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Dissimilar electron beam welds of nickel base alloy A625 with a 9% Cr-steel for high temperature applications

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Introduction

The worldwide increasing demand for energy, as well as the request for the reduction of CO_2 emissions are driving forces for an increasing thermal efficiency of fossil-fired power plants, which produce more than 60% of the worldwide used electricity. In steam power plants, thick walled components like casings or pressure valves are casted from 9-12% Cr steels for operating temperatures up to 650°C. Above the operating limits, Ni-base alloys are employed for operation. This study focuses on the creep behaviour of 50mm thick dissimilar electron beam welded (EBW) joints of Nickel-base alloy A625 to 9%Cr CB2 martensitic steel. The CB2 heat affected zone (HAZ) seem to be the weakest spot of the weld upon creep exposure. Comparative creep ruptured tests (1,000 – 10,000 h, 625°C) at different stress levels are carried out to determine the weakest spot in the weld. The microstructure investigations and creep rupture times are compared to gas metal arc welded (GMAW) specimen.

Experiments

Welding

Dissimilar welding of A625 to 9% Cr steel is a challenging task for GMAW. The EBW process is suitable to simplify and quicken this task.

EBW		GMAW
Simple I butt	*Joint preparation*	Single U - groove
-	*Buffering*	3 layer
-	*Heat treatment*	Pre- & post
-	*Filler*	4 kg
1	*Weld passes*	~ 180
30 s	*Weld time*	8 h

Tab. 1: Details for WPS samples: 50mm thickness, 350mm length; EBW vs. GMAW

Metallographie

The width of the EBW HAZ is between 0.5 and 0.7mm (Fig. 1). The GMAW joint shows no clear distinctive HAZ. For EBW and GMAW δ-ferrite grains close to the fusion line where found (50µm in GMAW, 20µm in EBW (Fig. 1).

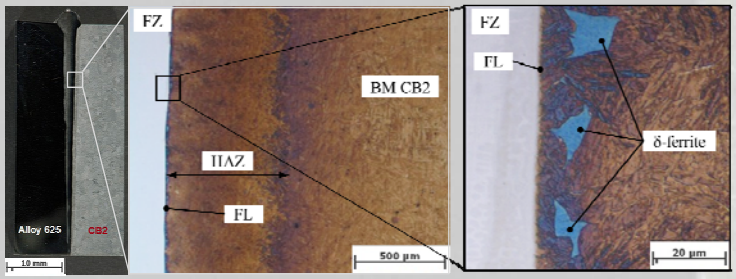

Fig. 1: Weld Seam; HAZ and FL on the CB2 side of the EBW samples.

Interrupted Creep Testing

EB dissimilar welded samples were tested at 625°C at six different stress levels between 156 - 100MPa. All samples were Investigated after rupture by means of light microscopy and EBSD measurements. The rupture location was in the CB2 material for every specimen. The 100MPa sample is still running (11,273 h; status 19.05.2016).

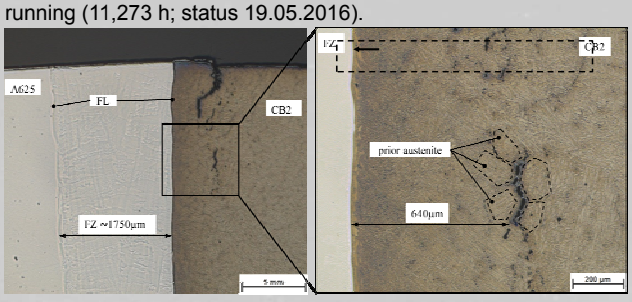

Fig. 2: Creep sample (156 MPa) showing cracks and porosity on the border between HAZ and BM. No defects in HAZ or the δ-ferrite rich zone.

Increased porosity and microscopic cracks were observed close to the end of the HAZ in Fig.2. Metallography shows that for higher stresses, that the porosity is concentrated along the prior austenite grain boundaries (PAGB) (see Fig. 2) with almost no porosity inside the BM.

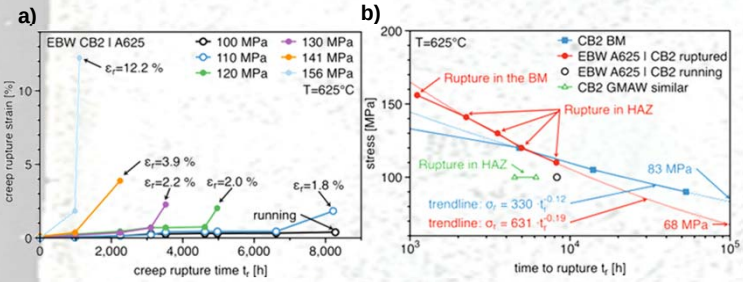

Fig. 3: Results from uniaxial creep testing at 625°C at different stress levels.

Creep rupture experiments (Fig. 3) compare the results of EBW specimens to GMAW specimens [2] and CB2 base metal (BM) [1]. A low creep rupture strain of 2% is observed (Fig. 5a). The EBW samples show above 130MPa) a better creep resistance than the CB2 BM samples (Fig. 3b).

EBSD

The inverse pole figure map (Fig. 4) shows fine spherical shaped grains inside the HAZ close to the PAGB. In comparison to the BM, the prior austenite grains within the HAZ appear smaller (indicated with dashed lines).

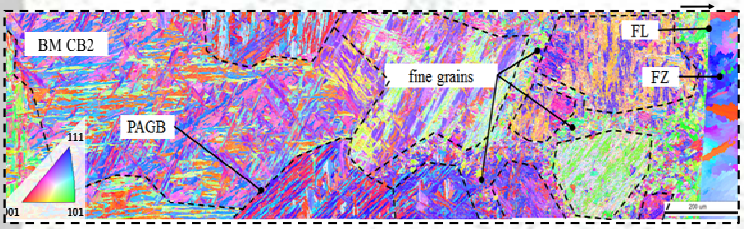

Fig. 4: Inverse pole figure map CB2-HAZ, indicating estimated high angle grain boundaries (from similar orientations) 156MPa creep sample.

Summary

- The δ-ferrite rich zone and the HAZ for EBW is less than half in width compared to GMAW
- No uniform fine grained HAZ was found in EBW (balanced B and N)
- No defects were found in the fusion zone or in the δ-ferrite zone.
- Increased porosity, creep damage and rupture occurred predominately at the border of the HAZ, at stress levels below 156MPa.
- For stresses below 141MPa, porosity was found all over the HAZ.
- The improved creep behaviour of EBW specimen can be explained by the smaller size of the HAZ and the geometry of the HAZ.

Conclusion

- EBW of this dissimilar joint has economical advantages over compared to conventional GMAW, providing at least equal mechanical properties.
- For the EBW samples no creep rupture in the δ-ferrite rich zone appeared.
- The small grains, in the CB2 HAZ along the PAGB, are prone to creep damage.
- The EBW specimen show low creep rupture strain
- Assuming the same creep mechanism and according to extrapolation the creep rupture life of dissimilar joints - EBW performs better than GMAW.
- The still running creep test at 100MPa is directional for the resulting creep strength.

References

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[2] M. Schuler, S. Baumgartner, R. Schnitzer, and N. Enzinger, "Creep investigation of CB2 joints using similar rutile CB2-flux cored wire," *Weld. World*, vol. 58, no. 6, pp. 903–913, 2014.

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