Brian Little

From: Hamouda Ghonem [ghonem@egr.uri.edu]
Sent: 15 October 2009 01:46
To: Brian Little
Subject: RE: FW: FW: BETA 21

Brian, All data available to me show that elongation of Timetal 21S at RT exceeds 8% while at 650C in vacuum, elongation reaches 11.5 %. (Timet data: 8-10% (aged 538C)). Since elongation depends, in addition to thickness, on temperature and length of exposure, it is important in calculating the reduction in elongation, to correlate with a reference condition that accounts for temperature but excludes effects of thermal exposure. For the condition we discussed this morning during our telephone conversation, the reference elongation should have been taken at 450C with zero time exposure. This may explain the overestimation in the reduction of elongation in their calculation.
Hamouda

11:58 AM 10/14/2009, you wrote:

Hamouda - I was confirming my arrangements and set up for Friday and asked a bit about the ductility number . I was referred to MAtweb Online material DATA SHEET where I was told that the enquiry showed a Elongation at Break of 4.5% (O content 0.25%) and Elongation at Break of 5.0% (O content 0.14) as the basis of the number they used

Is that any of any help ? Look forward to hearing from your further before departure. I believe we have done all we can do now (other than the ductility number) before my Friday meeting

Many thanks again

Kind regards

brian

From: Hamouda Ghonem [mailto:ghonem@egr.uri.edu]
Sent: 14 October 2009 04:51
To: Brian Little
Subject: RE: FW: FW: BETA 21

Brian,
1- I carried out a rough calculation (important to underline rough) based on converting the limits I have for 1mm/450C/150 hours and projected this on 2 mm/45C/150 hrs taking the base ductility 4 (I expected this to be a higher number). These calculations give a ratio of 4/3.1 ~1.2 which means that the estimated first inspection should be >> 40000 flying hours. I have to confirm these results by plotting our data and fitting an equation to them correlating thickness, temperature, time and ductility. I could then extrapolate to the 2mm thickness and normalize with the 4% you given me. We could also inspect any data available to you on the ductility reduction for the 2 mm thickness and come up with a much better estimate for reduction in ductility.

2-The paper i mentioned to you concerning the crack growth in b21s is:"Effects of Temperature and Frequency on Fatigue Crack Growth in Ti- 21S Monolithic Laminate", H. Ghonem, Y. Wen, M. Thompson and G. Linsey, *Materials Science and Engineering, A161*, pp. 45-53, 1993". The material, however is consolidated layers of b21s thin sheet (0.8 mm), but the results can work as a first approximation to predict crack growth in the alloy. Unfortunately, I have no hard copies left of this paper.

3- An "Informed Maintenance Schedule" for the problem you have at hand can be established using "constant probability crack growth curves" approach. This approach provides probability weight to different crack growth curves which would then be used to determine intervals of maintenance following detection of a crack. This approach is based on work we developed in late 80s ["Constant-Probability Crack Growth Curves", H. Ghonem, *Engrg Fracture Mechanics*, Vol. 30, No. 5, pp. 685-699, 1988]. If interested, we can explore this further.

If you have any questions please do not hesitate to reach me tomorrow in my office; i will be available until 1.00 pm my time
Take care
Hamouda

At 12:39 PM 10/9/2009, you wrote:

Hamouda - Following our conversation this afternoon I checked through some more of the data /paperwork and can confirm that the sheet thicknesses were 0.61mm , 1.00mm, 1.47mm and 1.80 mm in the Trent 500 Nozzle and Plug .

I understand that some limited testing of these materials was carried out in 2005 with various sheet samples of the above . The tests they performed were

1 sample at 650 C for 1000 hrs
3 samples at 650 C for 20 hrs and then cooled in the furnace to room temperature
3 samples at 450 C for 150 hours then cooled in the furnace to room temperature

Simplistic results

The baseline specimens (not furnace exposed) had the lowest strength (110ksi)but the highest ductility **(over 4% elongation)**

Specimens from material that was furnace exposed at 650C showed slightly higher strength than the baseline (110 -140ksi), but less than 3% elongation

Specimens from material that was furnace exposed at 450C show higher strength (over 180ksi) , but are more brittle with less than **1.5% elongation.**

It is the **4/1.5** (=2.67) elongation number that has been used together with the Hybrid Fatigue Mission Mix at Table 2.1.1 (FD&T report Page 20) of 100000 flying hours to presently determine that the "Life Reduction factor is 2.67 – 37453 hrs) and therefore a estimated life span of 40000 flying hours prior to probable removal for repairs / replacement. The airlines are now been asking to carry out the maintenance checks as per the manuals I sent you at 40000 hours which coincides with when the Trent 500 engines are being removed for their second planned overhaul and at each subsequent 20000 interval.. Does that help explain the current "science" to date.

I hope this provides some further perspective and if I need to explain further please let me know. I have also been able to confirm the FE models would be available in this process to us

You I am sure will wish to consider how your work / research – calculations etc would relate to this info and how we may provide some further "scientific" but practical application to this subject.

Kind regards and many thanks for your assistance.

Brian