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Contractor Report

SPOT WELDING PROTOCOL

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Spot Welding Protocol

Introduction to Spot Welding of dcPD Probe Wires

After introducing the corrosion pit at one edge of the center hole of an aluminum alloy specimen, the specimen is ultrasonically cleaned in isopropanol for 15 minutes. After cleaning, the specimen is now ready for spot-welding of direct current potential difference (dcPD) probe wires. Polytetrafluoroethylene (PTFE) insulated copper wires (0.005" diameter) are used as dcPD probes for the pit-crack experiments. The copper wires are spot welded on each side of the corrosion pit at equidistance from the pit centerline.

Spot-Welding Stage

The portable spot welder also referred to as portable head piece (PHP), welding electrode (Cu-Cr alloy shank with tungsten insert) and the Dual Pulse 125 stored energy power supply are purchased from Miyachi Unitek Corporation. Figure 1 shows the spot welding stage that has been built in-house. The welding stage consists of an x-y translation table. The two tables are placed one on top of the other and are both fixed to the aluminum base. At one end of the base, another table is attached to the aluminum base by means of a hinge and controls the Z direction movement. The PHP is fixed to the Z-axis table by means of aluminum supports. The Z-axis table along with the spot welder is together referred to as the welder-handle in this document. The welder-handle can be rotated about the hinge toward and away from the work piece. A plastic knob (Figure 1: Z-axis knob) at the base of the welder-handle is used to secure the welder-handle to the aluminum base for the spot welding operation.

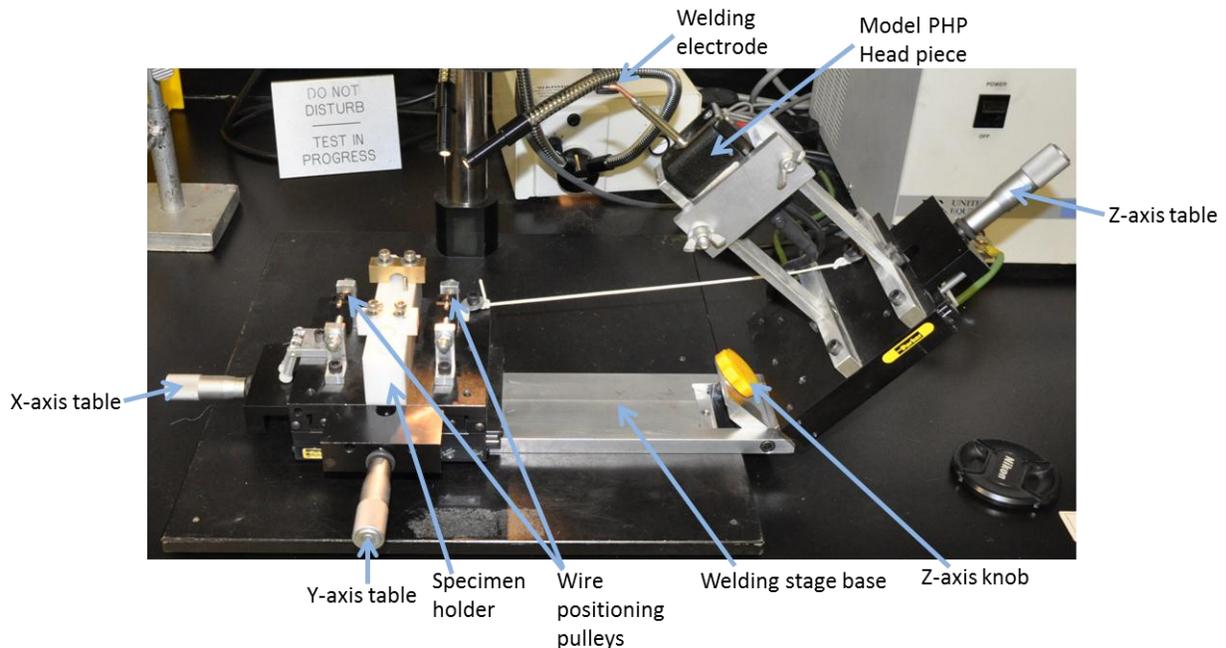


Figure 1. Spot welding stage showing various components of welding.

A specimen holder made of Teflon is fixed on top of the (X-axis, Y-axis) translation tables. The Teflon holder is grooved (diameter of the groove is same as that of the specimen threaded ends) on the top at the center along its length. This grooved top ensures that the specimen sits in place without tilting. The specimen is additionally held in place by means of two clamping blocks which are screwed at each end of the Teflon holder. One of the clamps is made of brass and the other is made of Teflon. The brass clamp serves as an alternate connection point for the negative terminal (green end) of the spot welder power

supply. Figure 2 shows the connection point for the negative terminal (green end) of the spot welder power supply.

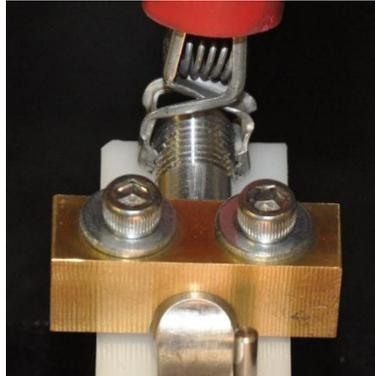


Figure 2. Connection point for negative terminal of spot welder power supply.

Figure 3 shows the Teflon wire-spacing pulley which is used for spacing the copper wires at a fixed distance. The image shows the pulley with grooves spaced at 1 mm (center-to-center). There are two such pulleys positioned on either side of the specimen holder. Figure 4 shows the two wire-spacing pulleys on each side of specimen holder. The pulleys are placed on pulley holders which are fixed to the Y-axis table. The two pulleys can be moved up and down along the Y-axis by means of two pulley positioning screws. Once the specimen is placed on the specimen holder, the copper wires are placed along the pulley grooves and are held by Teflon thumb screws on either side of the specimen. Figure 5 shows the thumb screws to the left and right of the specimen holder.



Figure 3. Wire-spacing pulley with 1 mm spacing between grooves.

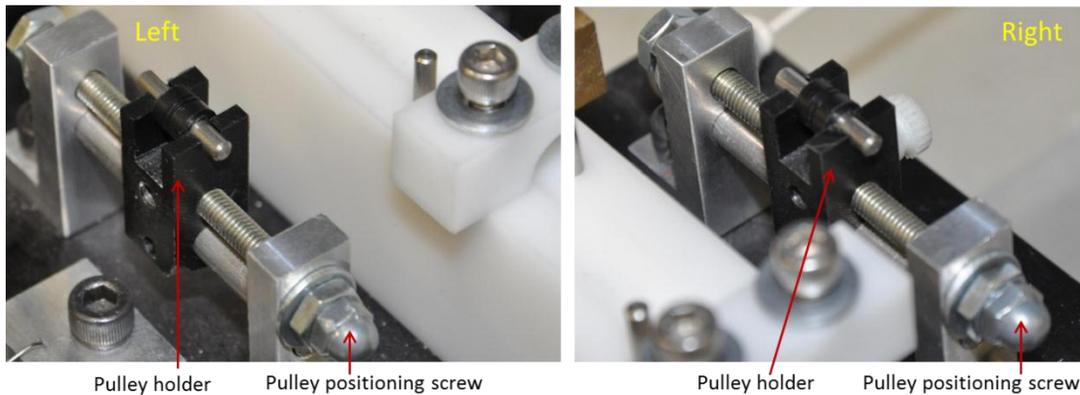


Figure 4. Wire-spacing pulleys on pulley holders on each side of the specimen holder

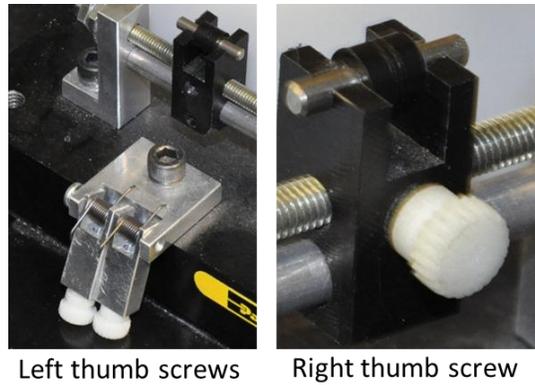


Figure 5. Thumb screws: 2 to the left and 1 to the right of the specimen holder

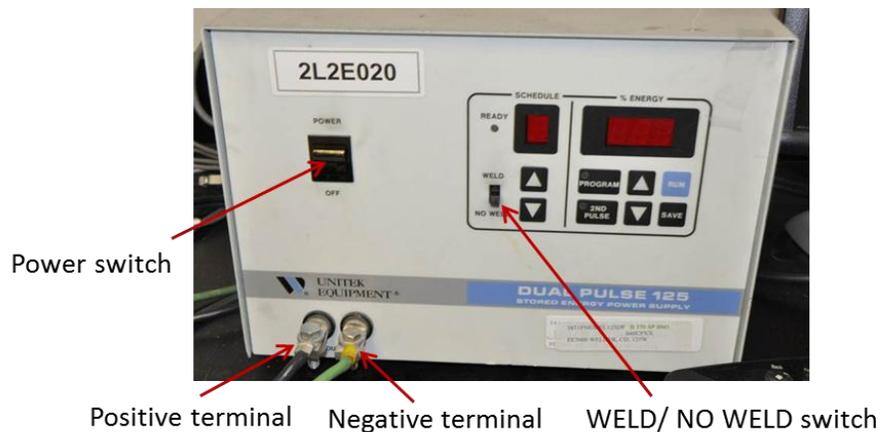


Figure 6. Dual Pulse 125 stored energy power supply showing the terminals and switches.

Figure 6 shows the Dual Pulse 125 Stored Energy Power Supply supplied by Miyachi Unitek which is used in the spot welding power source. The positive terminal (black end) is connected to the spot welder (PHP) and the negative terminal (green end) is connected to the work piece (either specimen or brass clamp). The required energy levels can be programmed and stored in the equipment for future use.

Spot Welding Procedure

The aluminum alloy specimen with the corrosion pit is placed on the Teflon holder and is held in place by means of the two clamping blocks. The specimen is placed on the Teflon holder in such a way that the corrosion pit can be viewed from the top and the pit is on the left side of the central hole of the specimen. The X-Y translation table of the spot welding stage is designed in such a manner that the dcPD probe wires (copper wires) can be spot-welded only when the corrosion pit is on the left side of the central hole. As mentioned previously, two pieces of copper wire with PTFE insulation are used as the dcPD probe wires. To interface with the test frame, about 2 feet of wire is needed. Before placing the wire in the welding fixture, about 3 inches of PTFE insulation is stripped off one end. The stripped wires are carefully placed along the wire-spacing pulley grooves and held in place with the help of Teflon thumb screws (Figure 5). The placement of the wires has to be in such a manner that the PTFE insulation on both wires come as close as possible to the corrosion pit. Figure 7 shows an image of how close to the corrosion pit the PTFE insulation of copper wires was placed. The image shows a post-welded wire placement.

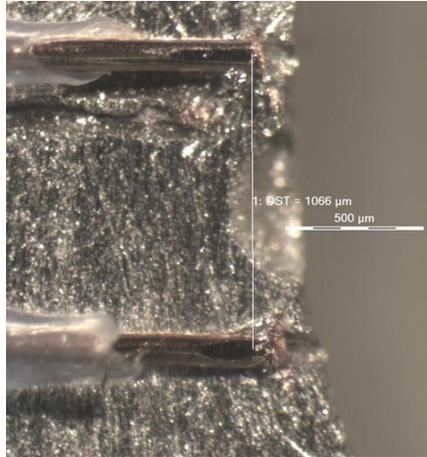


Figure 7. Closeness of PTFE insulation of copper wires to the corrosion pit.

Such wire placement will ensure that only a very small portion ($< 200 \mu\text{m}$) of the stripped copper wire is exposed to possibly be in contact with the alloy beneath. Once the copper wires are secured with all the necessary adjustments, the specimen is viewed through an optical microscope (Olympus SZH) to assess the accuracy of the wire placement on each side of the corrosion pit.

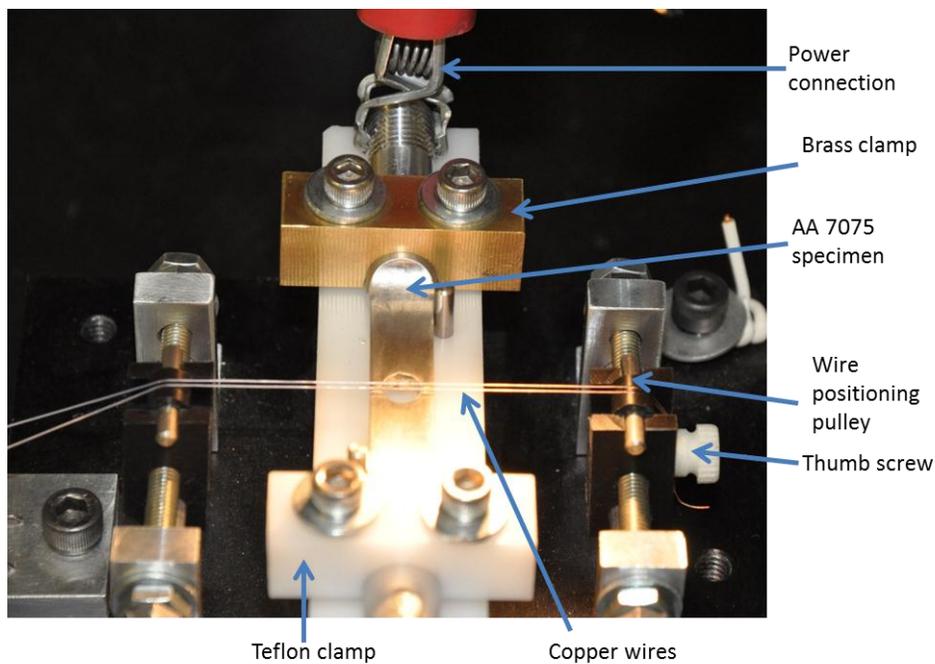


Figure 8. Specimen and copper wires held in position prior to spot-welding.

The placement of the two wire-spacing pulleys can be adjusted by means of two pulley positioning screws attached to the pulley holders (Figure 4). By viewing through microscope, the position of the wire-spacing pulleys should be adjusted so that the two copper wires fall equidistance from the corrosion pit centerline. The distance between the two copper wires can be measured before welding. Figure 8 shows the image of the specimen and copper wires held in position prior to spot-welding.

The welder-handle is now flipped toward the specimen and is held tight to the aluminum base by means of the yellow knob (Figure 1: Z-axis knob). The welding electrode tip which is threaded into the spot welder can be viewed through the microscope to assess the position accuracy on the copper wire. The spot welding is carried out for one wire at a time. The placement of the copper wire under the welding electrode is adjusted by means of the screw gauges on the X and Y axis tables. The welding electrode is lowered by moving the Z-axis screw gauge in a counter-clockwise direction. By adjusting the wire-spacing pulleys, and X, Y-axes tables, the copper wire is placed exactly below the electrode welding tip. The negative terminal (green end) of the spot welding power supply is now connected to the nut on the brass clamp or to the specimen itself. The power switch is turned 'ON' and the energy level for the spot welding is SET to 12.7% and saved. This energy level is optimized for spot-welding AA 7075-T651. The switch on the power supply unit that enables welding is set to 'NO WELD.' The welder-handle is lowered toward the copper wire by turning the screw gauge in a counter-clockwise direction. Once the welder is engaged (weld tip makes contact with the probe wire), a 'click' sound is heard. This is an indication that the weld is made. Then the welder-handle is raised by making two to three clockwise turns on the screw gauge. The welder switch is now flipped to 'WELD' position and the welder handle is slowly lowered by turning on the screw gauge in the counter-clockwise direction. The welder tip is held in this position for one clock second after the 'click' sound and is then slowly lifted by a clockwise movement of the screw gauge. The welder switch is now turned to the 'NO WELD' position. The weld is viewed under the microscope by moving the Y-axis screw gauge. If the weld is considered good, the same is carried out on the other copper wire as well by following the same procedure. The appearance of weld bead on either side of the copper wire can be considered as having a good spot weld.

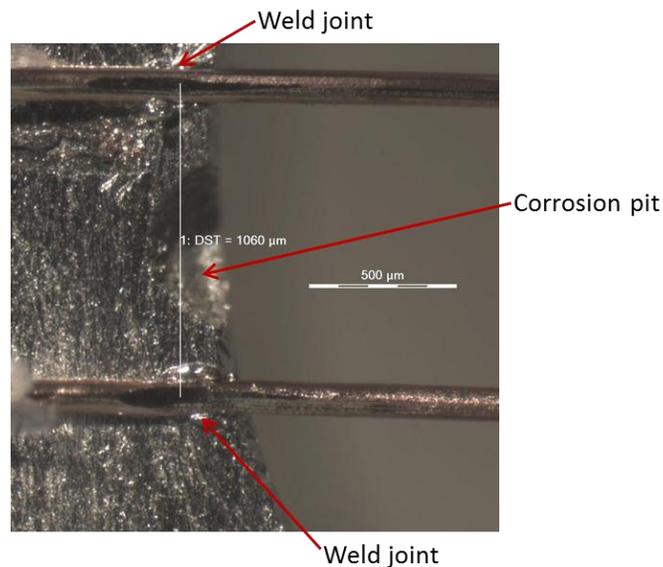


Figure 9. Spot-welded copper wires showing the weld joints.

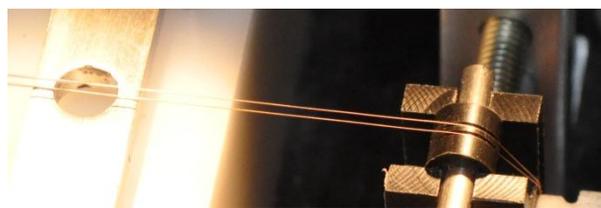


Figure 10. PTFE-stripped copper wires to the right of the specimen

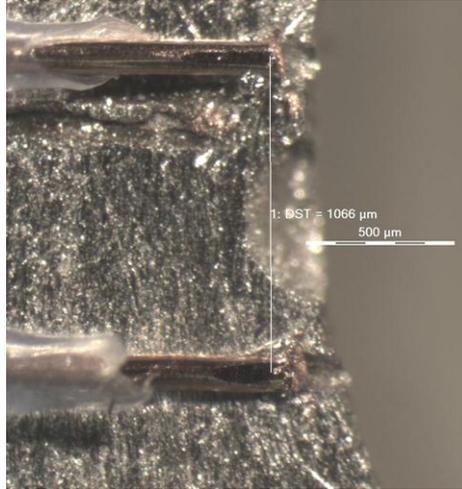


Figure 11. Spot-welded copper wires after cutting at the weld joints.

After spot welding both the copper wires on each side of the corrosion pit, the power supply unit is switched OFF and the negative terminal (green end) is disconnected from the specimen. The welder-handle is flipped away from the specimen by unscrewing the yellow knob on the aluminum base and lifting the handle. The copper wires are carefully released from the thumb screws by placing two fingers on top of the wire-spacing pulleys and pressing on the copper wires while the thumb screw is released one at a time. The fingers placed on the pulleys will ensure that the portion of copper wires between the two pulleys do not experience any strain while removing the wires from the thumb screws. After removing the copper wires from the thumb screws on both sides, the wires are carefully cut (one wire after the other) with a razor blade at the weld joints by viewing through the microscope (Figure 9). The two PTFE-stripped copper wires (Figure 11) that are to the right of the specimen are cut at the weld joint (Figure 11). It is advised that the Teflon clamp on the specimen be removed to provide more room to cut the copper wires. Care must be exercised not to damage the corrosion pit, vicinity of the pit, or specimen. Gently sliding one edge of the razor blade through the copper wire at the weld joint will ensure that there is no damage done to the corrosion pit or specimen. It is advisable to cut only about $\frac{3}{4}$ of the diameter through the copper wire with the razor blade and to fatigue the copper wire (holding the copper wire by one end and moving it up and down several times until it breaks) to remove the remaining portion away from the weld. This procedure is carried out for one wire at a time so that the specimen and corrosion pit are not damaged while ensuring the weld joint is intact.

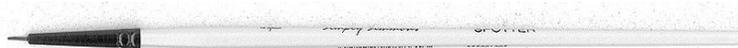


Figure 12. Spotter paint brush

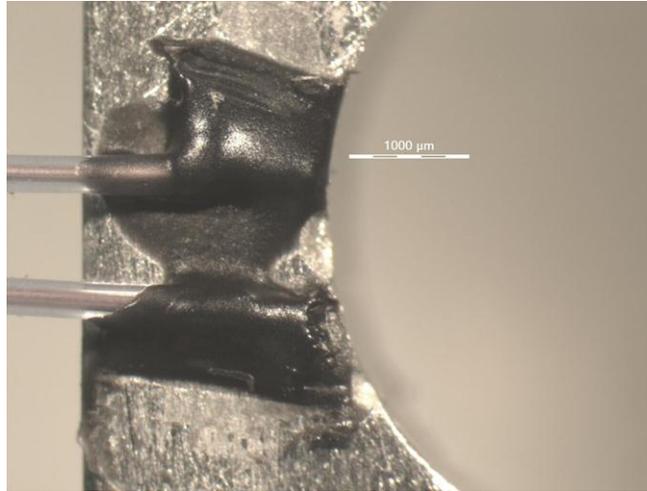


Figure 13. Liquid insulation tape coating on the two weld joints.

The wire-spacing (between centerlines of both copper wires), weld dimensions (length, width), and lengths from the centerline of the corrosion pit to those of the two copper wires are measured using the optical microscope (Olympus SZH) measuring software.

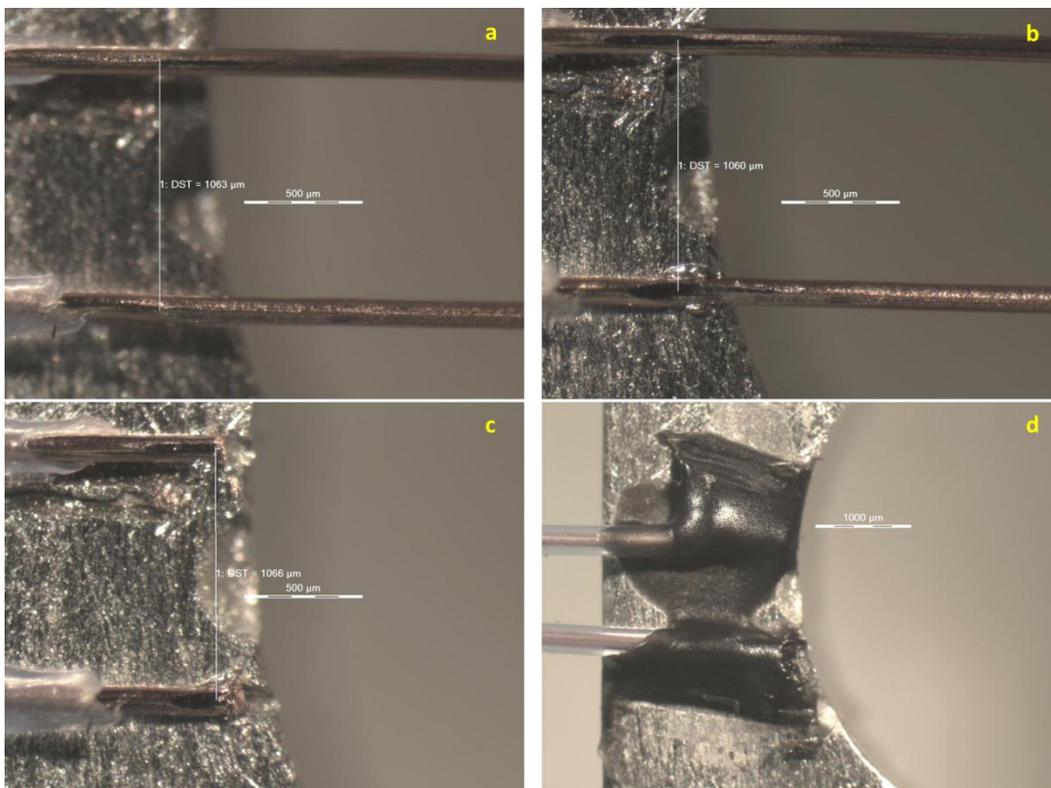


Figure 14. Stage of spot-welding: (a) copper wires ready for spot welding, (b) spot-welded wires, (c) wires cut at weld joints, (d) insulation coated weld joints

The exposed portion of the PTFE-stripped copper wire after spot welding is insulated from the specimen beneath by applying a very thin coat of liquid insulating tape. The required amount of liquid insulation tape

(black viscous liquid) is taken on a glass dish and is thinned by the addition of toluene. A spotter paint brush (Figure 12) can be used to accomplish the coating of copper wires. Care must be taken not to cover the corrosion pit with the tape. Two coats (if necessary) can be given in a span of 10 minutes between coats. The tape coat is then allowed to dry for 4 hours before the specimen is loaded to the test frame for testing. The liquid insulation tape dries to form a rubber-like film around the copper wire and hence does not interfere with the crack growth during fatigue testing. The specimen is carefully taken out of the Teflon holder and stored before testing. Figure 13 shows the insulation coated weld joints after 4 hours of drying. Figure 14 shows the different stages of spot welding.

Required Supplies:

- Spot welding power source (Miyachi Unitek ADP 125)
- Model PHP weld head piece
- Welding electrode (Cu-Cr alloy shank with tungsten insert)
- Olympus (SZH) optical microscope
- 0.005" diameter copper wire with PTFE insulation
- Teflon wire-spacing pulley set (2 Nos.) (Pulley groove spacing = 1000 μm or 0.0393")
- Razor blade
- Wire stripper
- 600 grit sand paper
- 100 mL glass cylinder
- Isopropyl alcohol (squirt bottle)
- Cotton tips
- Branson B5510 Ultrasonic cleaner (Tank size: 11.5"×9.5"×6", Capacity: 2 ½ gallon)
- Liquid insulation tape (Liquid Tape by Performix®)
- Toluene

Step-wise spot-welding Procedure

1. Place the specimen with a center hole and corrosion pit at one edge of the center hole in a 100 mL cylinder and pour isopropyl alcohol until the center hole is covered.
2. Place the cylinder in a Branson ultrasonic cleaner and clean the specimen for 15 minutes.
3. Secure the specimen on the Teflon specimen holder using the specimen holding clamps.
4. Cut two pieces of copper wire, each 2 feet long.
5. Carefully strip the PTFE insulation from each copper wire about 3 inches from each end using a wire stripper.
6. Inspect the copper wire after stripping the insulation to ensure that the wire is not damaged (small cuts or dents).
7. Clean the specimen's target weld area with a cotton tip soaked in isopropyl alcohol.
8. Mount the wires over the wire-spacing pulleys (black pulleys; 1 mm spacing)
 - a. Secure the stripped end of the wire using the plastic thumb screw.
 - b. Feed the wires inside the pulleys.
 - c. Secure the insulated wire at the other end using the plastic thumb screws.
 - d. Gently tighten the wires, until the slack is taken up.
 - e. Adjust the thumb screws so that the PTFE insulation portions of the wires are as parallel to each other as possible and as close to the corrosion pit as possible.
9. Move the wire pulleys so that the wires are positioned parallel to each other on either side of the corrosion pit and that each wire is equidistance from the center of the pit.
10. Clean the welder tip (tungsten insert) with a cotton tip soaked in isopropyl alcohol.
11. Move the X, Y axis tables to position one wire directly under the welder tip.
12. Check all alignments under the optical microscope.

13. Clip the negative terminal (green end) to the nut on the brass clamp or to the specimen itself.
14. Flip the welder switch to "NO WELD" position.
15. Slowly lower the welder tip until a "click" is heard. (Turn the Z-axis knob counter-clockwise)
16. Turn the Z-axis screw gauge clockwise three revolutions.
17. Power ON the spot welder power supply.
18. Select the appropriate program. (12.7% power with single pulse when welding 0.005" copper wire to AA7075 alloy)
19. Again, slowly lower the welder tip toward the copper wire to make the spot weld.
20. Make contact for one second after hearing the 'click' sound from the welder tip.
21. Flip the welder switch to "NO WELD" position.
22. Raise the welder tip and inspect the weld.
23. Repeat steps 11 to 22 for the second copper wire.
24. Flip the welder switch to "NO WELD" position.
25. Power OFF the spot welder power supply.
26. Unscrew the yellow knob and flip the welder handle out of the way. (Figure 1)
27. Carefully untie the wires from the pulley system.
28. Carefully cut the PTFE-stripped copper wire to the right of the specimen at the weld joint using a razor blade.
29. Gently remove the specimen from the stage, taking care not to snag the wires.
30. If the specimen is to be used in a corrosive environment, application of thin layer of insulation tape over the weld joint will protect the weld from galvanic corrosion.

Troubleshooting

In case of spark/arcing

1. Examine the specimen to see if the damage is localized and removable with sand paper.
2. If the damage is similar or larger in depth and width compared to the corrosion pit, discard the specimen.
3. Examine the welder tip for damage and re-shape with sand paper.

If the wire 'falls-off'

1. Examine the specimen and identify an ideal re-attachment point.
2. Use new set of copper wires and repeat the spot welding procedure.
3. Take care that the weld is on a clean surface.