Effect of post-weld heat treatment on microstructure, hardness and impact toughness at 77 K of electron beam welds of NIFS-HEAT-2 and CEA-J57 heats of V-4Ti-4Cr alloy

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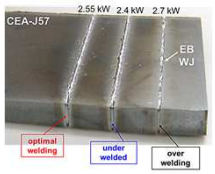
V-4Ti-4Cr alloys: NIFS-HEAT-2 and CEA-J57

*Chemical composition of V-alloys (wppm, *wt%)*

Heat	C	O	N	B	Na	Mg	Al	Si	V	Cr*	Mn	Fe	Ni	Cu
NH2	69	**148**	122	5	<1	<1	59	270	Bal.	4.02	<1	49	7	2
CEA-J57	70	**290**	110	7.5	40	5	190	280	Bal.	3.76	6.8	120	17	1

Heat	As	Zr	Nb	P	S	Ca	Co	Ag	Sn	Sb	Ti*	W	Mo	Ta
NH2	<1	2.5	0.8	0.7	3	12	0.7	<0.05	<1	<1	3.98	<1	24	13
CEA-J57	-	-	<10	1.2	8	0.4	0.4	-	0.3	<10	3.93	35	75	<10

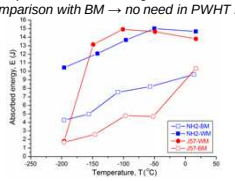
Bead-on-plate EB welding



NIFS-HEAT-2
96 % reduction in thickness followed by VA at 1000°C for 2h - 4 mm thick plate with optimum welding power 1.5 kW

CEA-J57
54 % reduction in thickness followed by VA at 1000°C for 2h - 7 mm thick plate with optimum welding power 2.55 kW

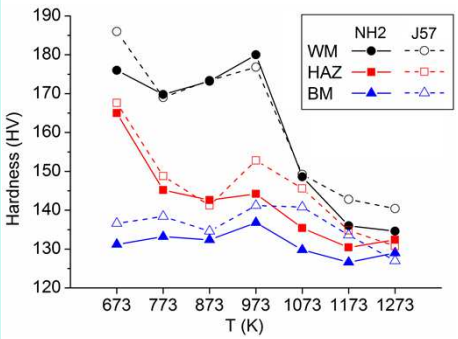
Superior absorbed energies of WM in comparison with BM → no need in PWHT !



Motivation: *A potential needlessness in PWHT of EB welds does not exclude the necessity to study the effect of post-weld heating to working temperatures on the mechanical and structural properties of weld zones !*

Hardness of zones of weld joints after PWHT

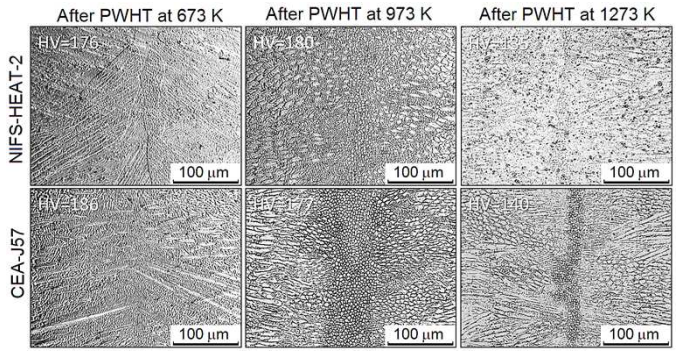
PWHT at 673-1273K for 1h in high vacuum atmosphere.



- After PWHT at 773 and 873 K, WM and HAZ were softened in comparison with as-welded state plus degassing at 673 K;
- PWHT at 973 K results in increase in hardness in WM and HAZ due to re-precipitation of Ti-C,O,N;
- PWHT in-between 1000-1273 K results in gradual decrease in hardness of WM and HAZ to the values similar for BM because of oxygen gettering from the solid-solution to Ti-C,O,N precipitates and their subsequent coarsening.

Structure of zones of weld joints after PWHT at 673, 973 and 1273 K

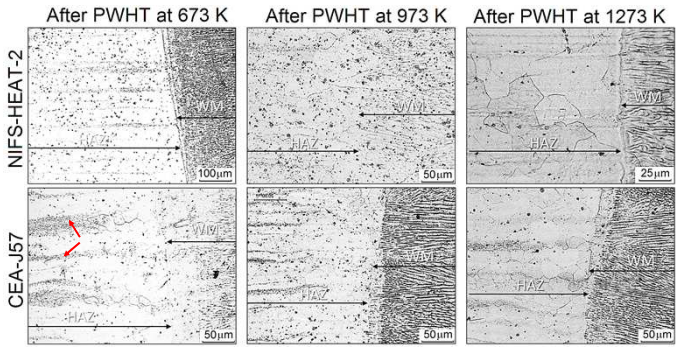
Morphology of Weld Metal (WM)



Columnar dendritic structure

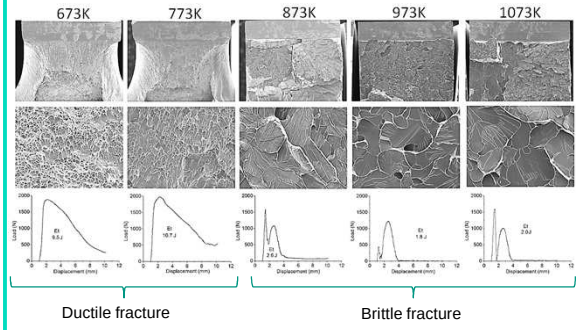
Partially recrystallized structure with fine equiaxial (center of WM) and elongated (periphery of WM) grains

Morphology of Heat Affected Zone (HAZ)



Effect of PWHT on impact toughness at 77 K of weld metal of Electron Beam Welds of V-4Ti-4Cr alloys

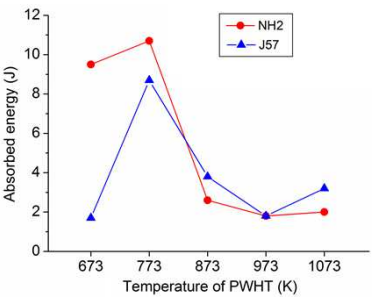
NIFS-HEAT-2



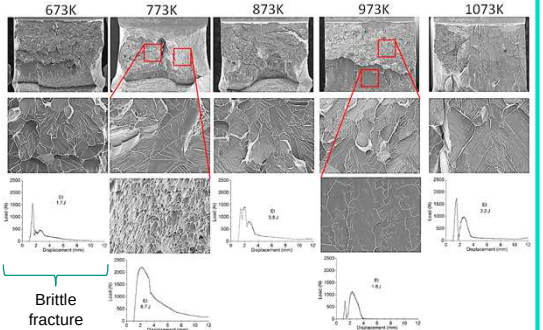
Ductile fracture

Brittle fracture

Absorbed energy of Weld Metal after impact test at 77K



CEA-J57



Brittle fracture

Mixed fracture

Brittle fracture

- PWHT at 773 K improves impact toughness of WM - absorbed energy increases noticeably for J57 and slightly for NH2 in comparison with as-welded state;
- After PWHT in-between 873 and 1073 K, absorbed energy decreases to the values similar for the base metal (2-4 J) while fracture mode is brittle.

Conclusions

- PWHT of EB welds of V-4Ti-4Cr alloys NIFS-HEAT-2 and CEA-J57, performed at 773 K, improves impact toughness of weld metal at 77 K, that accompanied by the ductile fracture mode and slight decrease in hardness while microstructure of weld metal remains similar to that one in as-welded state;
- PWHT at 973 K results in partial recrystallization of microstructure of weld metal while the highest level of hardening, induced by the re-precipitation of Ti-C,O,N, causes an embrittlement of the weld metal accompanied by the decrease of absorbed energy at 77 K to ~2 J;
- PWHT in-between 1000-1273 K results in gradual recovery of hardness and impact toughness at 77 K of weld metal to the level of base metal because of oxygen re-trapping from the solid-solution into Ti-C,O,N precipitates. Fracture mode is brittle in contrast to the ductile which is observed in the as-welded state.