CONSIDERATION OF RESIDUAL STRESSES ON CRITICAL CRACK SIZE CALCULATION

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INTRODUCTION

It is generally accepted that the residual stresses at static loading lower the fracture stress at brittle fracture, whereas their effect at ductile failure is negligible. However, the boundary between the brittle and ductile failure and the efficiency of coaction of residual stresses are not strictly defined. The contribution is an attempt to determine an index by which the effect of residual stresses could be respected quantitatively at different conditions for failure. This then might simplify the engineering calculations of the critical crack size.

INTERPRETATION OF PUBLISHED EXPERIMENTS

The effect of residual stresses on fracture stress is clearly shown by the experiments of Serensen et al (1) and Formby and Griffiths (2), Fig. 1a. Flat centre cracked plates (their dimensions are given in the attached sketches, right top) made of St3 steel (1) or of BS 1501-244 steel (2) were fractured under tension without and with contribution of residual stresses. The residual stresses were induced into the crack zone in work (1) by 50 mm long beads deposited from both sides and their value at the notch root was σr = 216 MPa. In work (2) the residual stresses were generated by pressing hot copper blocks Ø 50 mm on the plates and at the slit tip they attained the level of $\sigma r \doteq$ 300 MPa.

DETERMINATION OF TRANSITION TEMPERATURE tr

In the tests carried out at subambient temperatures the plates without residual stresses showed the fracture stress according to curves σc, eventually according to curves $\sigma c - \sigma r$ when they contained also residual stresses. The greatest difference of fracture stress $\Delta \sigma$ (in full value of σr) occured at a certain temperature tr, Fig. 1b. To this value we ascribe the so-called "coaction effectiveness factor σr" in the value αef = 1. As it can be seen the values $\Delta \sigma$ and

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α_{ef} are drooping on both sides approximately hyperbolically.

According to the idea of François and Krasowsky (3) a point on the curve of the temperature dependence of fracture toughness Kc will correspond to tr temperature, it being the intersection with SIF of the value $K_{tr} = Re\sqrt{a/\beta}$. The unknown parameter β was here determined graphically according to Fig. 1c : by the values of $a(Kc/Re)^{-2} = \beta$ calculated from the experimental data the curve β versus temperature was plotted. Both experiments have shown that at tr temperature this parameter attains the value $\beta \approx 1$.

CONCLUSION

As it follows from the above-mentioned results, the residual stresses coact on the fracture process most effectively at the transition temperature tr, at which the fracture toughness attains the value $K_{tr} = Re\sqrt{a}$. Verification of this finding, especially for the thicknesses over 20 mm and determination of the temperature dependence α_{ef} will require further work.

REFERENCES

(1) Serensen, S.V. et al.: The effect of notches, strain aging and residual stresses on brittle fractures, IIW Comm. X, Doc. X-428-67.

(2) Formby, C.L., Griffiths, J.R.: The role of residual stresses in the fracture of steel, WI Conference, paper N° 27, London 1977.

(3) François, D., Krasowsky, A.: Engineering Fracture Mechanics, Vol. 23, N° 2, pp. 455 - 465 , 1986.

SYMBOLS USED

Re = yield stress

Kc = fracture toughness

a = half length of a through-thickness crack

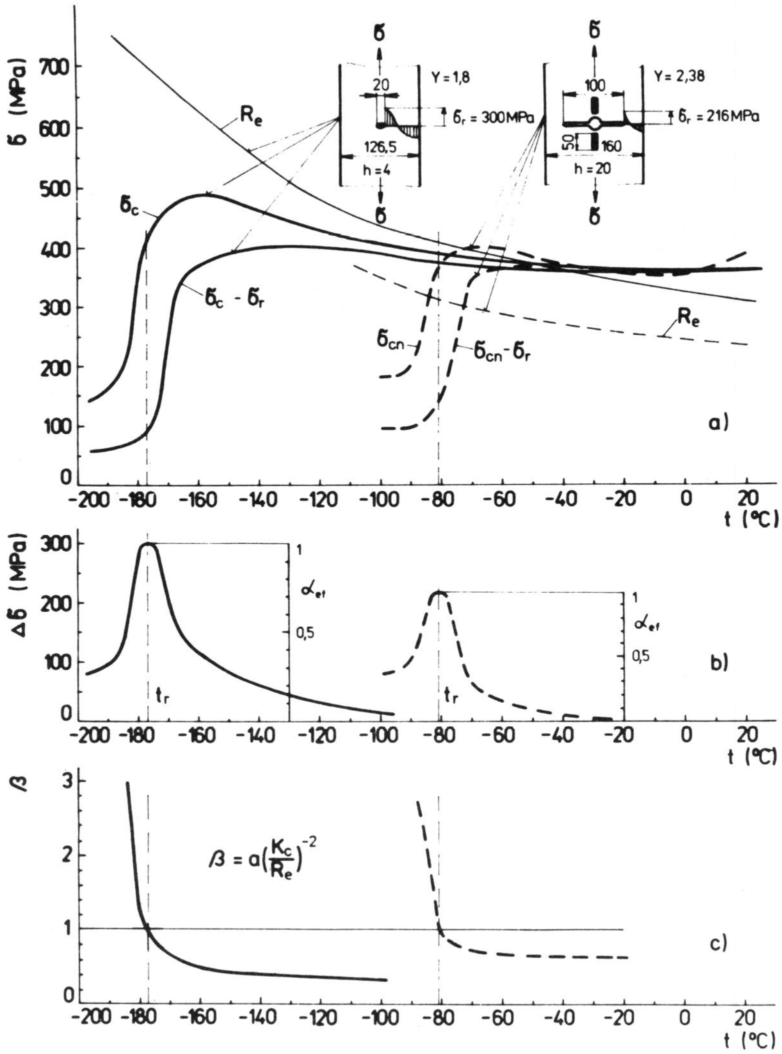

Figure 1 Graph of the fracture stress σ_r, factor α_{ef}, parameter β resp. plotted against temperature t.