Study of the Influence of Surface Defects of Steel Welded Joints upon the Process of Fatigue Failure

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1. Introduction

As generally known, the fatigue properties of unmachined joints affected by the degree of strain concentration caused by weld geometry. The deciding values of shape are weld angle α^{o} and fillet radius in the transition zone ρ of weld. Study of this problem was the starting point for the evaluation of fatigue properties and the process of fatigue damage of butt unmachined joints of steels with the increased strength.

2. Degree of strain concentration in the transition zone of real welds

Recently, the study of shape coefficients of strain concentration in butt unmachined welds was performed by help of plane photoelasticimetry /1/ and the results of measurement are plotted in Fig. 1. It is clear from the results that weld geometry affects the size of peak strains in an important degree especially in the critical section, and these strains affect in a decisive degree the fatigue properties of joints.

An estimate of fillet radius in the transition zone of welds is undoubtadly problemmatic. Study of the situation in the zone of transition of weld bead to base material showed that this transition is always sharp in the micro-zone, though visual evaluation of sharp transition notches is usually not registered. At fatigue strain and failure, however, the notch effect of the sharpest notch manifests before all, this determining both the initiation of fatigue failure and propagation of fatigue fracture through its section. In measuring the fillet radius on macroetches this fact was taken into consideration and the lowest fillet radius had been searched for /2/. Fillet radius has been measured on a projecting microscope by means of a template - magnification 100 X. The measurement showed that at manual arc welding the average value /from 10 measurements/ $\varrho = 0.231$ mm, at CO_2 welding $\varrho = 0.191$ mm, and at automatic submerged-arc welding $\varrho = 0.206$ mm.

3. Notch sensitivity of steels

The latest research and several experimental works showed that notch sensitivity coefficient in classical concept depends, in addition to material type, also on the shape of notch and even on others, less important factors. E.g. Peterson /3/ shows that notch sensitivity coefficient, in addition to chemical composition of material and its mechanical properties /strength in particular/, depends directly also on the size of notch fillet. Considering this fact, from the notch sensitivity and its dependence on fillet radius the coefficient value β_k, with known value of shape coefficient α_k can be determined.

4. Loading capacity of butt unmachined joints at variable strain /4/

The above given known facts has been applied in the evaluation of fatigue properties of butt unmachined joints of structural steels and high tensile steels. Going out from the possibility of sufficiently exact estimation or calculation of notch coefficient β_k from the relation

$$\beta_k = \eta_k(\alpha_k - 1) + 1$$

it is possible to determine fatigue properties of joints with rather good approximation through simple calculation /5/. Naturally, the notch sensitivity coefficient is here the function of fillet radius in the transition zone of weld bead and of base material strength. In Fig. 2 the results of measurement for notch fillet radius $\varrho = 0.25$ mm are plotted. Fillet radius in the zone of transition of real welds to base material is recommended considering the results of measurement $\varrho = 0.25$ mm.

Fatigue point of unmachined joints at alterating or pulsating tension stress $\pm\sigma_{Az}$ up to the value of 2×10^6 cycles can with sufficient exactness be determined from the relation

$$\pm\sigma_{Az} = \frac{\pm\sigma_{Am\,hl}}{\beta_k}$$

where $\pm\sigma_{Am\,hl}$ is fatigue point of material with smooth surface. Fatigue properties of steels of strength ranging from 40 to 90 kp/mm^2 with machined surface, black surface and butt unmachined and machined joints at pulsating tension stress /asymmetry coefficient $r = 0.1$/, according to the results of tests /4/ are plotted in Fig. 3. It seems that fatigue strength of unmachined joints with the increasing strength of base material is nearly unchanged, this being caused by simultaneous effect of the increased notch sensitivity of high tensile steels. The plotted results of experiments are within the scatter zone of calculated values of fatigue strength of joints at weld angle 30 - 60°. Imitation of fatigue failures, unless no important defects were found on the joints, was always in the transition of weld bead into the base material.

Welded joints made by turning the surface show, as compared to unmachined joints, markedly higher fatigue point. Here the difference in the effect of internal defects to fatigue strength is evident. While with carbon steels the fatigue properties of joints are approximately on the level of black surface, the joints of refined steels show more marked decrease of fatigue strength. The cause of this reduction is to be looked for in the intense influence of defects in machined joints on fatigue failure, particularly with high tensile steels. It follows from the aforesaid that with high tensile steels the claims for technological procedure and pureness of weld metal and defect-freedom are particularly justified.

5. Conclusion

As indicated in the contribution, the problems of fatigue strength of welded sections are still alive, particularly in connection with the introduction of steels of higher and high strength. The experience shows, however, that with the increased requirements for economical utilization of structural materials in welded structures, it is imperative that exceptional attention is paid to credible calculation of welded parts stressed by variable forces or impacts, further to structural design, as well as to the increased level of welding technologies.

References

/1/ Gregor V.: The latest knowledge on fatigue strength of structural materials and machine parts. SVUM Prague 1971.

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/3/ Peterson R.: Notch sensitivity, Metal Fatigue, 1969.

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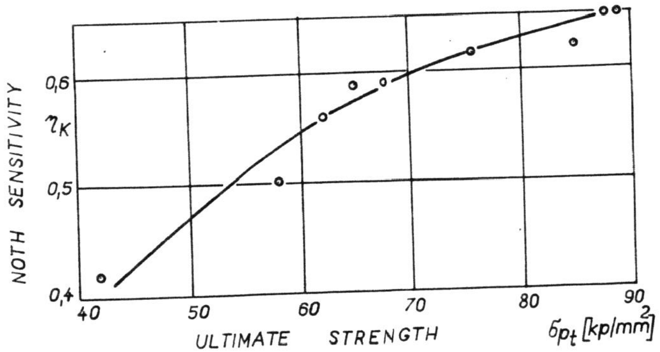

FIG. 2

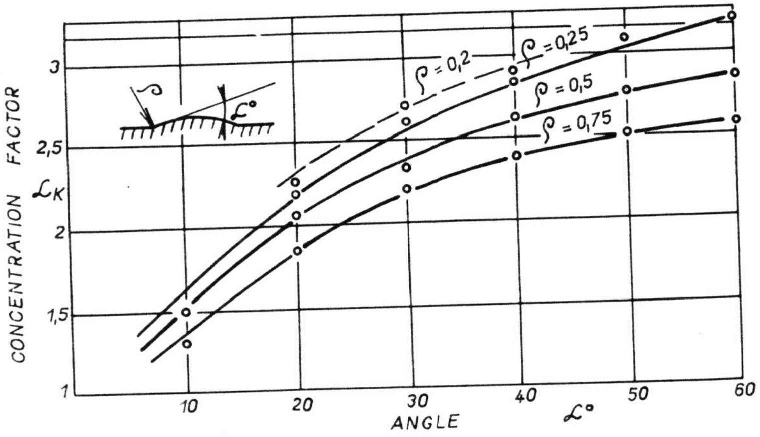

FIG. 1

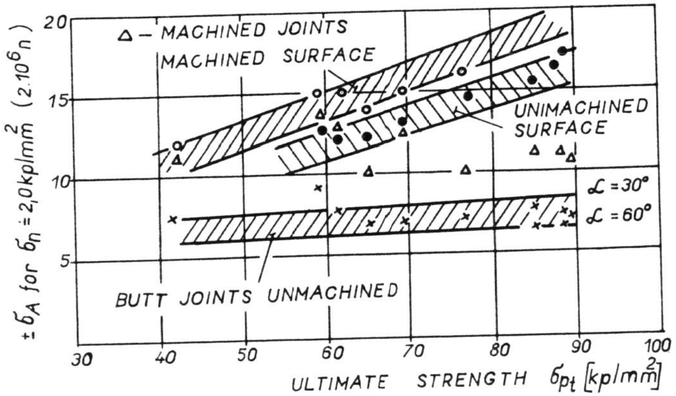

FIG. 3