B. CO_2 Simulation of Hydrogen-Oxygen Joining Thin-plate Fused Silica Hermetically Sealed Packages

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Introduction

Laser welding of fused silica is a common process today, while scientific glassblowing techniques continue to be used where appropriate. Recent applications requiring hermetic sealing of thin, pressure-bearing windows to thick-walled material required the re-thinking of the laser welding technique as normally used. Typical large-scale high temperature hydrogen-oxygen **(HTHO)** torch fusing techniques cannot be applied on the smaller scale without distorting the thin window. Laser welding techniques introduce temperature gradients in the joint. A scaled-down version of the **HTHO** torch fusing method using a CO_2 laser as the heat source was implemented. This required novel adjustments to accepted welding parameters.

Technical Approach

A Synrad 80 W, CW CO_2 laser with 5X beam expander, 4“ f.l. $ZnSe_2$ lens, and rotary head was used to weld 0.425“ diameter, 0.006” – 0.010” thick, fused silica plates to 0.500” outside diameter fused silica tubing with a 0.125” thick wall. Temperature profiles using a two-color pyrometer are measured and discussed. Thermal distributions as functions of laser power, rpm’s, number of passes, joint geometry and part thicknesses are evaluated. Process parameters are related to mechanical test results on finished parts. Finally, we will use a computer thermal model to examine differences between normal laser welding and the **HTHO** methods.

Results/Discussion

Laser welding techniques introduce high temperature gradients in the fused silica joint, promoting stress fractures normally mitigated by keeping thicknesses large. Torch methods use a broad heat source applied over a large area under a slow rotation to gradually heat the glass through the annealing, softening and finally working temperatures. The small size of the piece parts, thick-thin joint geometry and thin-plate pressure requirements prevented application of this method. Initial laser welding experiments were performed joining the 0.006” thick fused silica discs to cylinders of the same material. Different joint fit-ups were used: disk flush, welding orthogonal to the cylinder axis; disk countersunk (both with and without a beveled edge), welding concentric to the cylinder axis. Process parameters that created successful joints had thermal cycles that caused scorching of the glass, unacceptable deformation of the material, or uneven melting of the material. To simulate a typical high temperature hydrogen-oxygen torch fusing method using a CO_2 laser as the heat source, process parameters were adjusted in opposition to the welder’s experience with metal joining. Similar welds on metal parts are usually completed in one pass, at relatively fast speeds, giving deep penetration, hi-aspect ratio welds. This minimizes the thermal and stress effects near vulnerable parts. Spot size is usually minimized and heat sinking is employed to minimize heat diffusion to undesired areas. Thermal distributions as functions of power, speed, number of passes, joint geometry, and part thicknesses, fit-up and tolerances will be evaluated. Data will be used to assess test results on finished parts. We will compare a computer model (COSMOS®) of the normal laser welding regime and the high temperature hydrogen-oxygen torch fusing simulation. The laser welds will be checked for hermaticity. The hermetically sealed thin fused silica windows will then be checked for deformation under vacuum using interferometry.

Conclusions

Hermetic sealing of fused silica pressure-bearing packages with thin-thick geometries was studied using a CO_2 laser as the heat source in a scaled-down version of a high temperature hydrogen-oxygen torch fusing process. As opposed to a "normal" laser welding process, gradual, isothermal heating over a large area of the material was used instead of local deep penetration welds along a narrow molten zone. These glassblowing thermal regimes can be simulated by adjustment of laser parameters (many-pass, out-of-focus, heat-retentive considerations) in opposition to standard metal-welding practices. Thermal distributions and consequences in the two regimes are discussed using an attendant computer model.

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