NON-DESTRUCTIVE ACOUSTIC DETERMINATION OF RESIDUAL STRESSES IN HYDROSTATICALLY EXTRUDED ALUMINUM RODS

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ABSTRACT

Third order elasticity theory may be used to show that a longitudinal acoustic wave normally incident on a sample in a state of plane deformation experiences a relative velocity shift given by

\[ \frac{V - V_0}{V_0} = B(\sigma_1 + \sigma_2) \]

where \( B \) is the acoustoelastic constant, \( \sigma_1 \) and \( \sigma_2 \) are the principal stresses normal to the direction of wave propagation, and \( V_0 \) is the wave velocity in undistorted material. Hence, wave transit time measurements may be used to ascertain the sum \( \sigma_1 + \sigma_2 \) in the deformed state. We use a double pulse-echo technique to provide an accurate measure of transit time through the thickness of aluminum discs produced by hydrostatic extrusion (25% area reduction). The residual stress state produced during extrusion is axi-symmetric and we are able to separately determine residual radial and hoop stresses by a single longitudinal wave measurement at points on the disc face. The technique is extremely rapid and accurate, and the acoustic results are cross-checked by both x-ray measurements and finite element simulation of the extrusion process.
SUMMARY DISCUSSION

William Pardee, Chairman (Rockwell Science Center): Bill Moyer.

Bill Moyer (Union Carbide): Would you address the problem of getting zero stress state in the welded position?

Martin Scott (Stanford University): This is a big problem. I think this will require that the theoreticians do more work here. Echo elasticity can be couched in a different way. That is, if we can use an already deformed state, perhaps, as referencing our equation, that would give us a big help. At present, I don't know a better way to do it than simply stress relief. Obviously, if you are talking about a 30-ton pressure vessel, you don't believe that. I don't know what to do about that; this is the best I know how to do it.

Bill Moyer: Is the technique applicable to a weld where the weld nugget is different material so you have a variation in properties as you go across?

Martin Scott: Yes. By calibrating the already deformed state, you can essentially handle those kind of things. However, that has not been done before.

William Pardee, Chairman: How thick were your wafers, and did you have to take any special precautions to avoid introducing additional stresses in moving them out of the rod?

Martin Scott: Yes, to both your questions. They were on the order of anything from 4 millimeters to 6 millimeters in thickness. I used a gassed discharging machine to be very careful, using a very careful polishing technique. Although this technique is not very sensitive, you really don't have to worry about that that much.

John Simmons (NBS): Did you find any differences, in fact?

Martin Scott: There are axial stresses in the rod, and the order of difference is on the order of differences you would expect by adding the elastic solution to the longitudinal stresses; we picked that up.

William Pardee, Chairman: Thank you, Martin.