Crack Initiation Studies in Alloy 690 & Weld Metals

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Alloy 690 Initiation Experiments

The highest priority for initiation testing on Alloy 690 involves:

optimized test design

and

prioritized accelerants.

Optimized Test Design

1. *Specimens that don't undergo consequential stress relaxation, either by demonstrating that little relaxation occurs or actively loading, e.g., by springs or differential pressure or external loading, or using U-bends or bent beams with the stress accurately measured before and after testing.*
2. *Specimens of sufficiently large surface area tested with sufficient replicates to provide a statistically confidence result.*
3. *Inclusion of reference specimens, such as thermally treated Alloy 600 materials, which will help define a relative benefit.*
4. *In-situ monitoring that captures SCC on as fine a scale as possible, and on as continuous basis as possible. For highly resistant materials, this may be less critical – but still desirable.*

Prioritized Accelerants

1. *Stress has a strong effect, as does active straining. In many cases (e.g., U-bends and bent beams), the stress and strain go hand-in-hand. External or differential pressure stressing provides the option of changing stress vs. time.*
2. *Material inhomogeneity has a strong effect on growth rates, and certainly represents a key factor to address in initiation testing. The key feature is orienting the specimen so that the principal stress tends to promote crack initiation in the S-L or S-T orientation.*
3. *Cold work generally accelerates both crack initiation and crack growth, and reverse straining (e.g., a bend beam or U-bend) appears to be especially damaging.*

Prioritized Accelerants

4. *Temperature generally has a strong effect, although the highly susceptible microstructures and orientations of Alloy 690 show little dependence of crack growth rate on temperature.*
5. *Dissolved H_2 generally has a strong effect, although the highly susceptible microstructures and orientations of Alloy 690 show little dependence of crack growth rate on dissolved H_2.*
6. *Surface cold work (e.g., grinding or coarse machining) or surface defects are deleterious.*
7. *Thermally treated vs. weld HAZ microstructure, where thermal effect can alter the grain boundary carbide size and density.*

Specific Recommendations for SCC Initiation Tests

1 – For convenience (e.g., use of existing facilities) and to minimize cost, the use of U-bend and bent-beams is highly attractive. Such specimens should either employ springs to maintain load, or demonstrate that >90% of the original load is maintained.

2 – While there might not be a strong effect of temperature and dissolved H_2, it makes sense to aim for the peak H_2 level (Ni/NiO phase boundary) and elevated temperature.

Specific Recommendations for SCC Initiation Tests

3 – Replicates are very important, and testing of at least 10 replicate specimens for a given condition is desirable. But if the number of variables is sufficiently large and each is sufficiently important, it is probably wise to include a half-dozen variables involving 5 replicates than three variables with 10 replicates.

4 – Either continuous monitoring / detection or inspection at appropriately common intervals is important. Reference specimens (e.g., Alloy 600 MA or TT) should be included to help establish a relative benefit of various conditions of Alloy 690.

Specific Recommendations for SCC Initiation Tests

Primary variables should include:

1. *Cold work, including reverse bending will accelerate SCC and should be addressed, perhaps using 10% (limited) vs. 25% (severe) cold work levels.*
2. *High stress conditions should be evaluated, although in bend specimens there is a correlation between strain (bend radius & specimen thickness) and stress. Multiple levels would be help*
3. *Microstructure, including banded-inhomogeneous structures, grain-boundary carbide-free structures, and standard/ideal/homogeneous structures.*
4. *Surface cold work from aggressive grinding or machining.*

Specific Recommendations for SCC Initiation Tests

Specific proposal:

1. *Alloy 600 MA reference specimens*
2. *Banded, inhomogeneous microstructures with 20% 1D cold rolling with the preferred orientation of S-L or S-T*
3. *Homogeneous microstructures with 20% 1D cold rolling with the preferred crack initiation and growth orientation being S-L or S-T*
4. *Alloy 52 and/or 152 weld metals specimen*

The characteristics of the all of the above tests involve:

- *330 – 360 C, peak H_2, 1000 ppm B, 1 ppm Li*
- *5% strain in the outer fiber of the bend*
- *At least 5 and ideally 10 replicates*
- *Advisory team of 3 – 5 experts*