Cryogenic Stainless to G10 Epoxy Joints

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Abstract

Liquid Argon Time Protection Chambers may require bonding stainless steel items (e.g. structural members) to G10 (fiberglass epoxy) items such as circuit board.
We have calculated the stress on cool down, and cold-shocked several thin and thick samples.
We find that the resulting stresses are well within the epoxy shear stress limits.
The glue stresses are more difficult to assess.
We offer simple steps to reduce the risk of spallation even further.

Stresses on Cooldown

Stainless steel (SS) and G10 fiberglass epoxy in the directions of the fiberglass (in-plane) have similar coefficients of thermal expansion. When laminating the two materials we find that the stresses are moderate. From published sources we find that the integral contraction from room temperature to Liquid argon temperature is 0.00272 for SS, and 0.00208 for G10.
The modulus is 193 GPa for SS, and 18 GPa for G10.
The resulting stress is 1650 psi in the G10, well below the allowable 6000 psi for G10.
Below we discuss the shear stress in the bond.

Stress Distribution

When laminating together two sheets of materials with differing thermal expansion, the shear stress in the bonding material (glue) is (counter-intuitively) located only at the periphery of the sandwich. In the interior of the sandwich there is uniform in-plane stress, and no need to transfer stress from one material to the other.
Hence, we expect bond failure only on the periphery of the sandwich. We know the integral of the shear stress well—it equals the stress tension in the materials. However, the peak value, which allows us to judge whether the bond is in risk of shear failure, depends critically on the geometry, especially the thickness of the materials and of the bond line, and the modulus of the materials and the glue.
Typically, the stress in the materials will be transmitted, via shear stress in the bond over a very short distance , which can lead to high shear stress in the bond and the risk of spallation of the bond.
For thin materials this shear stress occurs over a wider band due to stress deformation in the materials; for thicker materials the transition will be shorter, and the shear stress in the bond will be higher. An FEA model calculation would be required to predict the shear stress in the bond.
Spallation can be dangerous, as it is a progressive failure mode. Once it starts the whole bond may fail.

Tests on Samples

We made tests on several SS-G10 sandwiches. All materials were bonded with translucent Scotchweld 316 , which was post-cured at 60 C for two days to reach final hardness. We made four thin samples (1/16” & 1/16”) and three thick samples (1/2” on ½”). The samples were cold shocked in LN2 and warmed several times.
One of the thick samples cracked on warm-up, which was done under warm water from a faucet.
We think some water entered a small crack between the materials, froze, and forced the two materials apart. The remaining samples were warmed in air, and survived several cold shocks, without failing.

Additional Safeguards

One can ensure safe cool-down without spallation by protecting the periphery of the bonding area.

Two methods can be used:

1. Reinforcement, e.g. with rivets
2. Widening the shear stress band by thinning the material with the lower modulus; if the bond width can be tripled, stresses go down by a factor of three.

Conclusions

We have calculated and tested SS-G10 bonded samples.
We conclude that bonding can work; additional safeguards are desirable and possible.