McMaster University & Dana Canada Incorporated

NSERC CREATE
Fitting Durability Study

Case Study – Summer 2019

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Abstract

Incomplete braze joints have been found inside the customer's cooling plates. The joints in question are limited to the intersection where the two core plates meet the fitting. These incomplete joints have resulted in leak sites during module assembly after having passed a cooler production leak test. X-Rays of many parts have shown braze joint lengths which range from completely filled (ideal) to having 2 mm or less of the joint filled. The customer has expressed that the fittings can be bent during assembly. They desire to know the potential consequences if they bend these fittings. The force applied has been estimated as 27N at a distance of 36mm from the fitting-plate edge interface, corresponding to a bending moment of about 1Nm.

Purpose

A cyclical loading-leak test has been developed to better show the robustness of this joint in comparison to the amount of joint that is filled. The occurrence of possible leaks for modules assembled is desired by the customer. To assess the occurrence, a sample of parts are subjected to non-destructive X-Rays in order to measure the braze joint length followed by bending these fittings in two orthogonal directions (parallel and normal) to the cooler. The occurrence of a leak is then detected by a production leak test.

Cyclical Deflection

Test Fixtures

Cyclical loading on the fittings is done in the normal (blue) and parallel (orange) directions, as seen in Figure 1. The plate fixture is made of two parts that clamp the plate flat, as seen in Figure 2.

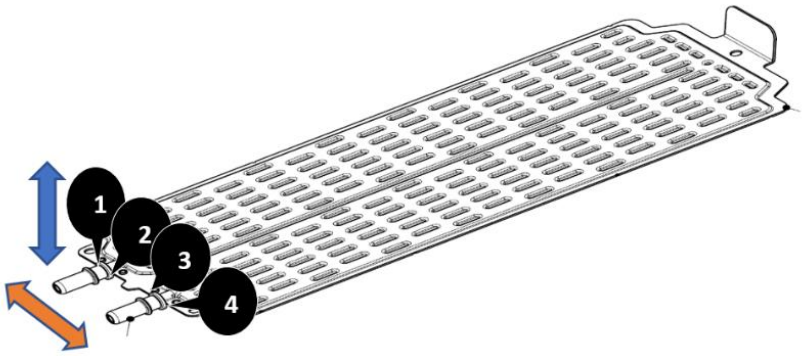

Figure 1: Deflection Directions

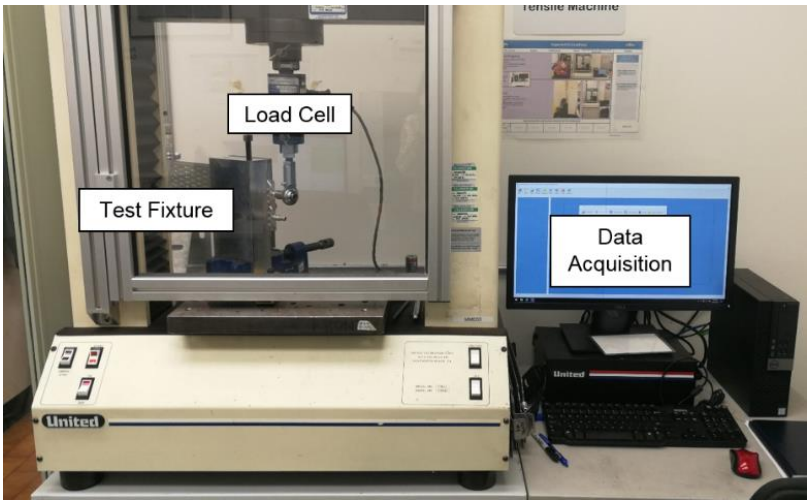

Figure 2: Instron Machine

Cyclical Deflection Procedure

The procedure to follow for the deflection tests is the following:

1. X-Ray the sample to determine the amount of braze joint present on each side of each fitting. X-ray images are found in the Appendix.
2. Dry leak test the cooler using the LT2 machine as seen in Figure 3a. Part setup can be seen in Figure 3b.
3. Clamp the cooler into the deflection fixture in the normal position. Part setup can be seen in Figure 4a. The plate is clamped near the first set of dimples; this is the assumed edge of the battery module and the location the plate bends about.
4. Cycle each fitting 2000 times by displacing its tip back and forth 1mm in a direction normal to the plate (2mm total tip movement).
5. Leak test the part. If it does not leak, test the fitting in the direction parallel to the plate using the parallel part setup in Figure 4b.
6. Apply a load of ±44N for 2000 cycles in the parallel direction (corresponds to a bending moment of 2Nm).
7. Dry leak test the part.
8. If the part fails either dry leak test, then wet leak test the part to locate the source of the leak.

Figure 3: Dry Leak Testing Machine (left) and Cooler Setup (right)

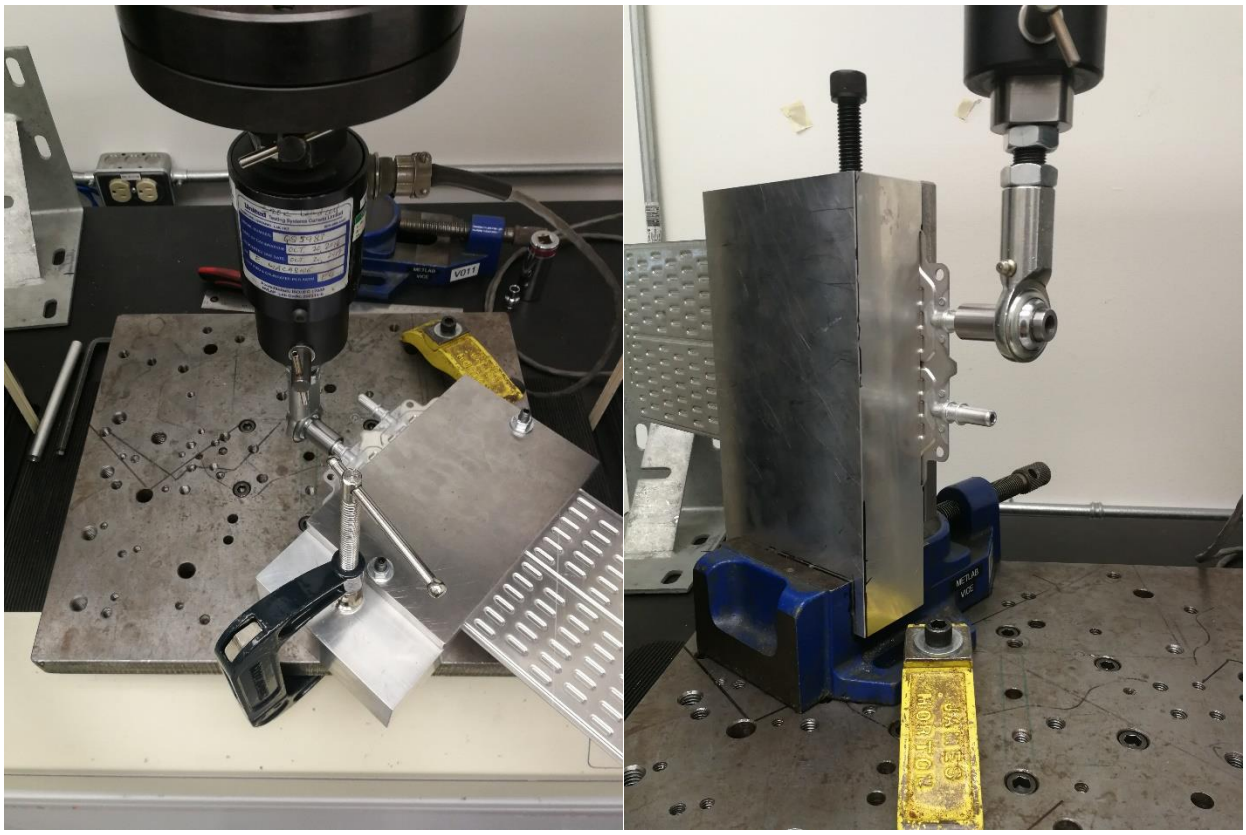

Figure 4: Instron Testing Fixtures - Normal (left) and Parallel (right)

Dry Leak Testing

Leak testing of the part was conducted at 55 psi. The flow rate was recorded after the testing had completed. Setup can be seen in Figure 3.

Testing Data

Table 1: Braze Joint Sizes

Lab X Number	Plate	Fitting	Braze Length 1 (mm)	Braze Length 2 (mm)
X0830	1	3 and 4	4.51	4.97
X0830	11	3 and 4	4.48	4.34
X0830	6	3 and 4	4.41	4.31
X0830	7	1 and 2	4.27	4.47
X0830	11	1 and 2	4.06	4.27
X0830	12	3 and 4	4.04	4.83
X0830	6	1 and 2	3.98	4.65
X0830	12	1 and 2	3.86	4.34
X0785	11	3 and 4	3.19	7.59
X0785	13	3 and 4	2.72	5.09
X0785	11	1 and 2	2.43	9.51
X0787	2	3 and 4	2.24	5.76
X0785	14	3 and 4	2.23	5.85
X0787	15	3 and 4	2.19	2.42
X0787	15	1 and 2	2.18	2.20
X0787	7	3 and 4	2.11	2.11
X0787	20	1 and 2	1.90	2.29
X0785	10	1 and 2	1.88	9.22
X0785	12	1 and 2	1.68	4.87
X0787	4	1 and 2	1.68	8.00
X0787	3	3 and 4	1.63	2.10
X0787	7	1 and 2	1.45	8.00
X0785	14	1 and 2	1.33	8.24
X0787	6	1 and 2	1.16	2.56
X0787	3	1 and 2	1.15	2.00

Table 2: Dry Leak Test - Leak Rates

Lab X Number	Plate	Fitting	Normal Leak Rate (CCM)	Parallel Leak Rate (CCM)
X0830	1	3 and 4	0.39	0.06
X0830	11	3 and 4	0.25	0.26
X0830	6	3 and 4	0.29	0.34
X0830	7	1 and 2	0.25	0.39
X0830	11	1 and 2	0.25	0.24
X0830	12	3 and 4	0.21	0.23
X0830	6	1 and 2	0.28	0.35
X0830	12	1 and 2	0.24	0.20
X0785	11	3 and 4	0.17	0.36
X0785	13	3 and 4	0.15	0.33
X0785	11	1 and 2	0.17	0.23
X0787	2	3 and 4	0.12	0.16
X0785	14	3 and 4	0.19	0.09
X0787	15	3 and 4	0.12	0.18
X0787	15	1 and 2	0.16	0.17
X0787	7	3 and 4	0.16	0.18
X0787	20	1 and 2	0.14	0.18
X0785	10	1 and 2	0.18	0.20
X0785	12	1 and 2	0.18	0.14
X0787	4	1 and 2	0.16	0.19
X0787	3	3 and 4	0.16	0.15
X0787	7	1 and 2	0.16	0.04
X0785	14	1 and 2	0.15	0.09
X0787	6	1 and 2	0.17	0.12
X0787	3	1 and 2	0.17	0.26

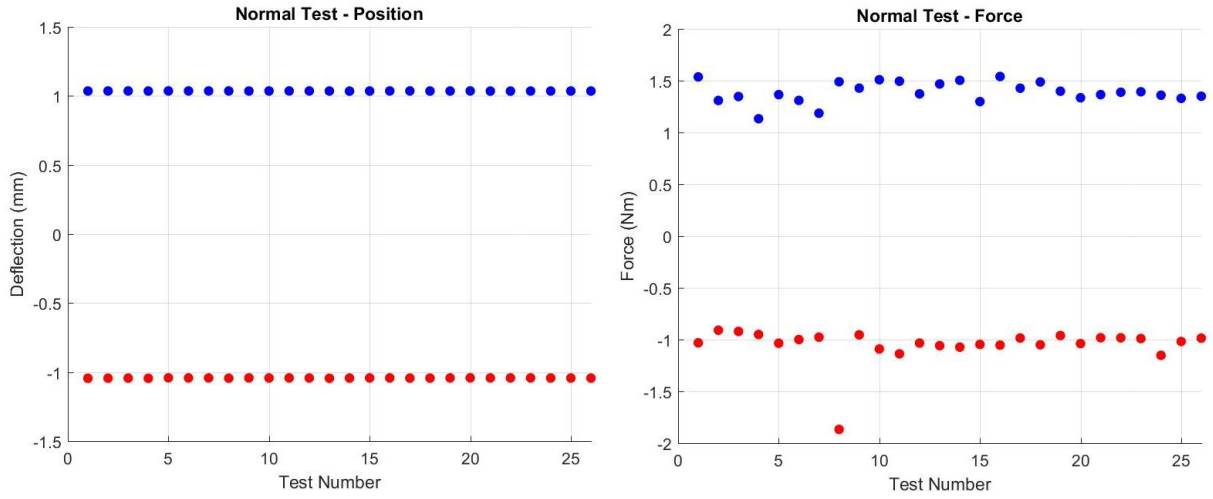

Figure 5: Instron Testing Results – Normal Direction

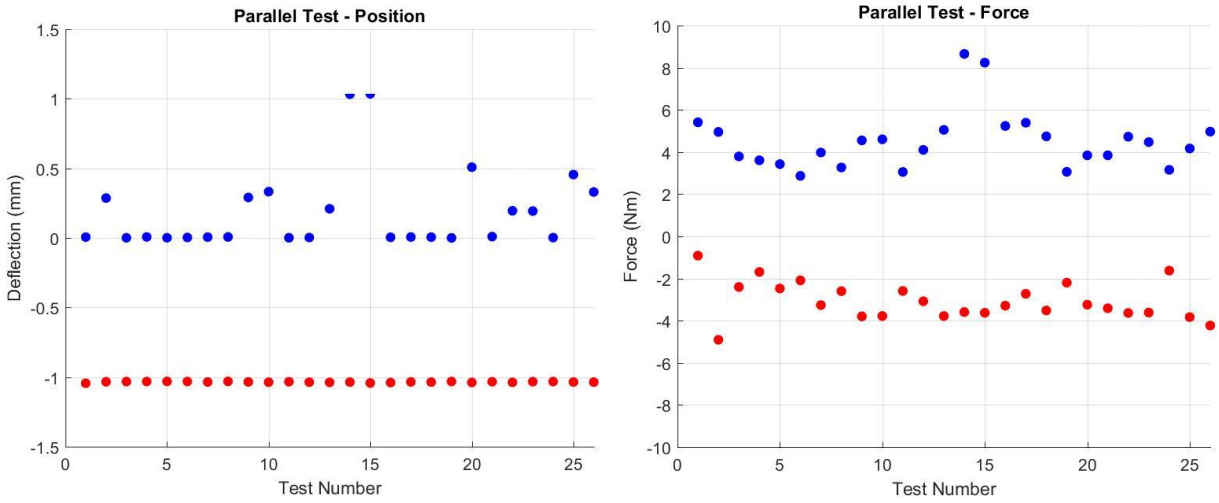

Figure 6: Instron Testing Results - Parallel Direction

Matlab Program

The Matlab script file titled *Instron_Data_Generation.m* runs the code. The user must make one change for the program to run: they must change the folder location to the current folder of the main script file. After that is completed, the script may be run.

The script takes raw Instron data collected during testing and outputs the corrected and normalized data in a Matlab data file. It also produces the figures seen above, used in the report given to the customer. The Instron collects the force data with an opposite sign, thus this is corrected in code.

Since the Instron collects position and force data in imperial units, conversion to metric must be done. The equations used can be seen below.

$$Millimeters = \frac{Inches}{25.4} \qquad Newton\ Meters = Pound * 4.44822 * Distance$$

Results

A sample of 25 coolers were selected for testing. The braze joints ranged in size from 1.15 to 4.51 mm, as seen in Table 1. Additionally, seven of the coolers had less than 2.6 mm on both of the joints.

The results of normal deflection testing are seen in Figure 5. Although the programmed range of movement was less than ±1mm, the Instron overshot the distance which resulted in a range of ±1.04mm. Thus, fittings were bent beyond specification for 2000 cycles in the normal direction. The forces required to move the fittings can be found in the Appendix. All coolers were subjected to forces above 0.9Nm in both directions, while fourteen of the 25 coolers tested were subjected to forces above 1Nm in both directions.

Parallel deflection tests can be seen in Figure 6. Achieving a total range of ±1mm in this direction was difficult due to the larger force required to bend the fitting. A maximum force of ±44N was imposed on the Instron to keep it within the 1Nm specification. The Instron overshot and resulted in larger forces that ranged from 4.92Nm in the negative direction, to 8.66Nm in the positive direction. In addition, the Instron had trouble bending the fitting upwards, resulting in a total deviation downward of -1mm by the end of most parallel tests.

In order to fully test the positive direction in the parallel test, nine plates were deflected upwards before the test began. Thus, Figure 6 shows that the range of motion of some plates was above 0mm.

To complete dry leak testing, the fittings were bent back to 0mm after both the normal and parallel deflection tests. This was to ensure that the plate fit snugly into the dry leak testing fixture. As seen in Table 2, all plates passed the dry leak test after both deflection cycles since all leak rates were below 0.4CCM.

Discussion

The results show that the plate fittings may be bent back to their original position if deflected ±1mm during assembly. However, it is more advisable to bend the fittings back if they are deflected along the normal direction since it requires less force. If fittings are bent along the parallel direction, care must be taken to ensure that they have bent less than ±1mm.