THE USE OF DISPERSION STRENGTHENED COPPER IN ACCELERATOR DESIGNS*

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Abstract

Dispersion strengthened copper, known by the trade name GLIDCOP®[1], has found various applications in accelerator designs. Glidcop has material properties similar to OFE copper, such as thermal and electrical conductivity. Unlike OFE, however, Glidcop has yield and ultimate strengths equivalent to those of mild-carbon steel, making it a good structural material. This paper covers some accelerator components fabricated with Glidcop, material properties measured from room to brazing temperatures, and a furnace-brazing process that has produced good, consistent results with Glidcop.

1 INTRODUCTION

The use of Glidcop in a design where high electrical conductivity and mechanical strength are required precludes having to fabricate the component out of a higher-strength material such as stainless steel and apply copper plating afterwards. Glidcop can be applied to the design with just about the same considerations as OFE copper relative to machinability and joinability.

The thermal and electrical conductivity of Glidcop are very close to those of OFE, and are significantly higher than these properties of other common higher-strength materials. This allows for a near-homogeneous structure that responds to transients much like an all-OFE structure would.

2 APPLICATIONS OF GLIDCOP IN ACCELERATOR DESIGNS

The selection of Glidcop for use in the design of new vanes for the Chalk River RFQ1 accelerator was one of the first applications for Glidcop in accelerator design [2]. Glidcop has also been applied to the crotch absorber design of the Advanced Photon Source (APS) facility due to its fatigue strength at higher temperatures [3]. The Spallation Neutron Source (SNS) project RFQ accelerator utilizes a combined OFE and Glidcop cavity wall design [4]. The Accelerator Production of Tritium (APT) project's Low Energy Demonstration Accelerator (LEDA) RFQ accelerator utilizes Glidcop in the design of several key components [5]. The end-sealing flanges, coupling plates, end walls, and vacuum-waveguide connections [6] all utilize Glidcop. To date the LEDA RFQ has operated for over two-thousand hours under RF power high duty factor or CW mode with no failures due to material yield or rupture. The RFQ fabrication also utilized Glidcop for the braze tooling needed to support components during brazing.

During the commissioning of the LEDA RFQ multipacting was found to occur in the tapered-vacuum waveguides at certain RF power levels that were very close to the operating power level. The solution used to overcome this was to reduce the number of RF feeds into the RFQ by half. This placed the operating power levels high above any multipacting level. However, this applied approximately twice the original thermal load on the vacuum waveguides coupled directly to the RFQ. Thermal/stress analyses predicted, and operation proved that these all-Glidcop structures could withstand the higher stresses from the higher RF thermal loads. It is unlikely that these waveguide structures could have withstood the higher loads if they had been made of OFE copper. The strategic use of Glidcop in an accelerator design can allow for later modifications in operation without requiring expensive and time-consuming redesign and refabrication.

3 HIGH TEMPERATURE TENSILE TESTS OF GLIDCOP

Peak temperatures of the copper wall of an accelerator or waveguide rarely exceed approximately 150 ^{o}F, so elevated temperature material-property data are not important for evaluating operating conditions. However, the fabrication of accelerator and waveguide components can bring them to within 80 ^{o}F of the melting point of copper when furnace brazing is used.

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For this reason reliable elevated-temperature properties are indispensable when predicting the response of a structure undergoing furnace brazing. If a component is not supported properly, or is over-constrained when undergoing brazing, permanent deformation can occur and possibly render the component unusable. Predicting if a component is properly secured for furnace brazing requires knowing the strength of the component materials at elevated temperatures.

Strength data used previously at brazing temperatures for estimating the strength of Glidcop was the OFE copper 10-hour stress-rupture strength at approximately 1,000 lb_f/in^2 at 1600 ^oF [7]. This provided a conservative design value, yet one that was considered too conservative for Glidcop. Tensile testing from room temperature to high temperature, 1900 ^oF, was obtained from a commercial testing laboratory in order to provide data for the elevated temperature yield strength of Glidcop [8]. Figure 1 is a plot of stress versus temperature. Table 1 lists some of the data obtained. The data reveal that Glidcop maintains appreciable strength at high temperatures. For furnace brazing with the gold-copper alloy 35-65 at a temperature of 1900 ^oF Glidcop would have a yield strength of 400 lb_f/in^2.

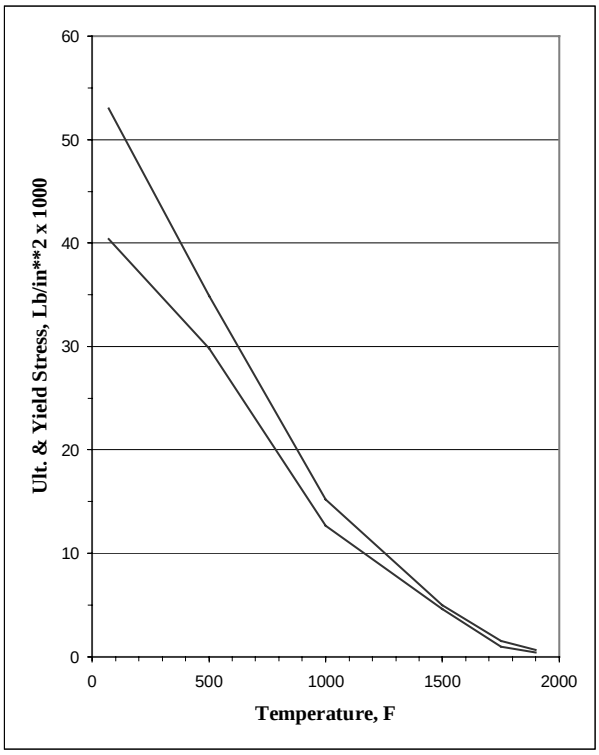

Figure 1: Glidcop AL-15 LOX ultimate and yield strength

Table 1: Glidcop AL-15 LOX strength

Temp F	Yield Strength lb_f/in^2, 0.5% offset	Ultimate Strength lb_f/in^2
70	40,400	53,000
500	29,800	34,900
1000	12,700	15,200
1500	4,600	5,000
1750	1,000	1,500
1900	400	670

The tensile testing was carried out using three material specimens at each test temperature that were fabricated from low-oxygen Glidcop, type AL-15. The Glidcop was stress relieved at 1950 ^oF. A low rate of strain, 0.010 in/in-s was used below the yield stress. Testing was performed per the standard ASTM E8.

4 HIGH TEMPERATURE THERMAL EXPANSION TESTS OF GLIDCOP

The thermal expansion of Glidcop is another important parameter to quantify when using furnace brazing as a joining process. Thermal-expansion testing of Glidcop has been commissioned and started, but has not been completed as of the date of this writing. The thermal expansion of two grades of Glidcop, AL-15 and AL-25 are being measured from room temperature to 1925 ^oF. Glidcop does have a directional dependency for thermal expansion. The measured thermal expansion will vary depending on whether the specimen was taken normal or parallel to the direction of extrusion and rolling [9]. The testing will cover checking for this dependency, and also checking if the dependency disappears after extensive rolling in two orthogonal directions of the material. Other materials common in accelerator design, namely OFE copper and 300-series stainless steel will also be measured since they can be joined to Glidcop, and the relative growth of each material will determine the expansion stresses experienced during the heating and cooling cycles of furnace brazing.

A laser-interferometer-based measurement system and procedure per the standard ASTM E 289 are being used rather than a dilatometer-based system per ASTM E 228 in order to obtain higher-precision thermal-expansion data. If a laser based measuring system is set-up and calibrated properly the accuracy of the length measurement can be one-half the wavelength of the laser type used. A helium-neon laser with a wavelength of 632 nanometers is being used to make

the length measurements for this thermal-expansion testing.

5 FURNACE BRAZING GLIDCOP

The first attempts to furnace braze Glidcop at LANL were made by joining it to OFE copper using gold-copper braze alloys. The gold-copper alloys used were (%gold-%copper) 35-65, 50-50, and 80-20. These brazes were generally successful, yet did produce occasional vacuum leaks that were not experienced with similar geometry in OFE to OFE joints. When the first Glidcop to Glidcop furnace brazes were performed using test pieces and the gold-copper alloys poor joint quality was experienced with porous interfaces and low tensile strength. Various methods for preparing the braze surfaces were tried, along with modification of the brazing process. One method that was tried and found to produce good repeatable results was plating the Glidcop braze surfaces with cyanide copper prior to brazing with the gold-copper alloys [10]. This method had been used at the Stanford Linear Accelerator Center (SLAC) [11] with success, and was recommended for the Glidcop brazing being carried out at LANL.

When final machining operations are completed the Glidcop pieces are plated in a cyanide-copper bath. A cyanide-copper plating thickness approximately 0.0008-in thick is applied to the braze interface surfaces. The surfaces to be plated undergo a warm, bifluoride/sulfamic-acid-dip-cleaning step that is added to the surface preparation process just before plating to help remove trapped-porous contaminants. Removing most porous contaminants helps reduce the occurrence of blistering during subsequent brazing.

Specimen testing revealed that better joints are produced when a static, distributed load of 4 lb_f/in^2 is applied to the braze joint throughout the braze cycle. Raising the loading does not harm the joint quality, but it does not provide any improvement either.

Braze test specimens using Glidcop were fabricated at Chalk River in support of designing and fabricating new vanes for their RFQ1[2]. The test specimens used nickel-plating thicknesses of 0.0005 in and 0.001 in to act as diffusion barriers for the alloy. Cusil and Palcusil 5 were the braze alloys applied. Successful, vacuum-tight joints were produced in the specimens.

6 SUMMARY

Within the past decade Glidcop has been successfully applied to accelerator designs due primarily to two reasons. First, it has comparable electrical and thermal properties to OFE copper, and can be substituted for OFE in areas where both high strength and high conductivity are required. Second, it can be fabricated into shapes and assemblies using processes that are very similar to those used with OFE copper.

The expansion of the material-property database of Glidcop will allow for even more reliable application of the material. Reliable high-temperature data enables the accurate prediction of the response of Glidcop at very-elevated temperatures where the strength has diminished to approximately 1% of the room-temperature strength.

7 REFERENCES

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