Test Report

BINDING STRENGTH OF COPPER CLADDING ON ALUMINIUM BUSBARS USING THE ELCOMETER PULL-OFF TEST

Restricted – In Confidence

By
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Summary

Elcometer pull-off tests were conducted to assess the binding strength of copper cladding on aluminium busbars. Tests were conducted using standard 12.7 mm diameter stubs attached to the copper cladding with FM1000 adhesive from Cytec Engineering. Three sets of copper clad specimens were examined which had been exposed to -40 °C to + 110 °C for 0, 50 and 100 cycles. None of the claddings were found to delaminate in the pull-off tests indicating that their binding strengths were all greater than that of the adhesive used to attach the stubs (>61 MPa).

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CONTRACT

The contract between NPL and Applied Composite Materials Ltd was as follows:

Initial and final binding force tests on copper clad aluminium busbars to be conducted.

Start: 7 October 2014

Completion: 14 October 2014

Customers artefacts:

Table 1 ***Copper clad aluminium busbars with different environment exposure cycles have been given the following NPL codes.***

NPL code	Environmental exposure
AAKJZ232A	0 cycles
AAKJZ232B	50 cycles (-40 °C to + 110 °C)
AAKJZ232C	100 cycles (-40 °C to + 110 °C)

1. INTRODUCTION

NPL was instructed by Applied Composite Materials to conduct a series of pull-off tests using the Elcometer pull-off tester to determine the binding strength of copper clad aluminium busbars exposed to -40 °C to + 110 °C for 0, 50 and 100 cycles. This report describes the tests and the results obtained.

2. TEST PROCEDURE

Adhesion tests were conducted by attaching aluminium stubs (12.7 mm diameter) to the copper cladding using FM1000 adhesive. The tests were conducted using a commercially available Elcometer Patti 100 test rig with a F12 piston (Figure 1). The tests involved screwing a pull-off stub into the top platen of the rig which could be moved freely relative to the lower platen. The stub was then pulled from the copper cladding by inflating a pneumatic bladder that pushes the two platens apart. The peak pneumatic pressure at failure was recorded and converted to a value of tensile stress (binding strength) through look-up tables supplied with the equipment.

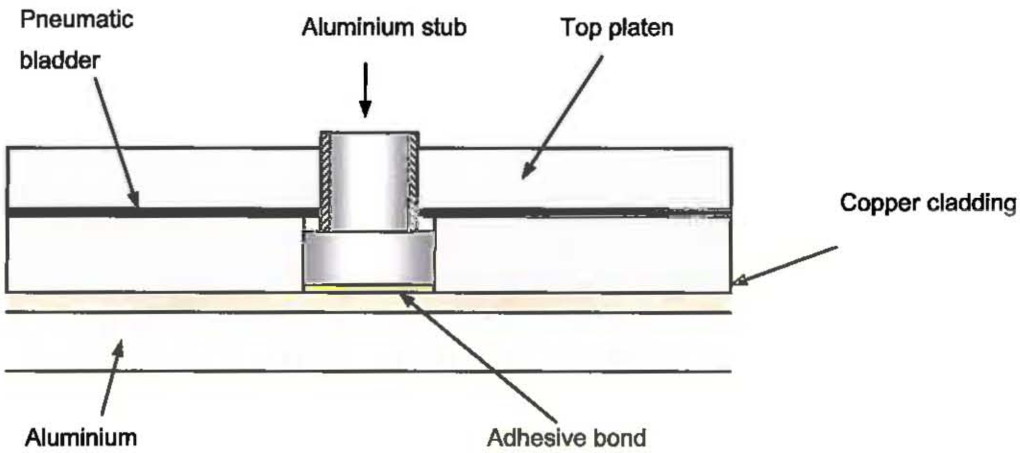

Figure 1 ***Schematic Representation of Pull-Off Test Equipment***

3. RESULTS AND DISCUSSION

The binding strengths obtained from the pull-off tests are shown in Table 2 with three repeat tests conducted on each bar.

After a stub had been pulled from the surface, the fracture surface was visually examined. In each case it was found that the FM1000 adhesive had failed with no sign of any of the claddings delaminating (Table 2). This indicates that the binding strength of the cladding is greater than the adhesive used to attach the stubs for each of the specimens examined. The variability in the results is due to variability in the adhesive rather than the cladding and it would appear valid to assume that the binding strength of the cladding is greater than the maximum value obtained using the pull-off test of 61 MPa. Increasing the number of exposure cycles the busbars were subjected appears to have no effect on the binding strength of the copper cladding (Table 2).

4. CONCLUSIONS

None of the claddings were found to delaminate in the pull-off tests indicating that their binding strengths were all greater than that of the adhesive used to attach the stubs (>61 MPa). Increasing the number of cycles the specimens were exposed to had no significant effect on the binding strength of the specimens up to 61 MPa.

Table 2 Pull-off tests results for copper clad aluminium busbars

Disc Number	NPL Material Code	Exposure cycles	Tensile strength (MPa)
1	AAKJZ232A	0	55.60
1	AAKJZ232A	0	60.90
1	AAKJZ232A	0	59.10
2	AAKJZ232B	50	58.10
2	AAKJZ232B	50	59.20
2	AAKJZ232B	50	61.00
3	AAKJZ232C	100	59.10
3	AAKJZ232C	100	60.10
3	AAKJZ232C	100	58.10

Appendix 1 Interfacial strength test

An additional test was conducted for the customer, which was outside the main measurement service contract. This involved conducting an interfacial strength test on a busbar prepared by the customer. The specimen was rectangular shaped with a width of 20mm and precisely drilled with a 4mm long channel cut from the upper copper layer through the sample leaving just the bottom copper layer. A second channel was then cut parallel to the first through the bottom copper layer leaving a bimetallic connecting area (Figure 2). The bars were tested using an Instron 5500 K8026 tensile machine fitted with a calibrated load cell (load cell no. UK034, E11809111310). The specimens were placed in the grips, taking care to align the longitudinal axis of the test specimen with the axis of the testing machine. Tests were conducted at a rate of 1 mm/min and the tests continued until the specimens fractured. Load-cell force measurements were automatically recorded throughout the experiments. The load-displacement results for this test are shown in Figure 3, with the maximum load at fracture recorded as 2.945 kN.

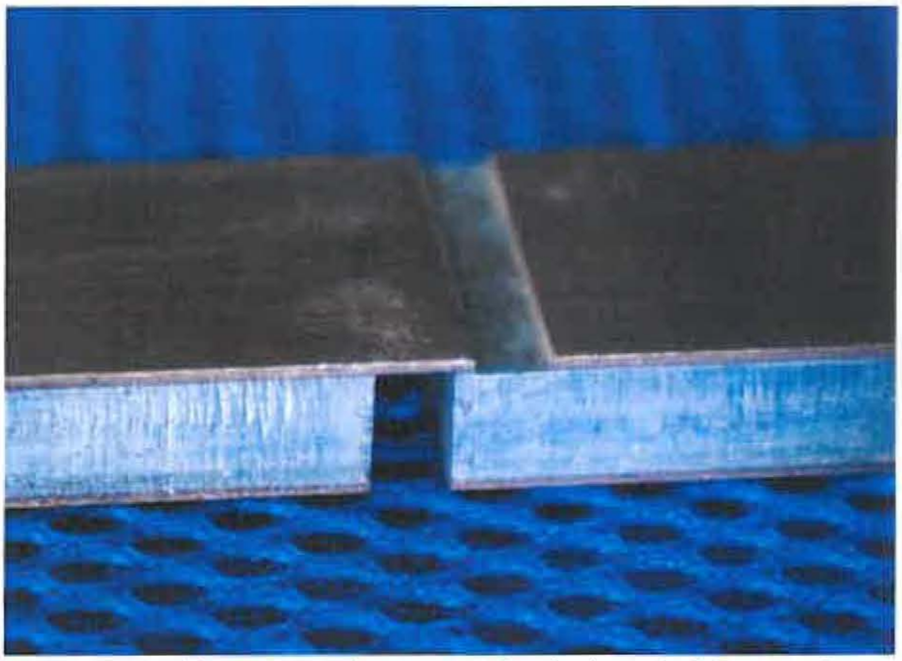

Figure 2 Typical busbar specimen used for the interfacial strength test

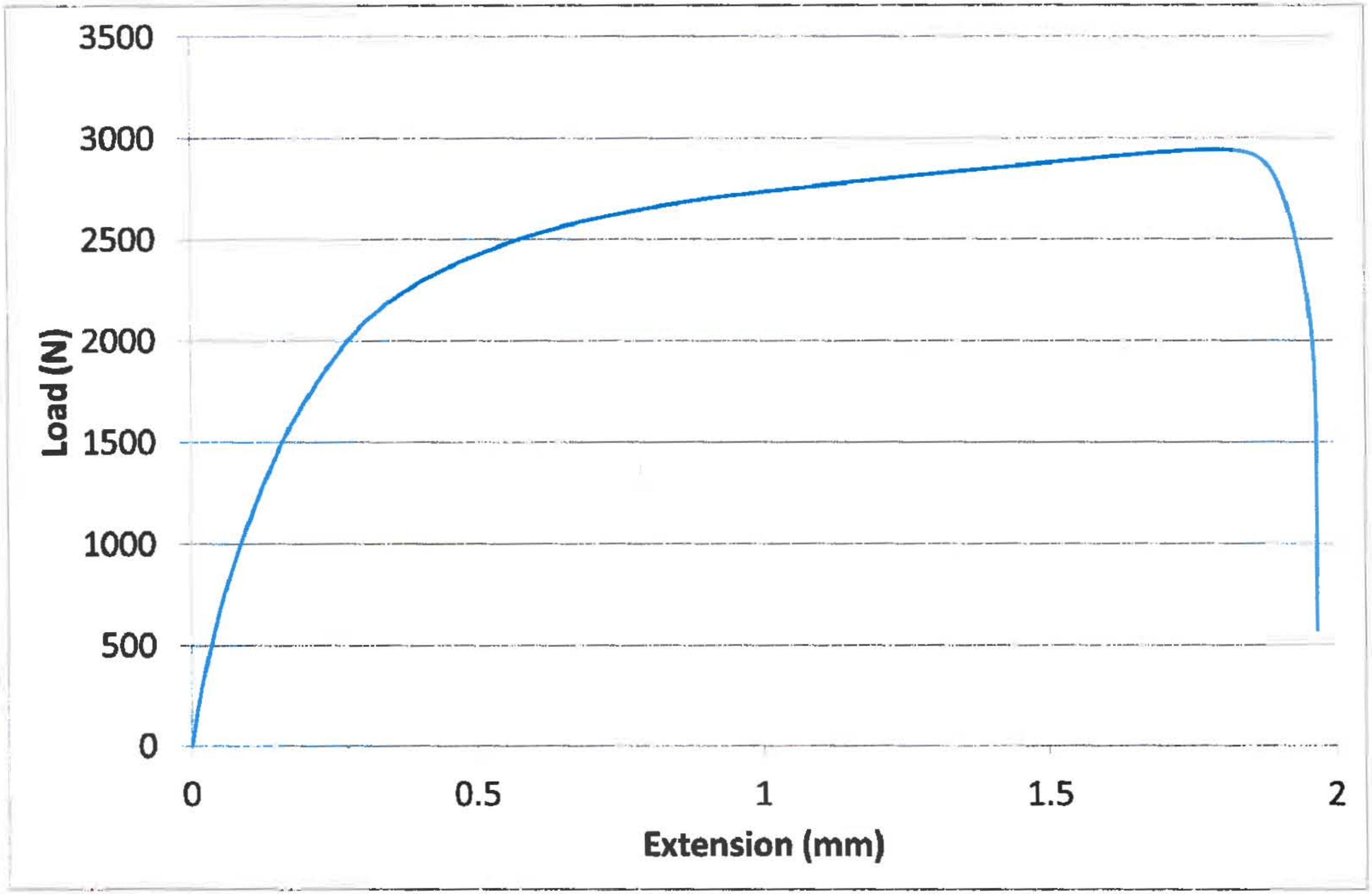

Figure 3 ***Load-displacement results obtained from interfacial strength test.***

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Continuation Sheet

Reference: 2014070246

Checked by: MPL Gower