EFFECT OF STRESS STATE TYPE ON FRACTURE OF AUSTENITIC STEEL UNDER THERMAL CYCLING CONDITIONS

A.Krajczyk * and R.Żuchowski *

INTRODUCTION

The behaviour of structural components subjected to temperature change is affected, among any factors, by the type of the stress state. The present study was aimed at assessing the influence of the stress state type upon the crack initiation and propagation as well as fracture type under thermal cycling conditions.

EXPERIMENTAL

The investigations were carried out on thin-walled tubular specimens made of austenitic steel containing (wt%): 0.09C, 0.90Mn, 0.45Si, 25.1Cr, 17.6Ni, Fe = balance. The specimens of 12 mm external diameter and of 1 mm thickness were subjected to pure tension (w = 0 rad) or pure torsion w = 1.57 rad as well as to tension and torsion (w = 0.52 rad). Value of axial force and torsional moment were so chosen as to obtain a constant value of stress intensity σ_i = 98 MPa. The state of stress was determined by the parameter w

$$w = \text{arc tg} \frac{\sqrt{3}\tau}{\sigma} \qquad (1)$$

where: τ - shear stress, σ - tensile stress.

The specimens were loaded at room temperature, then heated to the maximum temperature of cycle equal to 1073 K and then air cooled to minimum temperature 573 K The duration of one cycle was equal to 84 s, 20 seconds out of which were used up by heating. The fracture of specimen has been generally assumed as failure criterion. Only in the case of pure torsion a specimen has been regarded as failed when the angle of twist in one cycle was equal to 0.26 rad (where gauge length l_0 = 60 mm). This value of angle of twist was accompanied by change of deformation rate sign. One group of specimens was loaded to failure (N_f) while the specimens from the other group were loaded with a specified number of cycles (N) and then the loading process was stopped.

* Institute of Material Science and Applied Mechanics
Technical University of Wrocław, Poland.

MICROSCOPIC EXAMINATION

In the specimens subjected to pure tension the first cracks appeared in the middle of the steady deformation rate period ($N/N_f = 0.30$) while in the specimens subjected to tension and torsion - in the end part of this period ($N/N_f = 0.57$). In the first case the cracks were mainly of wedge-like type and appeared at the boundaries of grains located in the vicinty of internal and external surfaces of specimens. In the second case the cracks were located in the neighbourhood of external surfaces of specimens within the distance 0.05 - 0.1 mm These cracks were located under the grain refining zone During the accelerated deformation period both intercrystalline and transcrystalline type cracks were observed in the specimens subjected to tension and to tension with torsion. In the specimens subjected to pure torsion no cracks were observed before the loss of specimen shape stability.

Fractography showed that both intercrystalline and transcrystalline fracture existed in all specimens fractered in pure tension. Intercrystalline fracture was found to occur at the external and internal surfaces of specimens and a total contribution of these areas was about 68%. In the middle part of the fracture surface transcrystalline fracture was observed. In specimens subjected to tension and torsion three fracture areas existed. Fine transcrystalline fracture was observed at external surfaces of specimens (about 17% in area). Transcrystalline ductile fracture with the dimples was found to occur at the internal surfaces of specimens (about 56% in area). In between these regions intercrystalline fracture was observed. In all specimens fractured under pure tension and combined with torsion the fatigue fracture zones occuried between transcrystalline and intercrystalline fracture areas (fig. 1). Nearly parallel striations were observed in these zones. It is worth to note that very often the transcrystalline cracks were found to exist which started from intercrystalline cracks. On the surfaces of these cracks some oxidation was observed (fig. 2). This latter feature was an indication of a fairly long propagation period.

CONCLUSION

1. Distribution of cracks and fracture type depend on stress state type.
2. In all specimens fractured under pure tension and tension with torsion the fatigue fracture zones occurred between trans- and intercrystalline areas.

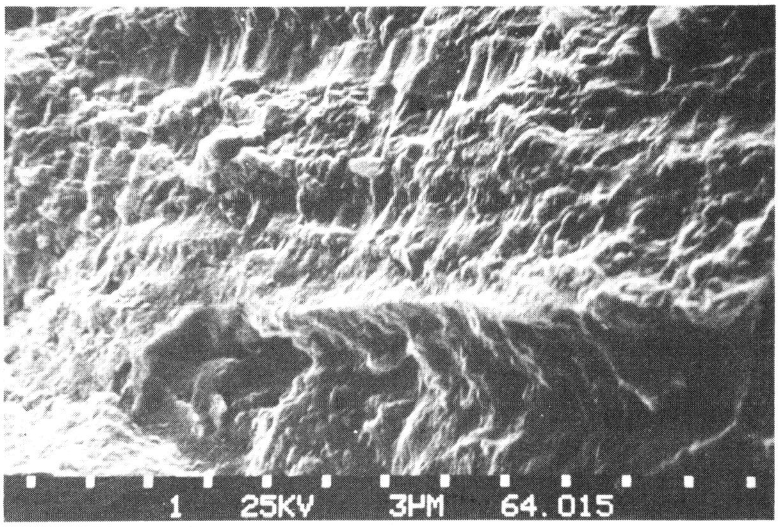

Figure 1 Tension, fatigue striations between two zones of fracture surface

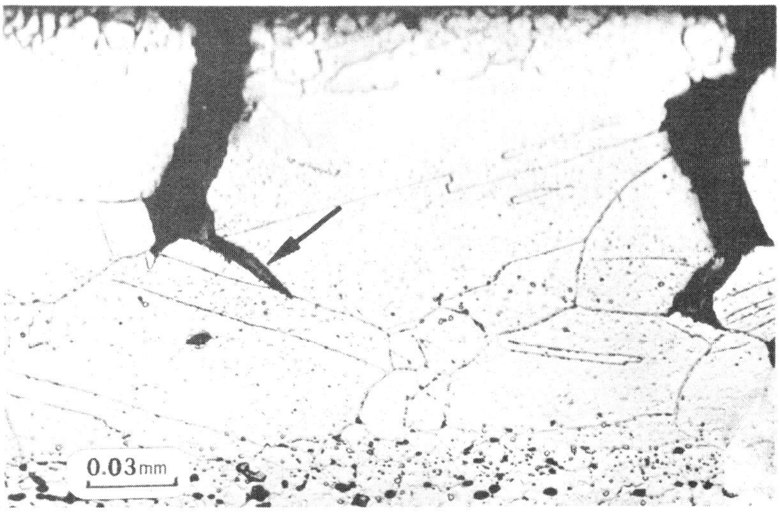

Figure 2 Tension, inter- and transcrystalline cracks, the arrow shows internal oxidation of crack