DEVELOPMENTS IN ELECTRON BEAM WELDING OF NIOBIUM CAVITIES

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Abstract

In order to produce niobium cavities with better control over their final tolerances work is being done at Cornell to develop better Electron Beam Welds. Cavities for machines such as an ERL will require tight tolerances be maintained and will need welds that are repeatable with predicable shrinkage and distortion. Full penetration outside beam welds with no under bead in .078 to .110 inch thick niobium have been developed for this purpose.

For over 25 years Niobium cavities manufactured by Cornell have been done using a Rhombic Raster pattern Electron Beam Weld. These welds are done using a 60 KV Sciaky VX3 Electron Beam Welder and allow a full penetration weld to be done with flat under bead that requires no post weld machining. Others have done similar weld with defocused and Circular pattern welds on machines with voltages up to 150 KV. These types of welds are all similar in that they have a large molten puddle that relies on surface tension to produce the smooth under bead.

However there are limitations using this weld. On thicker material the weld area has to be cut down to .080 inch (2mm) or less to archive the desired inside finish. While it is possible to weld thicker materials there starts to be an undesirable under bead. Inside welds or post weld machining were required to do welds on thicker material. Also to achieve a good weld the current of the electron beam is very close to blowing a hole in the part. Variations in material thickness or fit up can led to a hole being blown in the weld. These can be repaired but there will be extra shrinkage and some distortion after the repair. As tighter tolerances in cavity profiles are required these discrepancies may be come unacceptable. When possible using a combination inside and outside weld can be used so there is lessen the chance of blowing a hole but this requires multiple set ups and doing an inside weld exactly the same way each time can be very challenging. This can also makes shrinkage and distortion prediction difficult.

Cavities for future machines will require much tighter tolerances than have been necessary in the past. For example the ERL injector cavities that are being designed at Cornell will require tolerances of +/-.004inch (0.1mm) for the cells and +/- .01 inch (0.25mm) over the length of the 2-cell cavity. It was obvious that the procedures that we had used in the past were not up to this challenge and we need welds with better predictability and repeatability.

Several years ago Cornell added a high frequency circle generator to its beam defection circuits. This allows us to do welds with a circular pattern with frequencies up to 12 KHz. In exploring this capability we find that for .062 inch thick material we can do very similar welds with the Rhombic Raster pattern, a Circular pattern or just a defocused beam. But as we increase the material thickness we were able to produce a much better weld using the Circular defection pattern. We also discovered that by adding a small under cut to the underside of the weld we could weld increasingly thicker material and still maintain a flat under bead. This under cut, when sized correctly is filled in by what would normally have been drop through and leaves a perfectly flat surface. *fig.1*

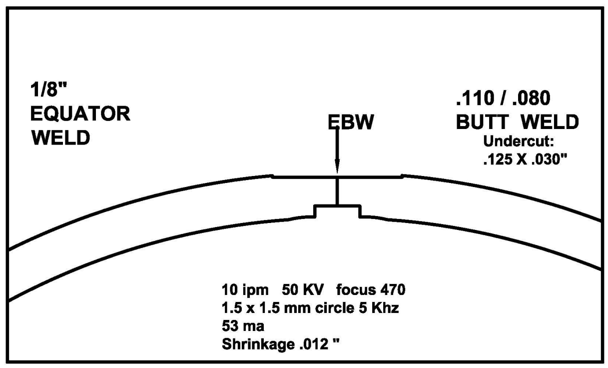

fig. 1

Starting with this Circular beam pattern we have been working on Electron Beam Welds that can provide full penetration welds with no under bead on Niobium up to .125 inch (3.2mm) thick. We also wanted a Weld with very reproducible shrinkage, minimal distortion and wider latitude in the current needed to produce a good weld. This has been done by maintaining tight tolerances, precise weld jigging and adding a slight under cut to maintain a good inside finish.

We have eliminated all but one internal weld on the ERL injector cavity. This allows us to do a weld all in one set with a straight on weld instead of at an angle We now use precision ground shafts and linear bearings for the welding mandrels instead of threaded rods. This gives us better control in keeping the parts perpendicular to the beam axis before and after welding. These along with stricter machining tolerances help to minimize distortion. In the past we would have compensated for any variation in material thickness by adjusting the beam current. This would have given a good weld but of unknown shrinkage. In general the machining tolerance for the weld joints are now held to within +/-.001inch instead of the +/- .005 inch that were asked for in the past.

There are in general two types of welds used, butt welds and step welds. Because parts may distort slightly after they are removed from the dies step welds help forcing the parts back into the correct shape when the two parts are fit together. But step weld require a lot of detail machining and variations in thickness or any voids left after the joints are fitted together may cause a hole to form during the weld. Butt welds are easier to machine and do not have the problem of voids but may have some mismatch between parts.

For Equator welds we have developed a butt weld. On the outside of the cavity we install a welding jig in the form of a ring that is cut to the same shape as the half cell forming die. *fig.2* This force the two half cells to fit up exactly before they are tack welded together. The jig is then removed for welding. To allow for some variations in the thickness of .125 inch material and to compensate for any distortion of the ID the material is cut down to .110 thick. This allows each cup to be identical.

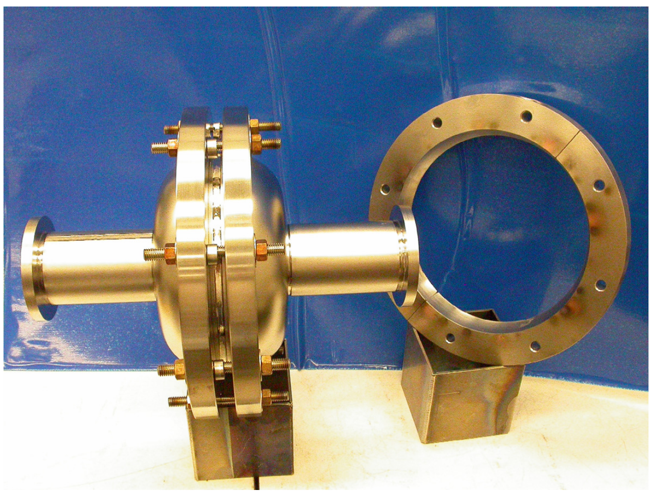

Fig. 2

For Iris and tube welds it is not practical to use this type of jig so we use a step weld and require that they be held to very tighter tolerances. These welds vary from .078 inch to .110 inch thick. The size and depth of the under cut is varied as the material thickness changes. As with the Equator weld a little extra material is cut off the ID and OD of each part to assure that all welds are identical.

Test welds on Niobium prototype parts have been completed, machining, jigging and fit ups test of copper prototypes are almost done and production of the first Niobium ERL Injector cavity is now starting. We believe that these full penetration, circular pattern, under cut, outside beam welds will allow us produce niobium cavities with better control over their final tolerances and allow us to do welds with repeatable and predicable shrinkage and distortion.