Proposed Matrix of Critical Tests on Alloy 690 & Weld Metal

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Alloy 690 Base Metal – Key SCC Issues

Microstructural Origins of "1000X" increase in growth rates
- not all heats have been characterized as "banded"
- initial indication that cracks grow preferentially in fine grained, high carbide density bands.

Deformation Level and Equivalence of rolling vs. forging vs. tensile straining vs. HAZ residual strain.

Crack Orientation vs. Deformation for banded & homogeneous 690
- will CGR be elevated in all materials in S-L, S-T orientation.

Dependencies on K, Temperature, Dissolved H_2, etc. as a function of heat, deformation and banding/CGR.

Must adopt a guideline on "threshold growth rate", ~1 – 2 x 10^{-8} mm/s

Proposed Test Matrix

Base Metal Evaluation* (Default = S-L Orientation)

Form**	Heat #	As-rec'd	10% F	20% F	30% F	10% R	20% R	20% T
Plate	#1	X	X	X, YY	X	X	X	X, YY
T-L	#1			X	X		X	
Plate	#2	X	X	X	X	X	X	X
Plate	#3			X			X	
CRDM	#1	X		X	X		X	
T-L	#1			X	X		X	
CRDM	#2			X			X	
CRDM	#3	X		X			X	
Billet	#1			X			X	
Billet	#2			X			X	

- ** F = Forged, R = Rolled, T = Tensile strained*
- *YY listing on plate #1 represents banding oriented in the direction of deformation, e.g., along tensile or compressive axis. Crack plane remains S-L orientation relative to deformation, although some evaluation of the S-T orientation is needed.*
- *S-L orientation defined by relative orientation of deformation and crack plane/direction.*
- *** Plates #1 and #2, and Billet #1 should be banded and/or show high growth rates*
- *Key tests:* ***Banded 690 + Forging,*** ***Banded 690 + Tensile Strain,*** ***Billet & CRDM Behavior*** ***Crack Orientation vs. Deformation,*** ***Banding Orientation vs. Deformation (YY)***

HAZ Evaluation* (Default = S-L Orientation)

Test	Heat #	V-groove	Narrow gap	Electron beam	High constraint	NG / e-beam + banded
HAZ	#1 *	X	X	X	X	X
HAZ	#2 *	X	X	X	X	X

** S-L orientation defined by relative orientation of deformation and crack plane*

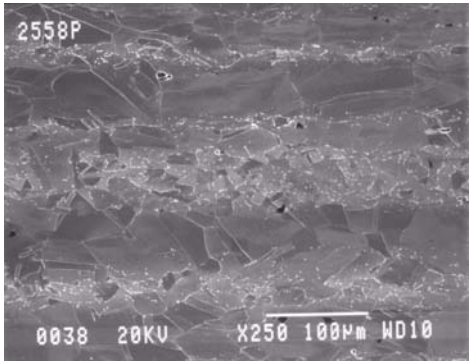
*** Heat #1 / #2 applies to each weld type, i.e., test two heats / welds with a V-groove prep*

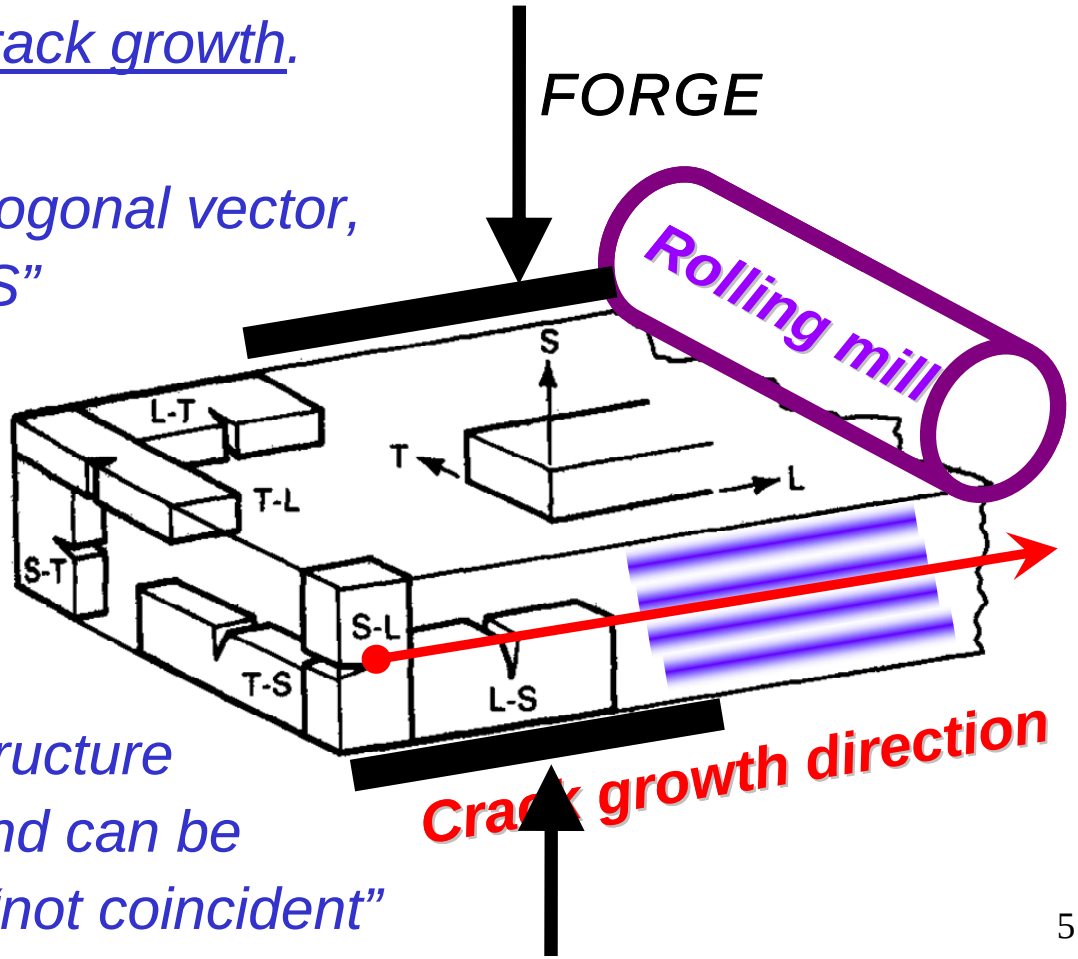
Last column (narrow gap or e– beam + banded) means that a banded, high growth rate plate material will be welded with S-L alignment between banding and weld residual strains

Alloy 690: Orientation Terminology

Orientation terminology describes the relative orientation of the plane and direction of deformation with the plane and direction of crack growth.

Plane is expressed as its orthogonal vector, so rolling or forging plane is "S"





Orientation relative to microstructure & banding is also important and can be expressed as "coincident" or "not coincident"

Alloy 690: Other Parameters for Evaluation

- *Ingot melting practice, including cleanliness and chemical homogeneity.*
- *The efficiency of the conversion route used to fully transform the cast ingot to an equiaxed structural material in terms of grain size, grain size homogeneity, chemical homogeneity, and carbide distribution uniformity.*
- *Heat and product form (e.g., billet vs. plate) variability due to very different ingot conversion routes.*

Alloy 690: Other Parameters for Evaluation

- *Effect of thermal treatment (TT), e.g., at 705 C for ~8 hours, designed to produce a high density of grain boundary carbides.*
- *Effect of deformation and crack orientation. The worst case is typically material cold rolled in one direction, with the crack plane oriented along the rolling plane. Some spreading occurs during rolling, so there is undoubtedly a continuum among 1D cold rolled, cross-rolled and forged materials. In turn, SCC response in tensile strained and HAZ-aligned specimens is also important.*

Alloy 690: Key Materials

1. *~250 pounds each of two double-melted heats of 4 – 7 inch diameter Alloy 690 billet*
2. *~250 pounds each of two double-melted heats of 2 – 4 inch thick Alloy 690 plate*
3. *We would like to have some of the plate cold rolled in one-direction to 10, 20 and 30% reduction*

Accumulating more forms/heats and types/orientations-of-deformation will eventually be necessary to have confidence in our understanding of material and deformation effects.

Alloy 152/52 Weld Metal: Materials

1. *Compositional variations among 52, 52M, 52MS, 52MSS… are expected to affect weld cracking, not SCC.*
2. *SCC is expected to be affected by:*
   - *Cr and perhaps Fe concentration*
   - *Carbide and other particles in the grain boundary*
   - *Residual strain in the weld metal (constraint, heat input…)*

As diverse a combination of 52 and 152 welds as possible should be evaluated, and demonstrating reproducibility and identifying the origins or high CGR welds is a priority.