Crack Initiation and Growth in Shot-Peened and Prestrained Peened High Strength Steel

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ABSTRACT

A low alloy high strength CrMnV-steel of o,5 % carbon content is quenched and tempered to a tensile strength between 12oo and 185o MPa.

Flat samples of 1oo x 15 x 4oo mm are shot-peened without or with a prestain of o.75 the yield strength. These two surface conditions are compared in four-point-bending tests to unpeened specimen. The applied load was chosen to give a fatigue life bezween $1o^4$ and $1o^6$ cycles. Special consideration is given to the crack initiation which is registered by on-line ultrasonic surface waves. By means of five detectors it is possible to locate individual cracks and follow their extension seperately.

These investigations are accompanied by microstructural and fractografic analysis.

KEYWORDS

High Strength-Steel, Four-Point-Bending, Shot-Peening, Shot-Peening under Presstress, On-Line Crack Detection

INTRODUCTION

The structure and mechanical properties of low alloy steels with a carbon content of about o,5 %, quenched and tempered to a tensile strength between 12oo and 185o MPa were thoroughly investigated in a recent study (Siekmann, 1983). In polished samples without any surface treatment, fatigue starts with glide traces on the surface in the vicinity of nonmetallic inclusions (Fig. 1a). In the bulk of the steel the dislocation pattern is gradually changed and a cell structure formed (Fig. 1b).

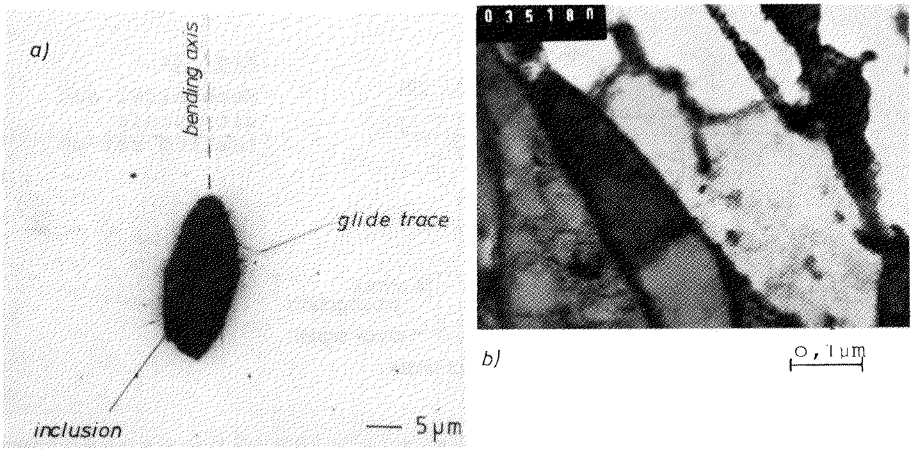

Fig. 1: Glide traces (a) and cell structure (b) in polished samples

The lower the tensile strength the earlier cracks are initiated in the glide traces. Crack extension though is accelerated with growing tensile strength.

The present investigation deals with the influence of surface treatment on the fatigue behaviour of as-rolled, quenched and tempered high strength steels.

EXPERIMENTAL PROCEDURE

The detection of small cracks in as-rolled unmachined parts of a certain surface roughness is not as easy as on polished samples. In order to measure the crack size on-line a number of possible procedures were tested:

- Sprayed films, which change their colour as a crack is started, alter - as a surrounding medium - the fatigue life.
- The change of electric resistance under high direct current of short intervals is not sensitive enough to locate small cracks.
- For the same reason the use of the electric-surface-potential set-up was dropped.
- Ultrasonic surface waves are able to locate small cracks and follow their extension. Therefore this kind of testing was chosen.

Samples of 4oo x 1oo x 15 mm were subjected to cyclic four-point-bending as is shown in Fig. 2.

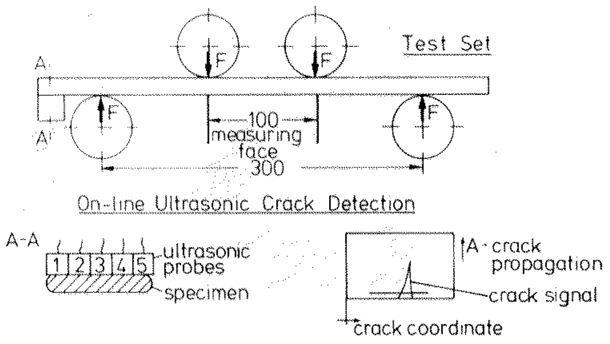

Fig. 2:
Mechanical and ultrasonic testing set-up

Five ultrasonic probes are attached over the width of the sample. By means of a PMMA wedge with an angle of 59^{o}, surface waves are generated. Thereby individual cracks are registered within a surface area of 1oo x 1oo mm. The crack depth is in accordiance with the amplitude of the echo on the oscillograph. The cloosed loop hydraulic testing machine is controlled by a computer which also processes signals of the ultrasonic detectors. The frequency of the cyclic loading ranges from five to ten Hz.

As mentioned before a low alloy CrMnV-steel with a carbon content of o,5 % was quenched and tempered to UTS levels of 12oo, 15oo and 185o MPa.

Three different unmachined surface conditions were tested:

a) Prestrained at a level of 1.2 times the yield strength.

b) Shot-peened (Almen intensity: o,59 A2) and prestrained as above.

c) Shot-peened under a prestrain of o.75 times the yield strength (Almen intensity: o,52 A2) and prestrained as above.

The resolution of the ultrasonic testing device depends on the roughness and is found in the vicinity of about o,2 mm crack depth.

The surface roughness and micro hardness are given in Fig. 3a und 3b.

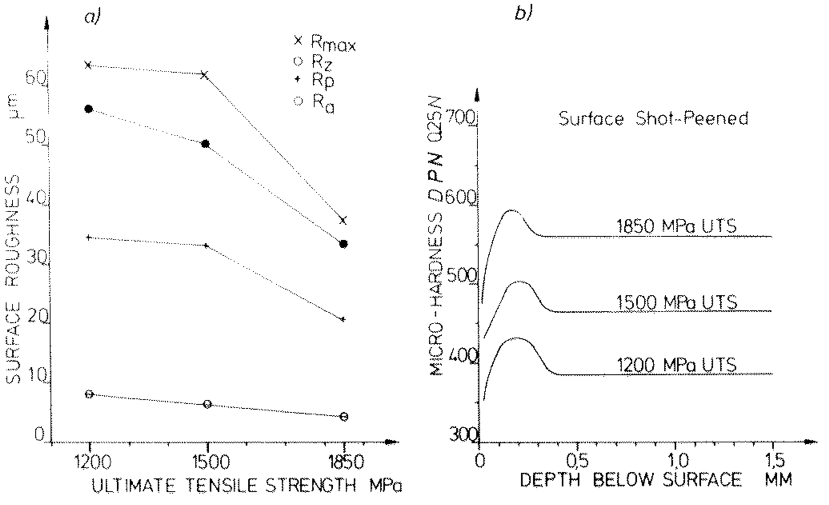

Fig. 3: Surface roughness (a) and micro hardness (b) of a CrMnV-steel

CRACK INITIATION

In spite of peening all cracks started at the surface and not within the area of highest residual stresses. Crack initiation is delayed by shot-peening and prestrain peening as is shown in Fig. 4.

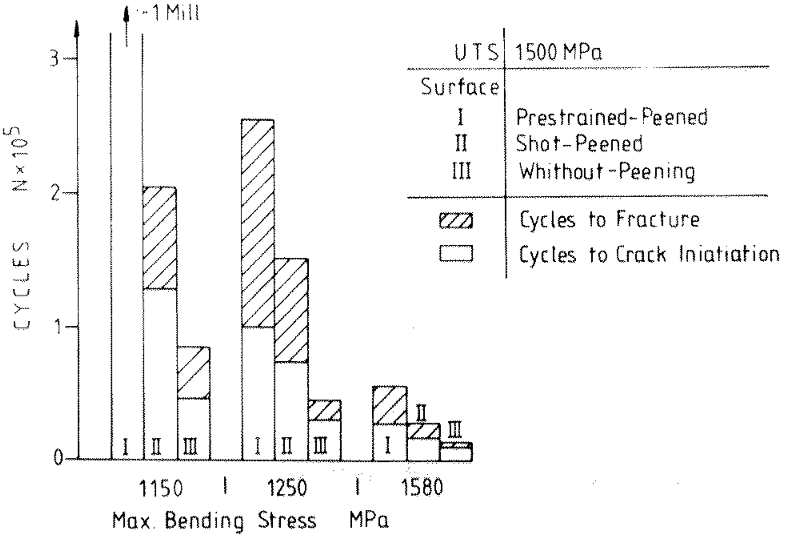

Fig. 4: Cycles to crack initiation and to fracture in respect to surface condition and max. bending stress.

The ratio of cycles to crack initiation is N_A and cycles to fracture N_B is reduced as the surface stresses by peening are raised (Fig. 5).

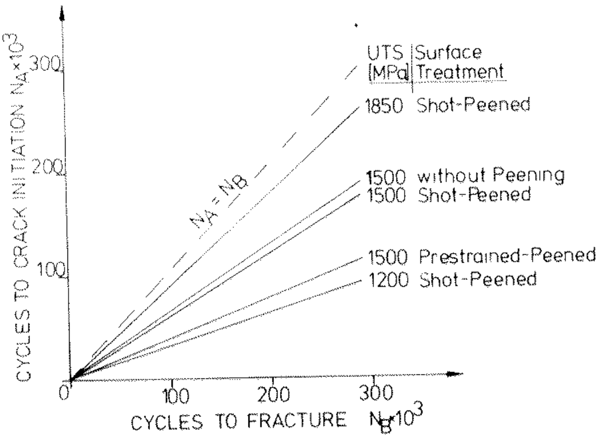

Fig. 5:

Cycles to fracture N_B vs. cycles to crack initiation N_A as a function of surface condition and UTS

CRACK GROWTH

Cracks first detected at N_A usually linger for a while or grow slowly until N_W - the number of cycles for a rapid stable crack growth - is reached (Fig. 6)

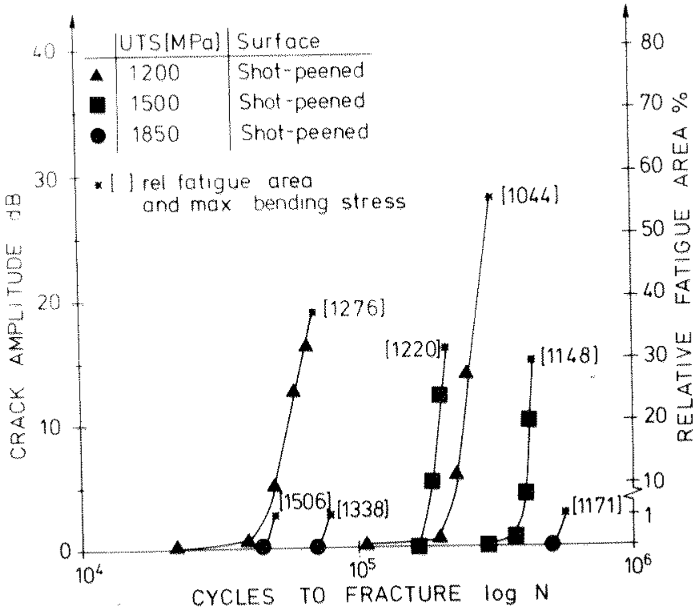

Fig. 6:

Cycles to fracture vs. crack amplitude and rel. fatigue area in respect to surface condition, UTS and max. bending stress

The interval from N_A to N_W declines as the tensile strength is increased. By shot-peening and prestrained shot-peening the period of crack growth (N_B-N_A) is prolonged more than the period of crack initiation N_A (Fig. 4 and 5). The fatigue fracture area at the beginning of instabil crack extension is the higher the lower the UTS and the bending stress.

SUMMARY

In order to seperate crack initiation and crack growth under cyclic loading in unmachined peened and prestrained peened surfaces of a quenched and tempered high strength steel, ultrasonic surface waves were used for on-line crack detection in a four-point-bending set-up.

By shot-peening stable crack growth is slowed down in the beginning and accelerates as the peened layer is surmounted. At the high strength level of 185o MPa no delay is observed.

REFERENCES

Siekmann, Gerd: Doctoral thesis, Ruhr-Universität Bochum 1983