

MICROSTRUCTURAL RESEARCHES REGARDING THE CRACKING OF 16Mo5.3b STEEL TEST SPECIMENS SUBMITTED TO THERMOMECHANICAL FATIGUE TESTS

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Abstract: In the present paper are mentioned the results of thermomechanical fatigue tests of 16Mo5.3b steel test specimens, from metallographic point of view and from microstructural view of starting and growing cracks at thermal fatigue. Are presented cross and longitudinal sections through the test specimens highlighting the cracks growing.

Keywords: thermomechanical fatigue tests; test specimens of 16Mo5.3b steel; microstructural researches; cross and longitudinal sections through the test specimens.

1. THEORETICAL CONCEPT FOR THE CRACK STARTING, THE CRACK GROWING AND THERMOMECHANICAL FATIGUE FRACTURE

The crack starting and the crack growing for fatigue crack take place in the following conditions, necessary to be respected also into experimental test [1],[2],[3]:

- a) There isn't surface roughness which to be stress concentrator factor;
- b) There isn't a material defect failure to lead to the formation of massive cracks in crystalline matrix (type defect: shrink hole);
- c) There aren't microscopically phase precipitations to increase stress concentration in the crystalline granule;
- d) There aren't coarse inclusions to increase stress concentration in the crystalline granule;
- e) There isn't phosphorus and sulphur coating at granules limit.

In [5], they mention about fracturing at thermomechanical fatigue tests.

The fatigue crack increase has three phases:

- In the primary phase, the cracking is developed at 45° in comparison with the surface and is influenced by the granulation size.
- In the second phase, the cracking perpendicularly develops on the principal stress direction. In this phase, material heterogeneity not influenced the crack.
- In the third phase, the cracking propagation is influenced by the material heterogeneities, defects, instabilities.

Also, these three phases depend on material and loads. So, at a low number of loading cycles and at big deformations, the second phase appears. At a high number of loading cycles and low amplitudes of loading, the first phase appears.

There is important that the starting of the fatigue crack begins from the surface [6],[7]. Here the weak link is the slipping surface, at the slip band exit from the granule interior on their free surface.

The cracks starting can be also produce by the surface roughness itself , but only the ambient temperature. At high temperature, the principal weak link of the cracks starting initialization is represented by the granule limits, and they mentioned.

Also, the inclusions or oxide precipitations induce an interaction with the persistent slipping surfaces, then they induce the stress concentration.

Those points can develop at that time an internal crack.

In the figure 1a, are represented the cracking stages into test specimen section [4]. In the figure 1b, are represented a metallographic ground slides for this aspect.

The stage I represent the initiation of a 10 μm micro crack along the slipping surface, 45° inclined in comparison with the stress axis, crossing 2-3 granules.

The stage II represent a crack growing perpendicularly positioned in comparison with the stress axis and it is characterized by the fracture mechanics parameters ΔK_I , and the Paris equation.

The stage III correspond to a crack critical lenght, because they arrive to an amplitude critical value of the stress intensity factor $\Delta K_{I_{cr}}$, and the test specimen breakes.

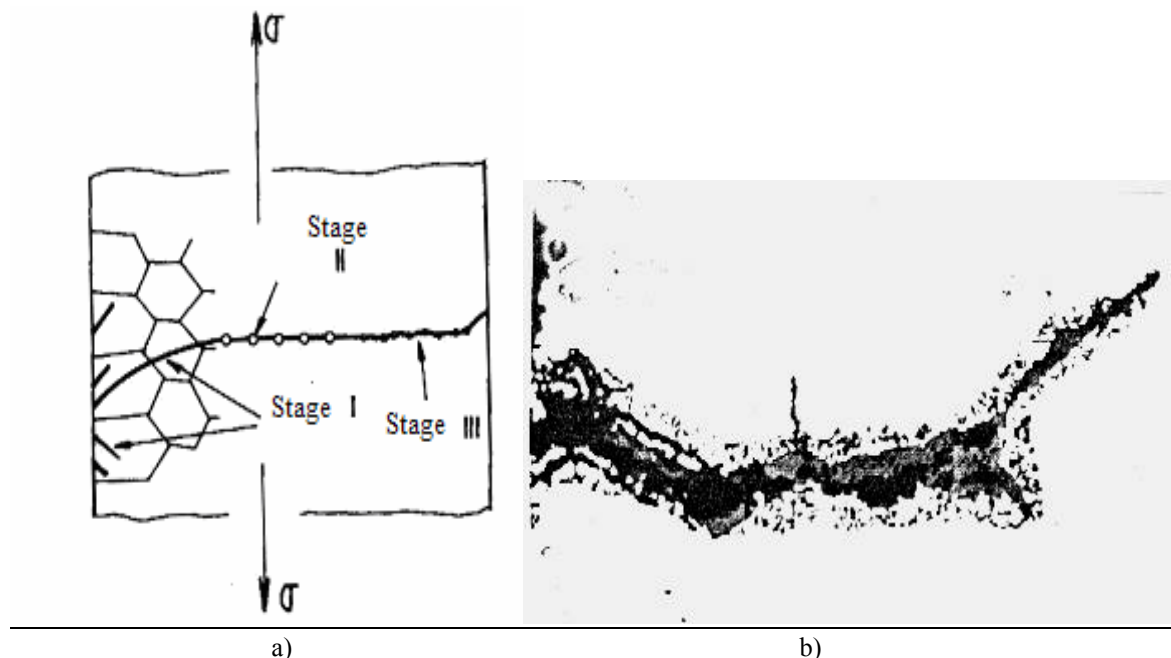


Fig. 1. The cracking stage into test specimen section.

The fatigue crack initiation in the first stage is due to the slipping dislocations in the lasting slipping plane. The free surface is the preponderant place of their appearance. At high temperatures the resistance at the granule limit decrease, oxidation rate increase, the microcrack grow and by thermal activation the climbing dislocations is

amplified. The most of the materials are characterized by a structural instability in the cycle degradation process at high temperatures. [4] These variations can allow the fatigue durability decrease of the element.

2. MICROSTRUCTURAL ASPECTS OF THE 16Mo5.3b STEEL TEST SPECIMENS CRACKING IN TERMOMECHANICAL FATIGUE CONDITIONS

They analyze the metallographic test specimens, obtained from the 16Mo5.3b steel in fatigue conditions.

The test specimens are presented in figure 2. The interior of this test specimen is smooth cylindrical, with 12 mm diameter. In the central ,built-up zone (hot-temperature zone ,zone of fracture), the exterior diameter is 13 mm.

In the interior smooth cylindrical zone, the diameter is 14 mm. The thread fixing ends are M16. The execution precision was in perfect correspondance with the standards proceedings.



Fig. 2. Test specimen from 16Mo 5.3b

In figure 3 is shown on the test specimen which was submitted to 1004 termomechanical fatigue cycles, in temperature range $60^{\circ}\text{C} \div 540^{\circ}\text{C}$, with total strain control ($\Delta\epsilon_{\text{total}} = 0,42\%$).



Fig. 3

They realized a transversal section through the minimum diameter of the test specimen, and the metallographical ground slides are presented in the figures 4.

In the figure 4a is presented the basic metal structure, affected by phase precipitations at the granule limits. In the figure 4b is presented a crack, revealed at the minimum test specimen diameter and the flanks are covered by oxide.

In the figure 4c is presented a crack, revealed at the test specimen surface and the free surface are covered by oxide. So, after the crack initiation along a slip band, which has a 45° in comparison with the test specimen axis, the crack growing is determined by the tension state from the crack top.

They can observe a dominant crack development, which is the principal crack. The crack propagation is realized in an over-crystalline manner, beginning from the test specimen surface, in the precised conditions a) - e) at first capitolo of this paper.

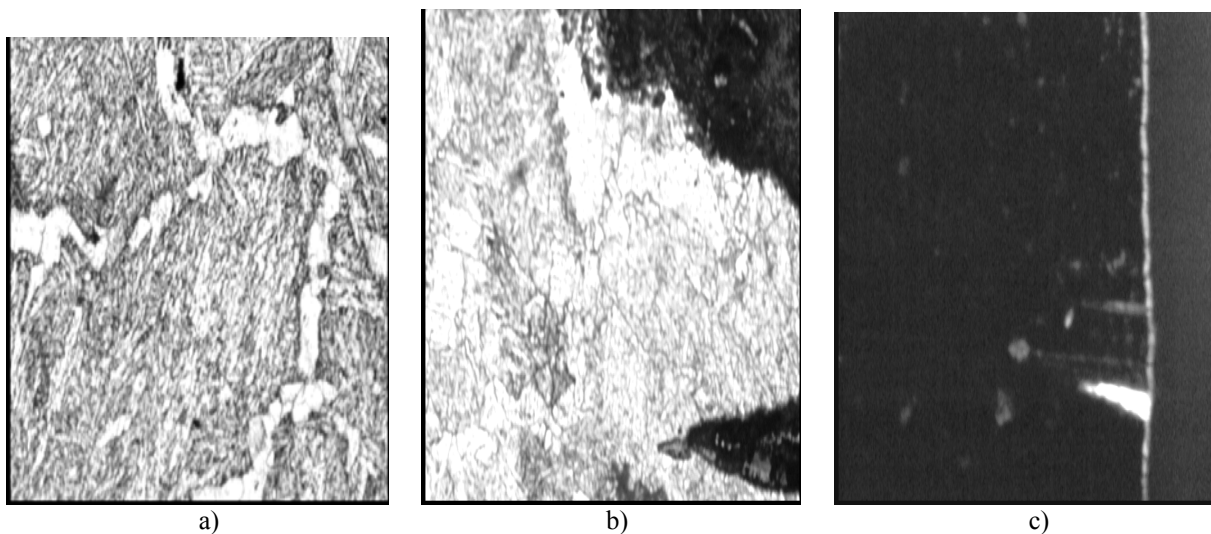


Figure 4. The metallographical ground slides for test specimen shown in the figure 3.

In the figure 5 is shown on the test specimen which was submitted to 292 termomechanical fatigue cycles, in temperature range $60^\circ\text{C} \div 540^\circ\text{C}$, with total strain control ($\Delta\epsilon_{\text{total}} = 0,6\%$).



Fig. 5

They realized a longitudinal section and the metallographical ground slides are presented in the figures 6. In the figure 6a is presented the basic metal structure, the granule beeing viewed on the s width of the metallographical test specimen.

In the figure 6b and 6c can see the fatigue cracks, revealed under a 45° angle in comparison with the test specimen edge, both on the right flank and the left flank. So, after the crack initiation along a slip band, which has a 45° in comparison with the test specimen axis, the crack growing is determined by the tension state from the crack top.

They can observe a dominant crack development, which is the principal crack.

The crack propagation is realized in an over- crystalline manner, beginning from the test specimen surface, in the precised conditions a) - e) at first capitol of this paper.

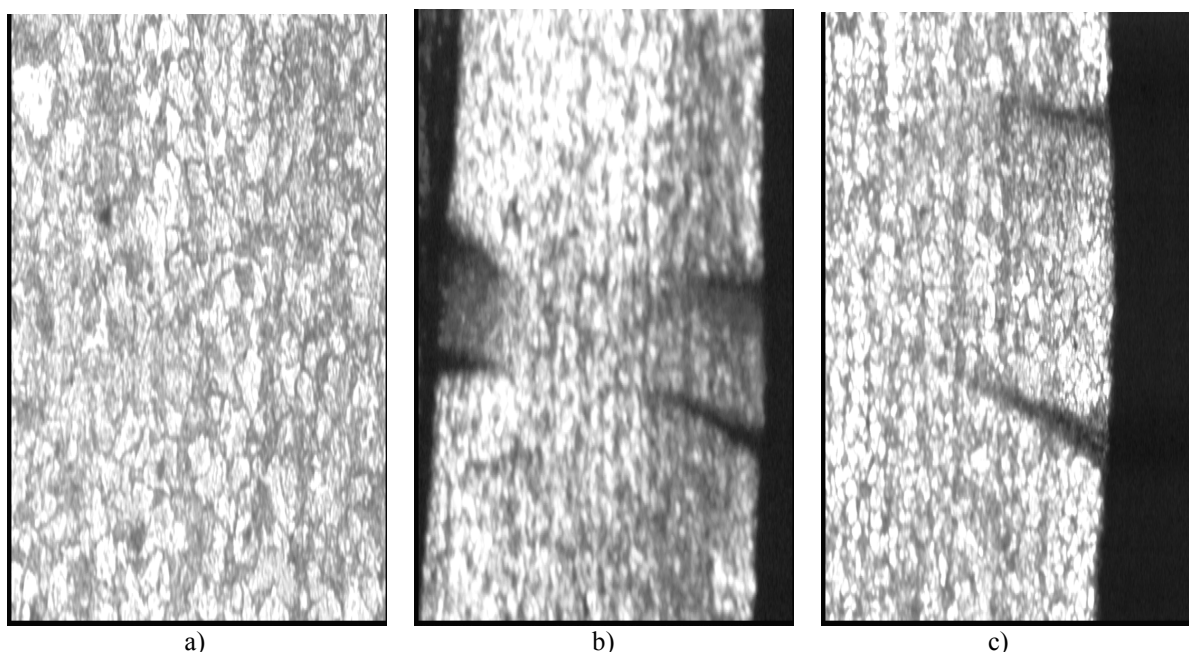


Fig. 6. The metallographical ground slides for test specimen shown in the figure 5.

At the thermal fatigue tests, without a level maintenance, a pure crack over-crystalline growing up results, which starts from the test specimen surface, being specific for the thermal fatigue strain.

This thing leads to the determination of the lifetime for the thermomechanical fatigue strained equipments.

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