Strain Gauge Installation for HRMT43

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Four graphite slugs were placed in the HiRadMat Facility at CERN and subjected to variable intensity 440 GeV beam to study its thermal shock response as an accelerator target material.

The slugs are outfitted with one circumferential strain gauge, one axial strain gauge, and one temperature sensor each. The gauges are glued to the slugs with VPG Micro Measurements M Bond 610 adhesive. Three soldering pads, one for each gauge, are also glued to the slugs’ surfaces using Loctite 401 adhesive. Three 28 AWG wires are soldered to each of the pads by a technician and terminated in a connector card.

Instructions come from VPG Micro Measurements Instruction Bulletin B-130. Not all steps in the bulletin are necessary for this specific project.

# Surface preparation

Clean the surface of a piece of glass with M-Line GC-6 Isopropyl Alcohol. Working with the sensors and the Mylar tape is made easier with a clean surface.

Clean the graphite surface with the alcohol. Apply the alcohol to the gauze and wipe the surface in one direction. Wiping the gauze back and forth will reintroduce contaminants to a cleaned area. [See note 1]

Apply M-Prep Conditioner A to the graphite surface and wipe it off the surface in one direction. [See note 2]

Apply M-Prep Neutralizer 5A to the graphite surface to neutralize its pH. Wipe it off in one direction.

# Gauge installation

Take a strain gauge out of its packaging with a pair of tweezers, making sure to touch only the edges of the gauge and its leads. Lay the gauge out on the cleaned glass surface.

Pull off a clean piece of Mylar tape and position it to cover a small portion of the edge of the gauge. Do not stretch the tape, as this will cause the gauge to contract later and affect its “zero” reading. Lightly push the tape onto the sensor.

Make sure the tape does not cover the alignment markings to be used in the gauge installation, if possible. [See note 3]

Pull the edge of the tape away from the glass at a shallow angle to bring the gauge up and away with it

Align the gauge on the graphite surface with the tape.

The gauges will be aligned a second time following the application of the adhesive, so the positioning does not need to be precise yet.

In this step you’ll realize if you can see the markings that you need to for alignment.

Pull the tape and the gauge away from the graphite surface for adhesive prep. Allow for the tape on one side of the gauge to act as a hinge by keeping it stuck to the surface.

This will hold the gauge up and away from the surface. [See note 4]

Apply a thin layer of the M Bond 610 adhesive to both the gauge and the graphite surface. Wipe the brush on the inside of the bottle to get excess adhesive off. [See note 5]

Allow the adhesive to dry on the gauges in the open air for 5 to 30 minutes.

Use tweezers to set the final alignment of the strain gauges.

Cut another piece of Mylar tape to be set over top of the entire gauge. Position the tape over the gauge accordingly and push the gauge down onto the surface, moving in one direction. Use a gauze sponge to push the tape over the gauge.

The tape ensures the gauge will remain in its final alignment position during the adhesive curing process.

The gauze sponge allows for minimal friction between your finger and the tape and gauge.

Lay a piece of Teflon tape over top of the secured gauge. Secure the edges of the Teflon with Mylar tape.

This ensures the Mylar tape will not come away from the graphite surface until it is ready to be removed. The clamps and silicone rubber pads involved in the next steps may stick to the tape during the oven curing process. The Mylar tape will need to be removed very carefully so as not to compromise the bond between the gauges and the graphite.

Center an appropriately sized silicone rubber pad over the installed gauges. This may need to be taped in place with Mylar tape.

Position a round clamp adapter over the rubber pad.

Make note of the circumferential center of where the gauges are aligned so as to center the clamps on them for equal pressure distribution. [See note 6]

Position a partially round adapter on the other side of the graphite slug. The flat portion of the adapter must align with the flat portion of the slug.

Secure the clamp around both halves of the clamp adapter. Center the clamp on the circumferential position of the gauges on the slug. Make sure the clamp is also centered axially down the length of the slug.

Adhesive curing

M Bond 610 requires high temperature curing and postcuring. The instructions include a plot of cure temperature over time, both of which vary. The adhesive can cure at 177 degrees C for one hour and postcure at 217 C for two hours. [See note 7]

Place the clamped graphite slug in the oven. The oven has been programmed to ramp to 177 C at a rate of 5 C per minute, dwell at 177 C for one hour, then come back to room temperature. [See note 8]

Remove the slug from the oven between cure and postcure to remove the clamps, Teflon and Mylar tape.

The slug should not be removed from the oven until it has reached at least 55 C. Allowing the adhesive to cool down too quickly may compromise the bond. The oven takes about three hours to cool to this temperature.

Dissolve the tape mastic with M-Line Rosin Solvent when removing the tape from the gauges.

This allows the tape to come away from the surface without pulling on the gauges. Although the adhesive bond has been formed by this point, take extra care not to disturb the gauges in this process.

Place the slug back in the oven once the gauges are all that remain on the graphite surface. The oven has been programmed to ramp to 217 C at a rate of 5 C per minute, dwell at 217 C for two hours, then come back to room temperature.

Similar to the curing process, the slug should not be taken out of the oven until it drops to 55 C.

Solder pad installation

Cut out a set of soldering pads for each gauge on the slug. Orient them so there is a split pad on the left (positioned like an upside down letter “Y”) and a straight pad on the right.

The strain gauges need soldering pads to split one of the leads into two signals.

Set the slug and the soldering pads on the glass for visual alignment. Position the pads beneath the gauge leads to be soldered to them.

Cover the pads with a piece of Mylar tape. Peel the tape back so it brings the pads with it, similar to how the gauges were installed. [See note 9]

Secure the tape and the pads to the slug in their desired position beneath the gauge leads.

Pull the tape and the pads away from the graphite surface.

Keep the flattened tape hinge down on the graphite.

Apply Loctite 401 to the back sides of the pads.

Flatten the pads and the tape back down to their desired positions on the graphite.

Use another piece of tape to keep the pads stuck down if necessary.

Fit the clamps around the pads.

This is similar to how the gauges were clamped for curing.

Let the glue set under pressure for 30 minutes, then remove the clamps.

Soldering

Precision soldering was done by electronics technician Paula Lippert, in the Infrastructure and Support Department.

The leads from the circumferential and axial strain gauges are soldered to the two top sections of the solder pads. Two 36 AWD wires, which are not included on the gauge, are soldered from the temperature sensor to the solder pads. Three 28 AWD wires are soldered onto the bottom three sections of each soldering pad.

The 28 AWD wires are initially cut to be 3 feet long to accommodate temperature calibration measurements from the oven used for curing the adhesive. 28 AWD wire was selected for the gauges because these will be soldered to a collection of 28 AWD connectors in a Burndy pin which will read out experimental data.

Tips and tricks

If components to be glued onto the surface are close together, lay down the Mylar tape on the gauge on the glass, and use an Xacto knife to cut precision edges that won’t overlap with anything else on the installation surface.

The Mylar tape will curl back on itself when you cut a piece off. Cut only most of the way through the tape at the length you want it, control the new edge with your other hand (which is now not occupied by scissors), and tear the tape the rest of the way from the new cut.

The gauze sponges will catch the edges of the gauges and potentially tear them away from the surface if you use the gauze to clean. You can probably just use a Kimwipe instead.

Add little tabs to all of the tape you plan to remove.

With the exception of Teflon tape, only use Mylar tape for components that will stay in the oven for the curing procedure. Mylar tape will melt at a much higher temperature than what else may be available.

Referenced procedure notes

[1] Cleaning surfaces with gauze sponges is nice because the gauze is abrasive, but if the samples are to be cleaned with a chemical after the installation of the gauges, the use of a Kimwipe is advisable, as the gauze may catch the corners and edges of the gauges.

[2] The conditioner is a chemical used in the wet abrading of the bond surface. I’m not sure if it’s actually necessary, but I didn’t want to leave a step out in case it was still important for the bond.

[3] The graphite slugs used in this project have only been marked in one plane each. It is possible that precision alignment will be necessary in both planes and will be marked accordingly, requiring tape to be set over one of the four available alignment markers.

[4] When holding the gauges away from the surface to prep them for adhesive application, the gauges will need to stay flat, relatively parallel to the ground, so that the glue will not distribute itself unevenly under the force of gravity. This may require more tape to hold the gauges back or some other brand of ingenuity.

[5] The M Bond 610 was very difficult to get to stick to the graphite. When applying the adhesive to the surface directly it immediately and fully soaks into the porous graphite. Applying the smallest amount of the adhesive to the under sides of the gauges, as the instructions dictate, give the gauges very little with which to hold onto the graphite, and they tend to come up and away from the surface after the oven curing process. Allowing for a very shallow pool of the adhesive to be applied on the gauges yielded uniform distribution and much more substantial bonding.

[6] Adapters for the clamps have been specially printed to securely seat the graphite slugs. You may want to tape this half of the adapter in place on the slug so it doesn’t move. If it moves, the alignment could be compromised. These adapters are printed from Formlabs High Temp Resin for heat resistance and can withstand 289 degrees C. These pieces started to disintegrate in the middle of the oven curing process, but I suspect that they were not properly hardness cured. Other pieces made of the same materials under the same pressure were not affected.

[7] The postcure must be at a temperature 30-40 C above either the curing temperature or the operating temperature, whichever is higher. The operating temperature is much lower than the curing temperature. The graphite slugs from this project were outfitted with two strain gauges and a temperature sensor. The temperature sensor is the only bonded element requiring the postcuring process, as indicated in the instructions specially for transducers. The postcuring process is not necessary for the strain gauges, but will not damage them.

[8] The instructions allow for the temperature to ramp at a rate of 3-11 C.

[9] Position the pads in their desired orientation relative to the gauges and to each other on the glass. Use one piece of tape to completely cover them, but leave about an eighth inch of tape over the top edge of the pads. This edge will act like a hinge to keep the pads in place when you lift the bottom edge up and apply adhesive.