EXAMINATION OF HRR FIELD EXISTENCE UNDER PLANE STRESS

V.A.Rackowsky* and Y.G.Matvienko**

INTRODUCTION

Hutchinson (1), Rice, Rozengren (2) asymptotic analysis of the singular stress-strain field near the crack tip in an infinite strain-hardening plate (HRR field) is the theoretical background for the J-integral use as a fracture parameter . The existence of the HRR field in the finite fracture toughness specimens was studied repeatedly by FEM computations,but direct experimental investigations of the HRR field existence conditions are almost completely absent with the exception of the works by Matvienko (3), Guerry and François (4) where only the fact of the existence of such a field in thin sheet specimens was pointed out. The objective of the present paper was HRR field existence investigation for the case of plane stress in uniaxial and biaxial tension.

EXPERIMENTAL METHOD AND RESULTS

The aim of this study was attained by the comparison of plastic strains measured in the vicinity of the crack tip in thin sheet specimens by the fine grids method with the HRR strain field computed using the Hutchinson's approach (1).

Materials involved in this investigation are: mild and stainless steels (steels A and B, accordingly). They posses like mechanical properties but different materials laws. For steel B the stress-strain curve strictly follows the Ramberg-Osgood relationship $E\varepsilon/\sigma_Y = \alpha(\sigma/\sigma_Y)^n$. The stress-strain curve for steel A has a yield plateau preceeding the work hardening portion. For steel A the yield stress σ_Y =220 MPa, the strain hardening exponent n=4.4; for steel B σ_Y =340 MPa, n=5.05.

The testing was executed on two types of specimens: M(T) specimens of steel A and B and cruciform central crack specimens of steel A biaxially loaded in directions parallel and perpendicular to the crack line. The specimen dimensions are: width 2W=240 mm, thickness

* Institute for Problems of Strength
Ukr.SSR Academy of Sciences, Kiev, USSR
** Institute for Metals Corrosion Protection
GKNT USSR, Moscow, USSR

B=4 mm for steel A; 2W=300 and 70 mm, B=1.5 for steel B.

Figure 1 shows typical equivalent strain distribution measured on cruciform specimens of steel A in uniaxial and biaxial tension, as well as HRR strain distribution. Experimental results for steel A are in good agreement with the HRR solution in uniaxial tension if the values of M exceed M*=80. In the case of biaxial tension a sufficiently extensive HRR field was observed at smaller M than in the case of uniaxial tension (see Fig.1 where biaxiality parameter λ is the ratio of the loads applied along and transverse to the crack). For steel B a fair agreement of the computed and experimental data was observed at M=40 and was absent at M=20. M is the least distance from the crack tip to the specimen boundary $\times \sigma_Y / J$.

The procedure described is tedious and complex. It is clear that it is not applicable for wide-range experiments required for the development of the validity criteria for thin sheet specimens. A more simple way to obtain identical information is a comparison of the crack opening displacements measured near the crack tip with the HRR solution (Fig.2).

CONCLUSION

The condition of the HRR field existence under plane stress and consequently the criteria of fracture toughness parameters validity have been found to depend strongly on the character of mechanical behaviour as well as on the mode of the piece loading. The materials law deviation from the power law considerably increases the minimum size of the M(T) specimen. Application of the tensile load along the crack line leads to a decrease in the value of M* compared to the uniaxial tension.

REFERENCES

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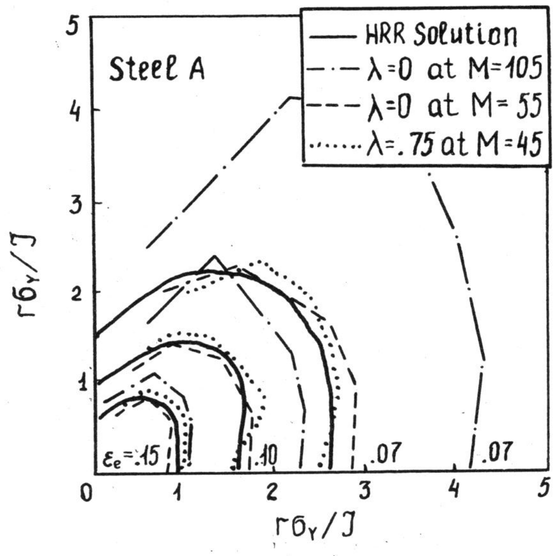

Figure 1 Plastic equivalent strain (ε_e) distribution in thin sheet specimen at different values of M . Here r is the distance from the crack tip

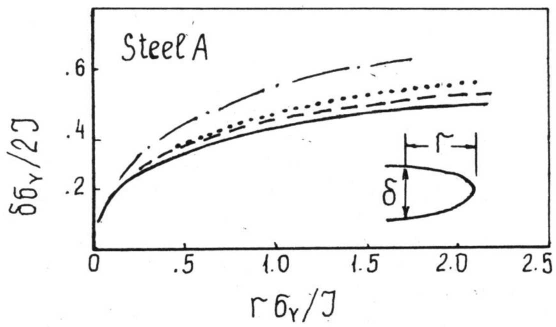

Figure 2 Crack opening displacement in thin sheet specimens. See the legends in Figure 1