



ENG-062 - TREP - TEST REPORT

HTT Diffusion Bonding Test Report

NSTXU_1-1-3-3-10_TREP_100

Work Planning #:
Effective Date: **02/14/2020**
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National Spherical Torus eXperiment Upgrade

Test Report

HTT Diffusion Bonding Test

CAT. A-3
REV 0
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Prepared By:

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1. SUMMARY

Three test runs were successfully completed over the total performance of the heat transfer diffusion test. Under specific conditions diffusion bonding was observed; no permanent diffusion bonding was observed between the testing fixture and the Inconel 625 tubing.

2. INTRODUCTION

The Heat Transfer Tube (HTT) serves as the main heating and cooling apparatus in the NSTX-U during Bakeout and operation, respectively. To ensure the longevity of the Inconel 625 tubing that is specified, a heat treatment process is imperative. During the heat treatment process, the HTT will be sandwiched between an Inconel 625 Sleeve and an Inconel 625 mandrel. As such, the feasibility of heat treatment without diffusion bonding is investigated and concluded in this report. Heat treatment in this test is performed with and without the stop-off brazing aid.

Testing was completed in the Vacuum Braze – Material Testing Lab, at PPPL. Tests were conducted under the supervision of Steve Jurczynski.

3. TESTING SPECIFICATIONS

I. Standards and Codes

These Standards and Codes set forth the minimum requirements.

ASTM American Society for Testing and Materials

ASTM B444 – Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625 and UNS N06852) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Pipe and Tube

ASME American Society of Mechanical Engineers

ASME BPVC.II.D.M-2015 – 2015 ASME Boiler and Pressure Vessel Code

II. Testing Parameters

Following the testing procedure [1], testing was performed at 950°C, for 2 hours, on each run.

The sequence of test runs are as follows:

TEST 1: 1000 lbf on each bolt (50 lbin torque per bolt)

TEST 2: <20 lbf on each bolt (~1 lbin torque per bolt)

TEST 3: 1000 lbf on each bolt (50 lbin torque per bolt) – **RED STOP-OFF APPLIED**

(Per [1], a fourth test was recommended, but not performed as TEST 3 provided sufficient data. The test was deemed not necessary by COG).

III. Fixture and Hardware

The fixture was fabricated from Inconel 625 plate per [2]. Inconel 625 plate was in PPPL inventory and manufactured in the PPPL Machine Shop. Tubing was straightened and cut after the fixture was produced. Inconel 625 Tubing was fabricated and purchased from Handy Tube, meeting ASTM B444 Grade 1 standard. Inspection of the fixture and tubing was completed by engineering, meeting necessary tolerances per [2]. Hardware was purchased from Extreme Bolts. All Hardware was Inconel 625.

4. Results

I. Test 1: 1000lbf per bolt (no red stop-off)

The results of this test are shown below. The discoloration of the hardware is due to the green stop-off applied to prevent any diffusion of the nuts to the bolts. Under the pressure applied by the load of each bolt, diffusion was observed in the hardware. Additionally, diffusion bonding was observed between the Inconel 625 fixture and the Inconel 625 tubing. The bonding was broken after a force was applied and the Inconel 625 tubing was removed from the fixture.

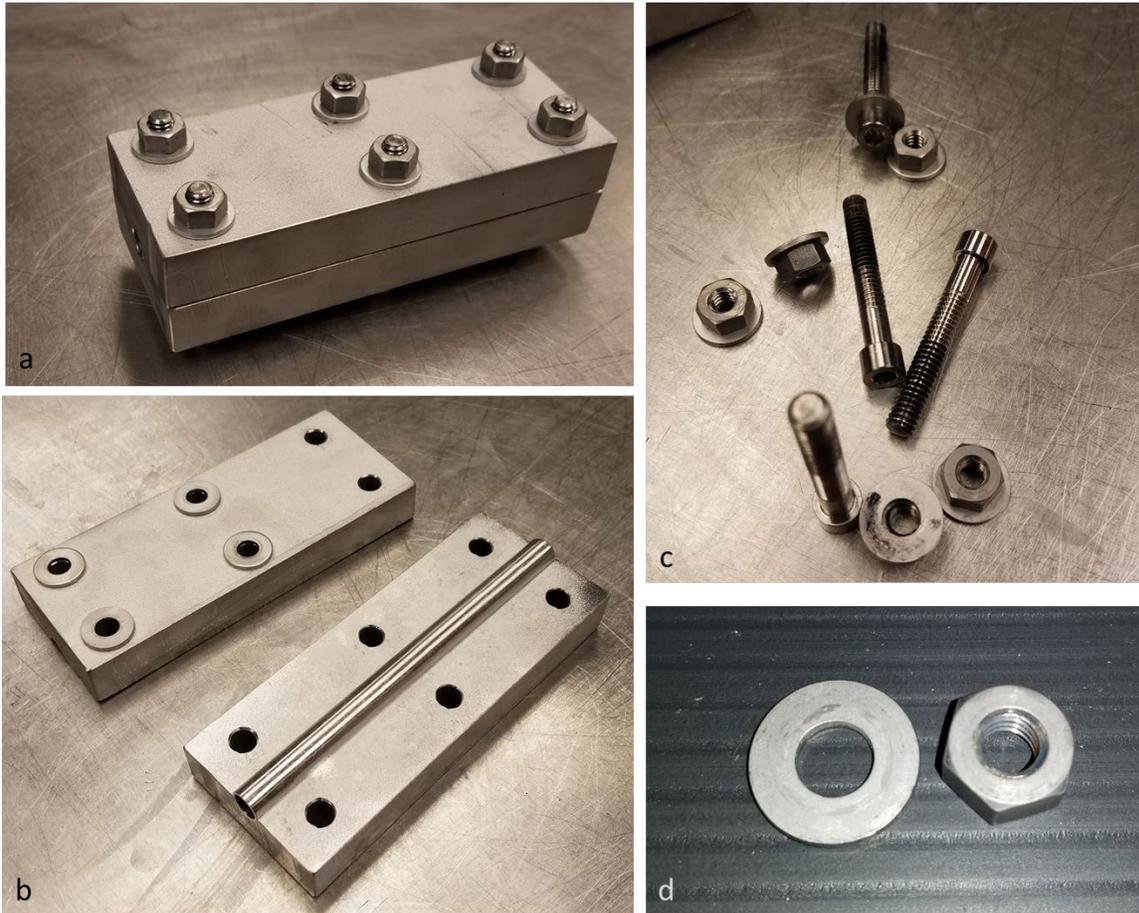


Figure 1: Test 1: 1000 lbf per bolt (no red stop off). (a) Diffusion Fixture after being removed from the vacuum furnace. (b) Diffusion fixture after hardware was loosened and removed, evidence of diffusion bonding is shown as the Inconel 625 tubing and Inconel 625 washers have remained on the fixture. A simple application of force is used to break the diffusion bonding. (c) The Inconel 625 hardware after heat treatment. The black discoloration is due to the application of the green stop-off brazing agent. (d) A close up view of a washer and nut after the diffusion bond has been broken. On the washer, a visual outline of the nut can be seen as the locations of diffusion bonding.

II. Test 2: <20lbf per bolt (no red stop-off)

The results for this test are shown below. There was no diffusion bonding observed during this test. The Inconel 625 Tubing was easily removed from the fixture after heat treatment was completed. There was no force applied as no bonding was observed. The hardware is from Test 1.

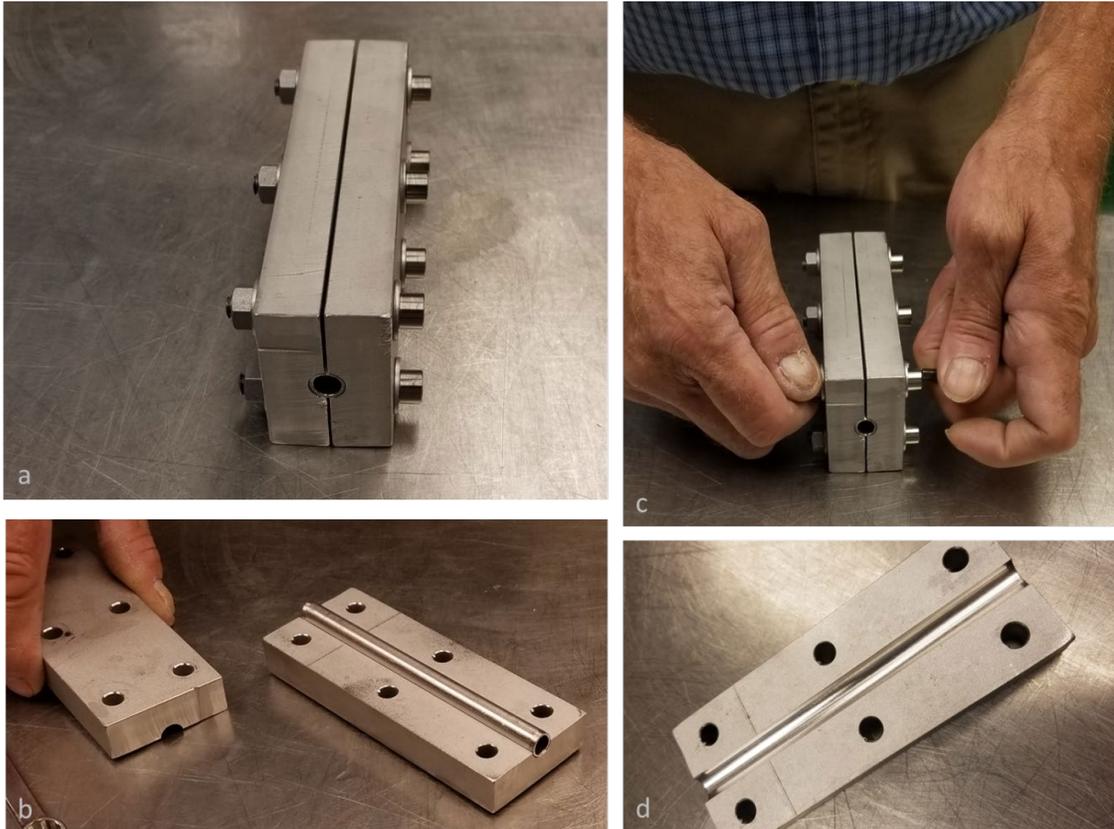


Figure 2: Test 2: <20 lbf per bolt (no red stop off). (a) Diffusion Fixture after being removed from the vacuum furnace. (b) Bolts were loosened by hand or by a wrench where heavier application needed to be applied. (c) Once the hardware was removed, the fixture easily came apart, the Inconel 625 tubing was also easily removed as represented by (d).

III. Test 3: 1000lbf per bolt (red stop-off applied)

The results of the test are shown below. Diffusion bonding of the hardware was once again observed. There was no diffusion bonding between the Inconel 625 fixture and the Inconel 625 tube. The discoloration of the Inconel 625 tubing is a result of the red stop-off that was applied.

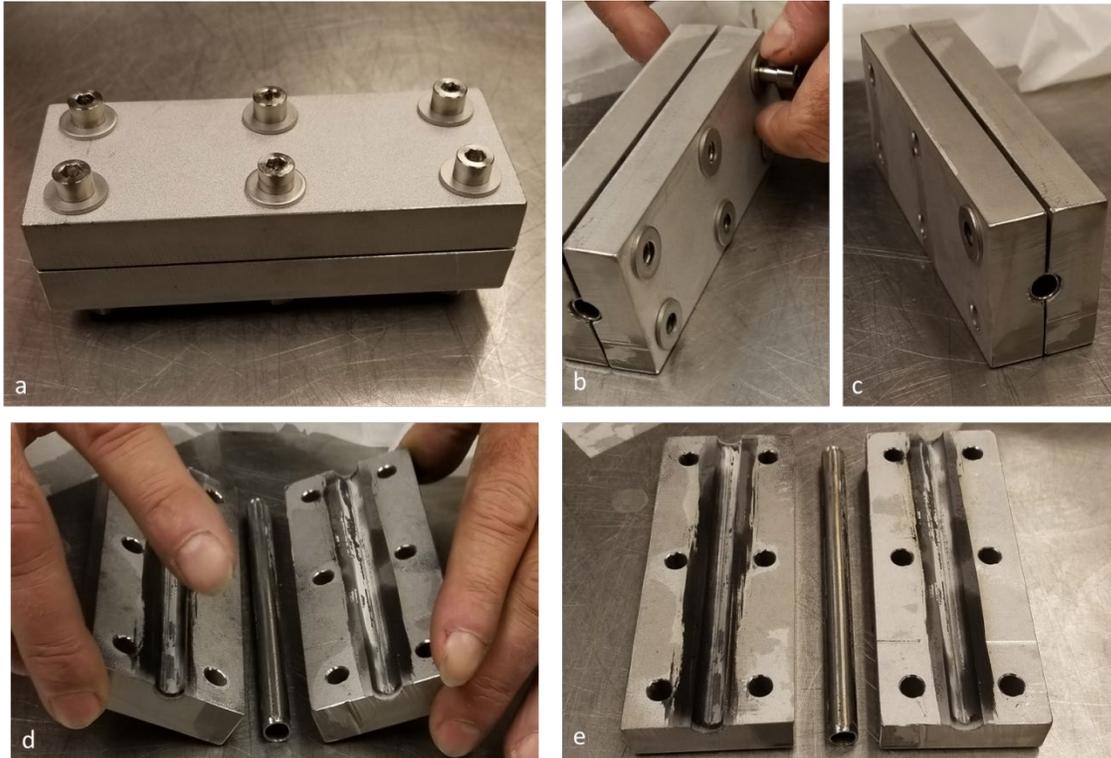


Figure 3: Test 3: 1000 lbf per bolt (red stop-off applied). (a) Diffusion Fixture after being removed from the vacuum furnace. (b)-(c) Hardware is removed from the fixture after being removed from the furnace. Diffusion Bonding was observed and the application of an applied force was enough to break the bonds. (d)-(e) Once the hardware was removed, the tubing fell out of the fixture. No diffusion bonding was observed with the tubing. (d) Shows the tubing the moment the fixture was opened, (e) shows the complete fixture and tubing unobstructed. The black coating is a result of the red stop-off application.

5. CONCLUSION

No permanent diffusion bonding was observed over these three tests. As there was some diffusion bonding observed, these bonds were broken easily under the application of an external load. After the red stop-off was applied, the Inconel 625 Fixture and Inconel 625 tubing did not experience any diffusion bonding; as it previously did under the same conditions without the red stop-off.

6. REFERENCES

- [1] NSTXU_1-1-3-3-10_PLAN_100 Test Plan for the Heat Transfer Tube Annealing Diffusion Test
- [2] 0DDB1510 Heat Transfer Tube, Inconel Diffusion Test Fixture