Bulletin Board

January 9 –11, 2007 Key West Florida

United Dynamics "AT" Corporation

Presents the

12th Annual

All Users Conference

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David N French Metallurgists are pleased to announce the addition to our staff of Dr. David Crowe, Chief Metallurgical Engineer. Dave brings to our team over 20 years of experience. At the recent TAPPI conference, he was presented with the Dennis M Anliker Award, in recognition for enduring and outstanding contributions to the Corrosion & Materials Engineering Committee.

Congratulations, Dave!

David N. French Metallurgists offers a variety of services to complement your maintenance program. For example, Life Assessments provide a tool to plan and implement required repairs and replacements that will reduce forced outages. The DNFM metallurgists and lab personnel combine over 75 years of industry experience to provide thorough and concise life assessment reports. Please call with inquiries or for a quote.

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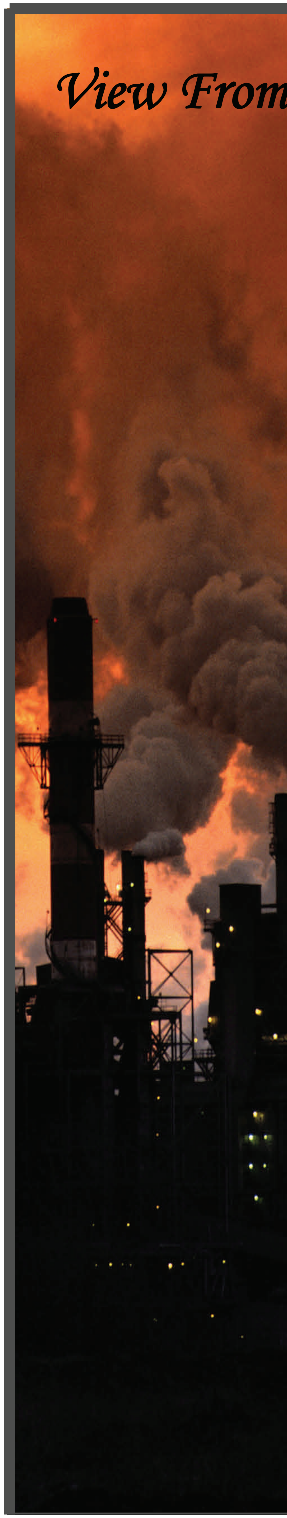

View From the Penthouse

2006

Fourth Quarter

Creep Fatigue

Usually we associate creep with exposure of a metal component at elevated temperatures while experiencing a constant stress, but a cyclic stress can also drive creep, and we refer to this as creep fatigue. Increasingly, older generating plants are being used to top the demand cycle, and these units experience creep fatigue.

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View From The Penthouse

The DNFM Quarterly Newsletter

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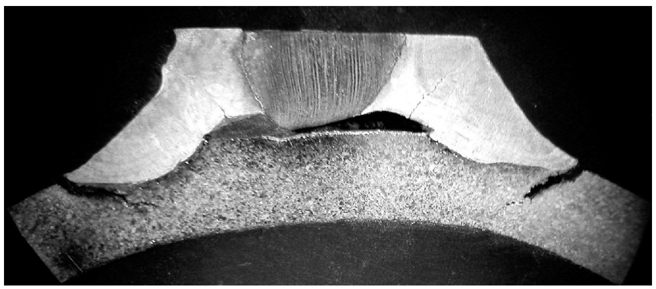
Dr. David N. French

Dr. David C. Crowe

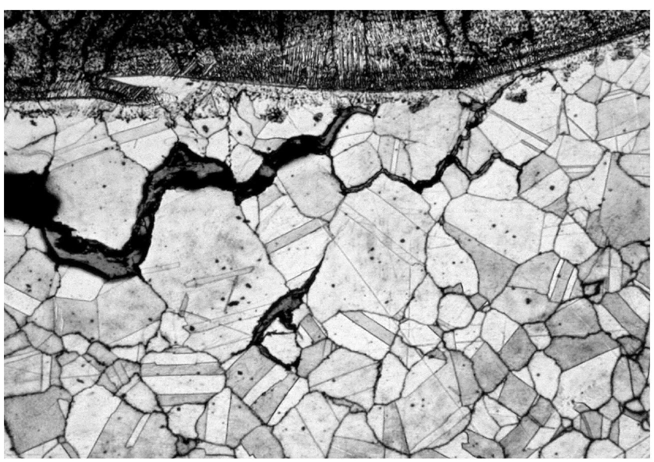
Creep Fatigue

Creep Fatigue at a Lug Attachment

A creep failure was found at an attachment in a reheater with type 304 stainless steel tubes which had been cycled to an operating temperature of 1000 ^{o}F some 800 times over a period of 16 years. The picture below shows the cross-section at the weld to the Inconel 600 attachment. The weld composition matched as-deposited analyses for Inconel 182. There was cracking at the toe of the attachment weld, and it had propagated through the tube causing the failure. The cracking had initiated at the end of the attachment where stresses would be highest. There was also cracking of the weld outward from the unwelded area beneath the attachment.



The cracking of the tube adjacent to the weld is illustrated in the view below. This intergranular cracking is characteristic of creep. Separated grain boundaries can be seen in addition to the main cracks. The cracking was not confined to the heat affected zone of the weld. When heated, this stainless steel tube would have expanded more than adjacent carbon steel tubes because stainless steel has a higher coefficient of thermal expansion than carbon steel. Stresses between these carbon and stainless tubes would be transferred by the ties and attachments. In the example, the attachment was nickel-base Alloy 600, a good choice to resist high temperature oxidation. Its coefficient of thermal expansion is closer to that of carbon steel than to stainless steel, so stresses will be induced at the weld when the attachment is heated. The Alloy 600 weld is stronger than the tube material, so strains at the junction with the stainless steel are shared unequally, with the stainless steel yielding before the Alloy 600. The cracking initiated at the end of the attachment where the weld was not carefully wrapped around the attachment, resulting in a notch at the toe of the weld, presenting a stress riser.



Drivers

Failures of tubes at attachments can involve a number of factors. Temperatures are high in service, especially at the attachments because, compared to the tube wall, the attachments are further from the heat sink (the steam or water inside the tube). In the example, temperatures of the attachment may have been elevated because there was a lack of penetration at the base of the attachment, so it would not be cooled as well as it would have if it had been in full contact with the tube. Additionally, as temperatures increase, the strength of the tube or attachment material decreases.

Stresses can be high depending on the restraint required, the design of the attachment and its condition. A worn or poorly made attachment can have stress concentration points at the weld termination or at other imperfections. This was a factor in initiating cracking in the example lug attachment. During start-up, stresses can be especially high as components heat up, not necessarily all at the same rate, producing a transient thermal gradient. And when a unit experiences many cycles in its life, these stresses present a low cycle fatigue on the attachment and the tube.

Another effect involves the thermal gradient in a tube when heated. The surface will heat faster than the core of the component, putting the surface into compression. When the core reaches operating temperature, the surface will then be in tension, and this could add to other operating stresses to drive fatigue or creep.

Carbon steel and stainless steel have significantly different coefficients of thermal expansion, so stainless steel will expand (and contract) at a greater rate for a given temperature change, producing a tug-of-war with any carbon steel component to which it is tied.

Oxide formation may be a factor where welds are incomplete, allowing the environment to enter and form oxide underneath an attachment. The volume of oxide is greater than the metal it replaces, and that volume of oxide 'jacks' the attachment away from the surface. Oxide can be seen in the photo, between the tube and attachment, and this could have influenced the failure.

Creep and Remaining Life

The amount of creep fatigue damage is dependent on the frequency of the stress and thermal cycling, magnitude of the transient loss and temperatures, and the properties of the material. In attempting to evaluate the combined effects of creep and fatigue on component life, researchers have developed rules for adding damages of these separate processes together, for use in design. At high cycle frequency, fatigue is most important, but at lower cycle frequency and withhold times when stressed, creep becomes more important. The condition of the material can also have an impact: initially some creep softens the material, thereby improving the fatigue life. But if creep has progressed to the point where cavitation has occurred, then the voids in the material will reduce the fatigue life.

The damage summation method is the simplest method for estimating creep fatigue life. In this method, Robinson creep damage is added to Miner fatigue damage values. In some cases, this approach is too conservative, but in some cases it may overestimate the remaining life. Other more complex approaches provide increasingly accurate evaluations. Practically speaking, any of these methods are difficult to apply after the fact, where the thermal and stress history of a component is based on corporate memory and someone's best guess. Metallographic examination of representative components provides a very good way to check the condition of tubes to look for creep fatigue damage. Non-destructive testing may be used to detect cracking after initiation.

Ways to Minimize this Problem

Good attachment design is vital to minimize stresses. Slip type attachments may be used to accommodate differential thermal expansion. Terminations of attachments should taper to the surface to reduce the localized stress concentrations at the termination.

Lack of penetration in attachment welds can result in them running hot, or increase stress concentrations. Good weld design and adherence to welding procedures are essential.

Weld metal should be a match to the tube, or weaker so that the failure occurs in the attachment rather than in the tube itself.

Regular visual inspection followed up with spot checks using magnetic particle or penetrant testing is recommended in order to find these problems.

Transient stresses can be reduced by starting up more slowly.