Qualification of electron-beam welded joints between copper and stainless steel for cryogenic application

C Lusch[1,2], M Börsch[3], C Heidt[1,2], N Magginetti[3], J Sas[2], K-P Weiss[2] and S Grohmann[1,2]

[1] Karlsruhe Institute of Technology, Institute for Technical Physics, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

[2] Karlsruhe Institute of Technology, Institute for Technical Thermodynamics and Refrigeration, Kaiserstrasse 12, 76131 Karlsruhe, Germany

[3] WEKA AG, Schu¨rlistrasse 8, 8344 Ba¨retswil, Switzerland

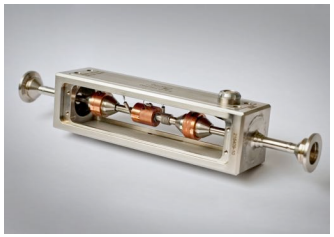
M1PoB

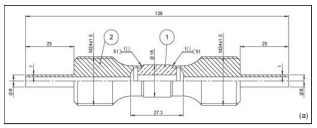
Introduction

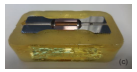
The joints between oxygen-free high thermal conductivity copper (OFHC) and 316L play an important role for cryogenic application. A possibility to join these materials is electron-beam (EB) welding. One of the many advantages of this method are the deep and narrow welds as a result of the high energy density. EB-welding between 316L and OFHC will be used for a new cryogenic mass flow meter for the determination of mass flow rates in gases and liquids. The method of this new mass flow meter is explained in [1].

A technology transfer project together with WEKA AG was started in order to develop this new mass flow meter for a working range of 300 K down to 4 K and with pressures up to 50 bar.

As few data is available for classifying EB welds between 316L and OFHC, specially designed samples were produced and tested between 300 K and 4 K, and with high pressures. The geometries were close to the original design of the mass flow meter.







Qualification Program

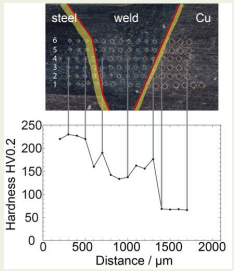
Hardness test

To investigate the quality of the weld, Vickers HV0.2 was performed (ISO 6507-1)

Pressure and leak test

The samples passed successfully a pressure test up to 160 bar

Leak tests at RT gave $\leq 3.2 \cdot 10^{-9}$ to $\leq 1 \cdot 10^{-10}$ mbar l s^{-1}
and at 80 K $\leq 7 \cdot 10^{-10}$ to $\leq 1 \cdot 10^{-10}$ mbar l s^{-1}
(EN 1779)



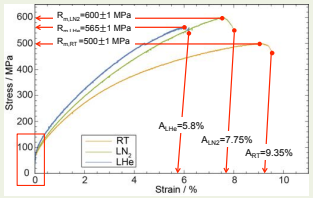
Temperature cycling

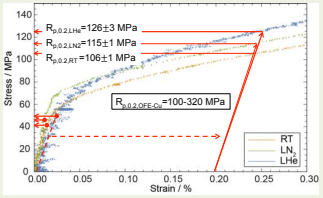
Leak tests gave same results after 10x cycling between 77K and RT

Destructive tensile tests

Tests were conducted according to ISO 6892-1 at RT, ISO 15579 at 77 K, and ISO 19819 at 4 K.

Yield point was determined to be in the range of 40 – 50 MPa.

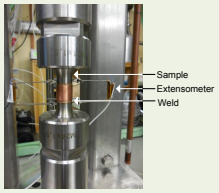


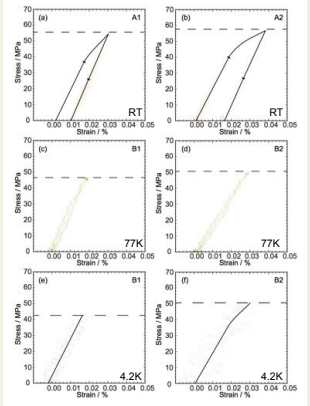


Non-destructive test

Using the yield values form the destructive test cyclic loading up to 50 MPa was performed, followed by leak tests.

The tested samples exhibited no degradation of their performance.





Conclusion

The performed test program with the hardness test, the helium pressure and leak test, the destructive- and nondestructive tensile tests and the temperature cycling test yields the desired results.

The EB weld was resistant against pressures of about 160 bar and also the weld was found to be leak-tight with measured leak rates smaller than 10^{-9} mbar l s^{-1}.

The elastic region was measured between 40 and 50 MPa for all performed tensile tests at RT, 77 K, and 4 K and the temperature cycling from RT to 77 K did not damage the weld.

Therefore, EB welding is a suitable method for cryogenic application.

[1] Grohmann S. A new method for flow measurement in cryogenic systems 2014 Cryogenics 60 9-18