Structural Integrity: Materials Testing
Drilling Holes

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This piece of equipment is for performing incremental hole drilling measurements, which is a method for measuring the residual stress profile near the surface of a sample or a component. This is the sample that we're measuring, this roughly triangular sample which has been mounted on the top of this base plate, and what we've done is we've stuck, glued, a strain gauge array which is this orange rectangle. That's been glued to the surface of the component. And this strain gauge array has three separate strain gauges arranged around a central point.

And what we're going to do, is using this drill, we're going to drill down through the centre of the strain gauge array and then down into the sample, and we'll record the readings from each of the strain gauges as we drill down, at each successive increment, we'll record the strains and we'll use those values to back calculate the residual stress that was in the sample before we started.

So the first step is to move the sample into place. Have some illumination and then I'm just going to use this eyepiece to centre the sample beneath where the drill will be mounted. That's now centred, so I can take the eyepiece out and mount the drill. What we're doing now is we're just going to lower the drill down until it touches the surface.

Now, obviously I could just place it down in contact with the surface but that would cause the gauge and the surface underneath it to deform slightly, and it's better to come in very slowly in controlled steps with the motor running and see when I start to skim layers off the surface of the gauge and then I know that I'm coming into contact with it and I can start to move down from there, through the gauge, to the surface of the sample.

What we're doing now is we're lowering the drill in order to find the surface. And what we'll see is that when the drill touches the top of the strain gauge, there'll be some swarf as the top layer of the strain gauge is removed. And that's it. We've now made contact with the top of the strain gauge.

I know that this gauge is around 50 microns thick so I can now step down in four increments of 10 and know that I will still be above the sample surface.

The next stage is to go down in very small increments of only 2 microns [drill starts again] and to see when the surface of the sample is revealed.

So when we finally go through the bottom of the gauge [end of drill sound], what we're looking at is the clean metal surface underneath.

The drill is now in contact with the surface of the sample and we're ready to drill the first increment and take the first set of strain readings.

One of the things that you see is that the drill actually has a milling action; it doesn't just drill down, it mills out the hole and that means that we get a much more accurate hole when we're doing this process.

So we've just drilled our first increment of 32 microns and the relaxed strains are 2, 4 and 4 micro strain on the three gauges. And now I'll do the next increment.

It's worth saying that it's not possible to do a direct conversion from strain to stress because this isn't as simple as saying that we've multiplied by the modulus against stress; we have to take these strains and use them to back calculate the residual stresses.

That's the second increment completed so we're now at a depth of 64 microns and the strains are 4, 5 and 11 micro strain on the three gauges.

We're using larger increments now, 128 microns, and the reason for doing this is that those gauges are mounted on the surface. As we go deeper, the sensitivity of those gauges to the relaxed strains becomes less.

If we take a larger increment, we're more likely to see something that's measurable. So we're now at a depth of just over 1.15 millimetres and the strain readings are 86, 75 and 110 micro strain.

Once the test is finished and we've recorded all the strains of the successive increments, what we can do is use that to calculate the residual stress profile that was in the sample before we started. Now, this isn't a simple process; you can't go directly from strain to stress, you have to use the strain values at successive increments and use that to back calculate the profile. We take the values that we measured and input them into the spreadsheet so these are the values from the three different gauges at the depth that we measured.

Firstly, what we get are some smooth values of strain because there will be some scatter from point to point in the experimental measurements. We also give the spreadsheet information about the elastic properties of the material, the Young's modulus and the Poisson's ratio, and also we've measured the final diameter of the hole. This is the actual strain profile with depth plus the smooth values, and then calculations are performed in the spreadsheet, there's underlying programming built into this spreadsheet which allows us to calculate the residual stress profile that you see here.

This magnesium sample had been given a surface treatment called shock peening which introduces a compressive residual stress profile near the surface, and indeed that is what we've measured. What we see is a variation of stress near the surface which is compressive, and we can see the peak compressive stress, it's just over 100 megapascals, up to a depth of just over 200 microns.