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RESIDUAL STRESS IN SWAGE AUTOFRETTAGED CYLINDERS WITH AXIAL SEMI-CIRCULAR MID-WALL COOLING CHANNELS

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13. ABSTRACT *(Maximum 200 words)*

ABAQUS finite element modeling and experimental residual stress mapping have been performed for several swage autofrettaged compound cylinders with semi-circular mid-wall cooling channels. The experimental results verified most features of ABAQUS-predicted stress distributions, except near the bore and at the channel roots, where significantly reduced compressive residual stresses were observed. These observations have been attributed to reverse yielding effect in these areas.

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INTRODUCTION

Residual stresses have been induced by the swage autofrettage process in A723 steel cylinders of 155-mm diameter containing axial mid-wall cooling channels. These cylinders consist of liner cylinders with semi-circular channels that were shrunk fit into steel jackets. Then the swage autofrettage operation was performed. The introduction of the axial channels significantly modifies the magnitude and location of the stress concentrations and expected failure sites.

Fatigue life calculation, stress concentration, and stress intensity of similar cylinders have been reported (ref 1). In this work, experimental X-ray diffraction residual stress analysis was performed and compared with Tresca's model of a mono-block solid cylinder under 40, 50, and 60 percent overstrain, and with predictions from an ABAQUS elastic-plastic deformation finite element model. Because of the presence of high-gradient components in the stress distribution, X-ray beam spread function and the effect of resolution were investigated.

OBSERVATIONS

Figure 1 shows half of the cross section of the cylinder, where OD and OM are radii extending from the cylinder axis to the outside diameter. OD crosses the cylinder wall at A, root of cooling channel at B, flat side of cooling channel at C, and outside diameter at D. OM represents a mid-channel direction.

Figure 2 shows the radial distribution of hoop residual stresses along OD and OM. Residual stress at points A, B, C, and D were also determined for 180° of the cylinder arc to show the uniformity of induced stresses. Our experimental results are in good general agreement with Tresca's classical deformation model of a solid cylinder under internal pressure. Deviations were observed near the bore, which are generally explained by the Bauschinger effect (ref 2). Modifications to the stress distribution along OD and OM due to the existence of the cooling channels are obvious.

A two-dimensional ABAQUS finite element deformation model was used to study the elastic and plastic deformation of the cylinder. Figure 3 shows ABAQUS-predicted residual stress distribution from the bore to the channel root (ref 1). A comparison of ABAQUS predictions and experimental stress distribution yields good general agreement, with important deviations near the bore and the channel roots. Reduced compressive stresses were observed near the bore. While experimental measurements verified the tensile stresses turning into compressive stresses near the channel roots, the compressive stresses were not as high as predicted.

CONCLUSIONS

Conclusions from the present investigation include:

- Residual stress distribution in a cylinder with axial channels is comparable to a 54 percent partially swage autofrettaged solid cylinder.

- The Bauschinger effect plays an important role both near the bore and the channel roots in reducing compressive residual stresses.

- Based on this work, channel roots and the bore are critical sites in the design and safe operation of the component, with the channel root being most critical.

- Using current measured residual stress levels, the fatigue life estimates give a lifetime at the channel roots of only 60 percent of life at the bore. During operation of fatigue testing to failure, cracks were first observed near the channel roots, as predicted from our investigation.

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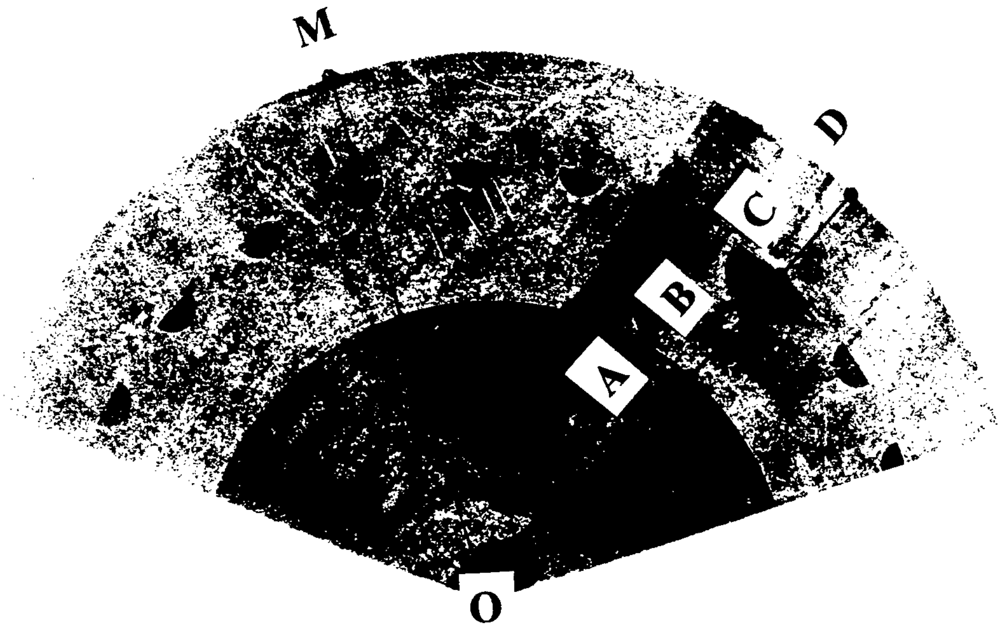

Figure 1. Cross section of cylinder showing OD, OM, and an exaggerated cooling channel. Point B is at the channel root.

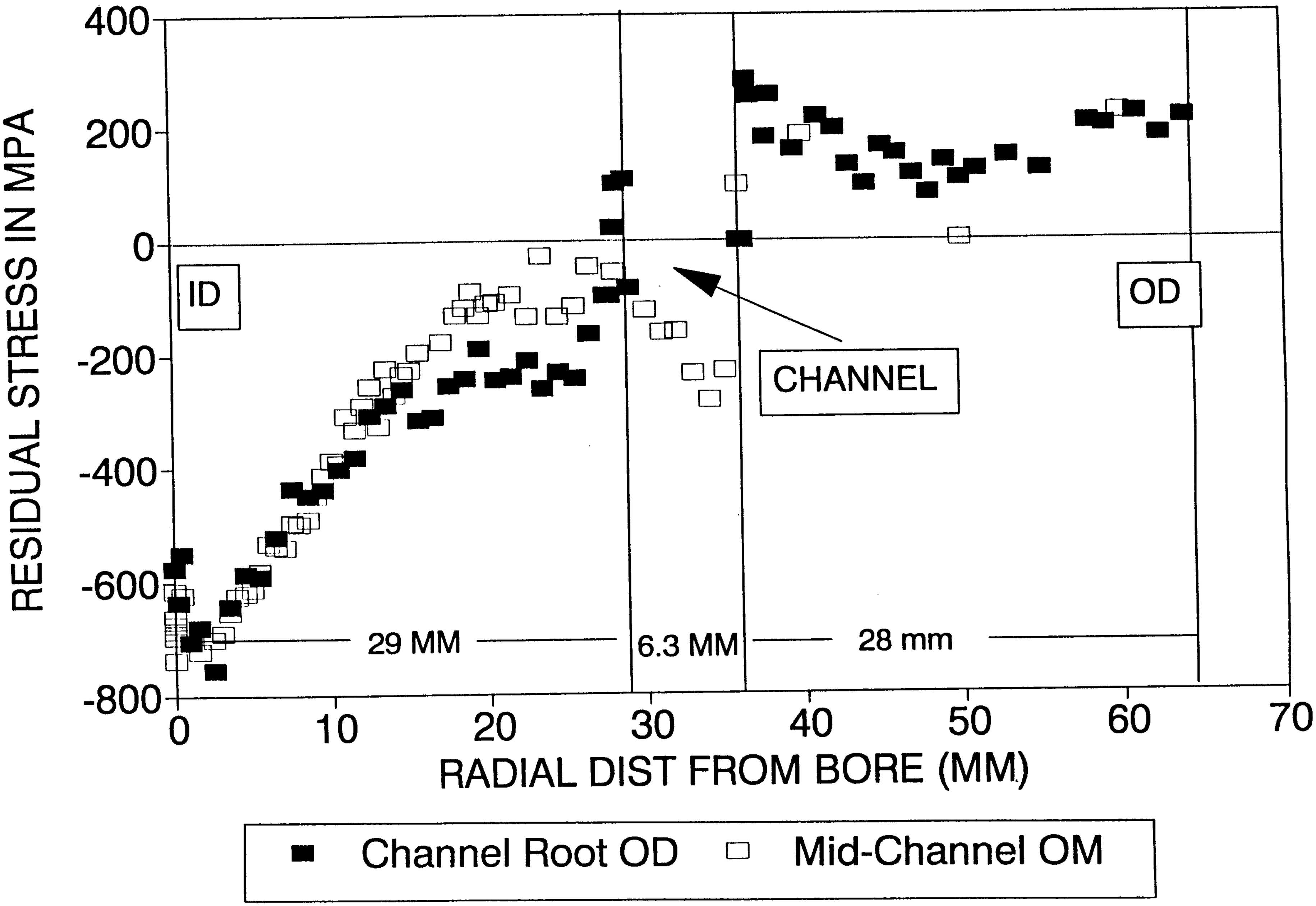

Figure 2. X-ray residual stress distribution along OD and OM from ID to OD.

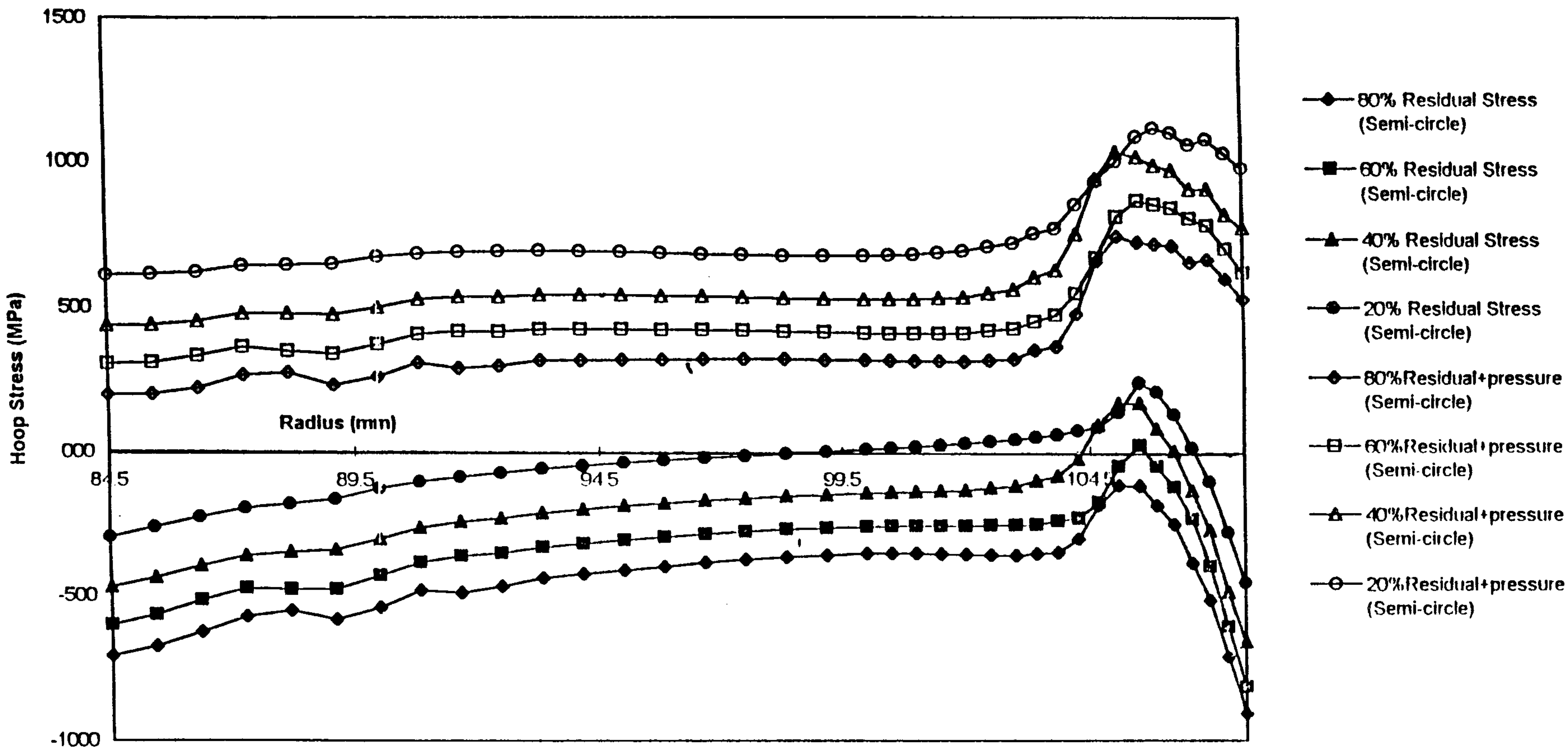

Figure 3. Top four curves representing ABAQUS residual stress plus pressure; bottom four curves representing residual stress at 20, 40, 60, and 80 percent, bore to channel root residual stress distribution.

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