N92-15862

1991

NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

MARSHALL SPACE FLIGHT CENTER
THE UNIVERSITY OF ALABAMA

USE OF PHOTOSTRESS TECHNIQUES TO CHARACTERIZE THE MECHANICAL BEHAVIOR OF WELDMENTS

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Contract No.:	NGT-01-008- 021

INTRODUCTION

Photoelastic coatings are useful to view strains in a large field and to examine strain gradients in the field. Contrary to strain gages which average strains along their length, photoelastic coatings provide measurements of strain over a gage length of essentially zero (at a point).

When testing is done using specimens having welds between parent material, there are, in general, four zones in which strains may be significantly different. These zones are (a) the weld material, (b) the fusion boundary, (c) the heat affected zone, and (d) the parent material. To date, most all strain measurement on welded specimens has been done using strain gages to measure strain in the various zones, thereby averaging across the strain gradient and across zone boundaries in some cases.

BASIC TECHNIQUE

In an effort to eliminate strain averaging, photoelastic coatings were used to characterize the mechanical behavior of weldments when tested in uniaxial tension. Data were taken at various points along the specimen and were used to construct stress-strain curves. The basic strain-optic law states that

$$\gamma_{max} = \epsilon_1 - \epsilon_2 = \frac{N\lambda}{2t_pK} = Nf \qquad [1]$$

where N = fringe order,
λ = wavelength of light = 22.7×10^{-6} inches,
t_p = thickness of coating, and
K = calibration constant of coating.

Since $\epsilon_2 = -\mu\epsilon_1$ for uniaxial tension, equation [1] may be written for the elastic range as

$$\epsilon_1 = \frac{Nf}{(1+\mu)} \qquad [2]$$

where μ = Poisson's ratio. For the inelastic range, Poisson's ratio must be replaced by the contraction ratio, α, which Chakrabarty (1) approximates as

$$\alpha = 0.5 + (0.5 - \mu)(\frac{E_t}{E}) \qquad [3]$$

where E_t = the tangent modulus and
E = the modulus of elasticity.

Thus, equation [2] becomes

$$\epsilon_1 = \frac{Nf}{(1+\alpha)} \qquad [4]$$

for the inelastic range. The contraction ratio may be calculated for each value of uniaxial stress using a tangent modulus curve constructed from a regular stress- strain curve. Contraction ratios for the weld material and parent material were calculated, and were approximated for the fusion boundary and heat affected zones.

Since strains exceeding the 0.2 percent offset are seldom allowed in design, data collection was limited to maximum strains of from one to two percent where the engineering and true stress-strain curves are essentially the same. Figure 1 shows an example of the stress-strain curves obtained for the various zones using photoelastic coatings. Color photographs of the fringe patterns in the coatings clearly showed the strain gradients and the four zones previously mentioned.

CONCLUSION

In comparison to use of strain gages, more technical expertise, calculations, and care are required to successfully use the photoelastic coating technique. However, strain averaging is eliminated and, up to a maximum strain of from one to two percent, photoelastic coatings provide a useful method to characterize material behavior.

References

1. Chakrabarty, J., Theory of Plasticity, McGraw Hill Book Co., Inc., New York, 1987.
2. "Operating Instructions and Technical Manual-Strain Measurement with the 030-Series Reflection Polariscope," Measurements Group, Inc., Raleigh, NC.

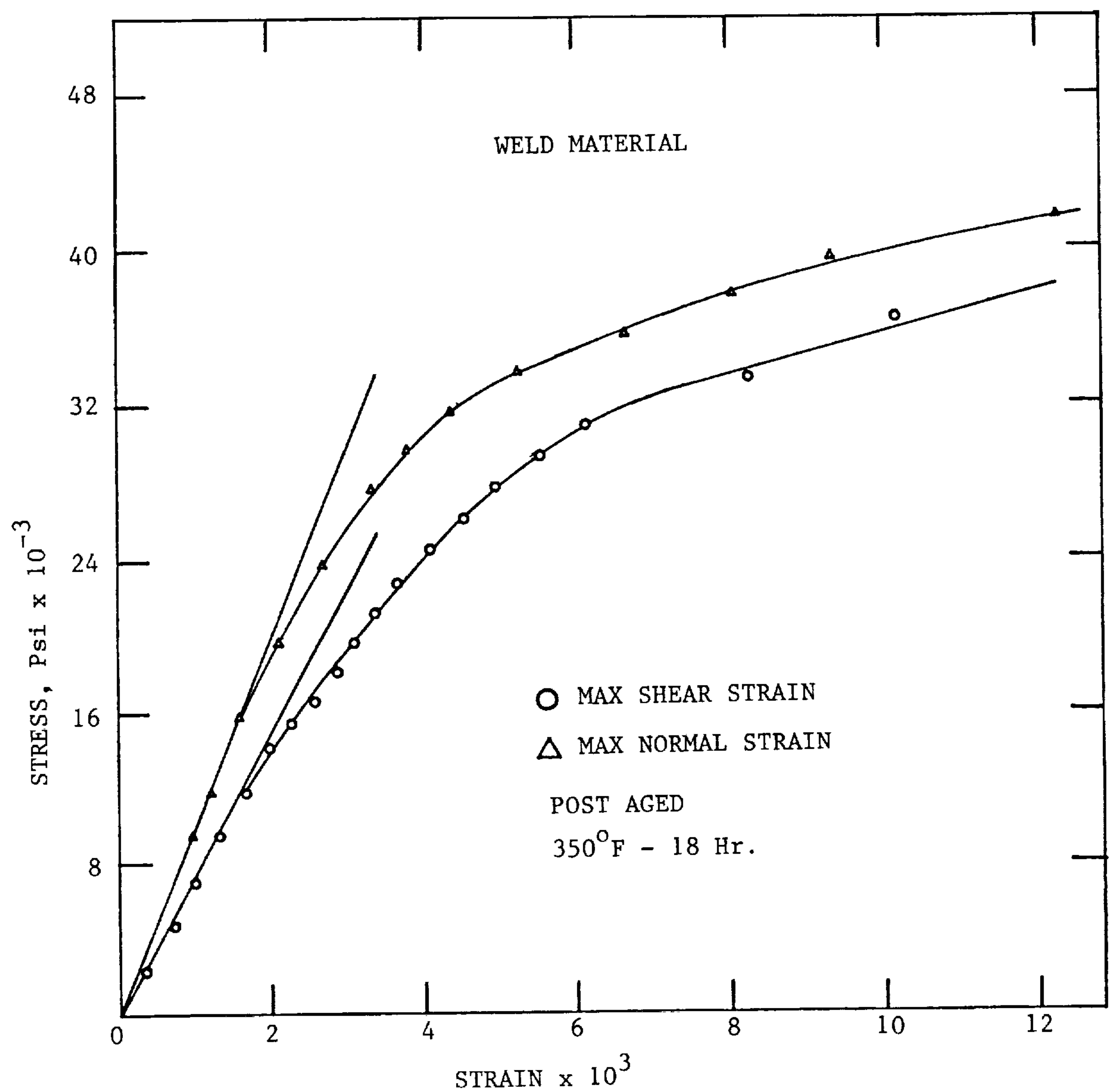
WELD MATERIAL
MAX SHEAR STRAIN
MAX NORMAL STRAIN
POST AGED
350°F - 18 Hr.
STRESS, Psi x 10^-3
48
40
32
24
16
8
0
2
4
6
8
10
12
STRAIN x 10^3

FIGURE 1