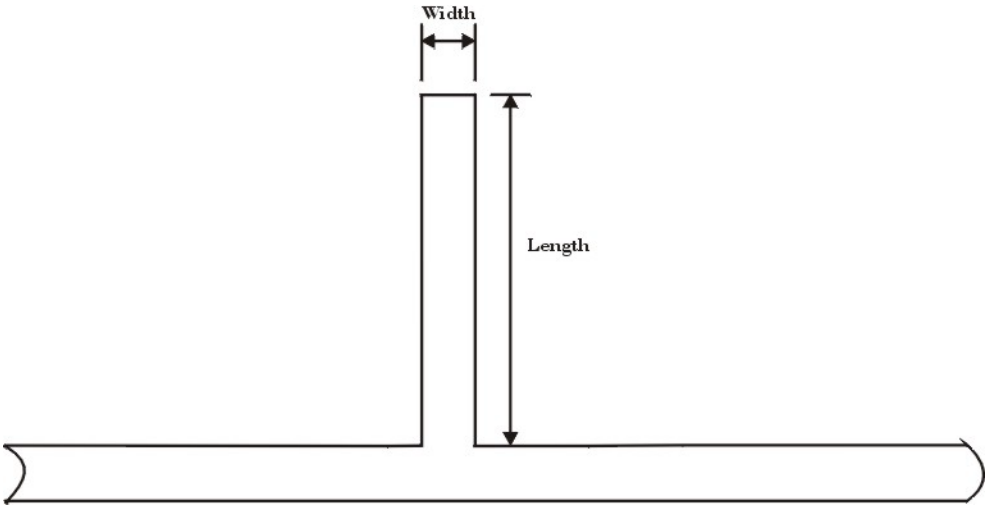

Figure 2: Side view of the impeller showing the length to width ratio. Other blades and details of the impeller toward the hub have been removed.