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EVOLUTION OF SOME STRUCTURAL FINE PARAMETER IN THE SUPERFICIAL LAYER DURING LOW CYCLE FATIGUE PROCESS

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ABSTRACT

Using laminate samples, investigations have been realized at variable solicitation of pure bending on a patented machine. The machine has two working places and it can be adjusted for different deformations, frequencies and number of cycles. The tests have developed in a symmetrical alternative regime at two frequencies. In this paper some results concerning the evolution of the crystalline lattice parameter, level of the texture were realized in steps of each two thousand cycles until a limit of 10^4 cycles. The X-ray diffraction method was used and information on the ferrite phase was obtained. The crystalline lattice parameter presents a decreasing tendency when the number of the fatigue cycles increase. This decreasing in jumps occurs. During fatigue tests at high testing frequencies, an increasing texture process is displayed, but at small fatigue testing frequencies, increasing and decreasing texture processes occur. Experimental data allows to estimate the history of the sample and its behavior in fatigue process.

KEYWORDS: steel, fatigue, low frequency, lattice parameter, texture, X-ray diffraction

1. General considerations

In order to perform a complete study of the behaviour of the superficial layer during fatigue test and to evince the main factors, which determine the damage process, the structural cybernetic model was introduced.

In fig.1 this model is presented and it allows to a systematic study of the input parameter changes under action of the commanding ones.

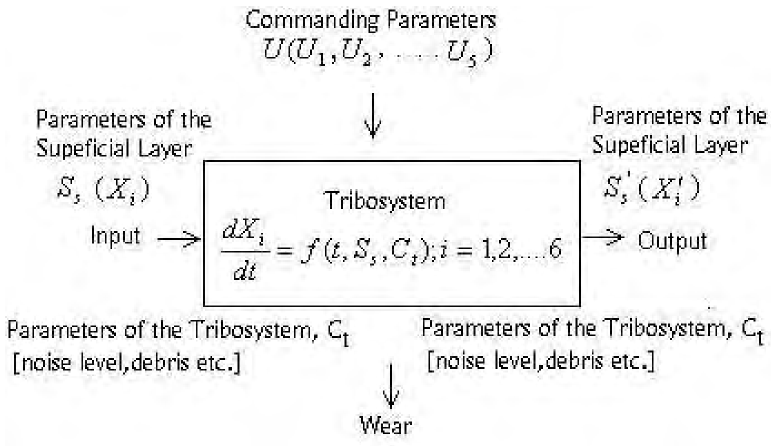

Fig.1. *Used cybernetic model*

The input/out parameters are: superficial layer parameters (S_s-S'_s) [X_1- macro and micro-geometry, X_2 - microhardness and hardness, X_3 – tension state, X_4 – chemical composition, X_5 – structure, X_6 – purity] and tribosystem parameters (C_s) [noise, debris]. Some of the mentioned parameters, as X_2, X_3, X_5, can be changed from exterior such the durability of the material to be in a certain interval.

The commanding parameters (U) [U_1 – nature of material, U_2 – shape of the sample, U_3 – dimension of the sample, U_4 – working medium, U_5 – kinematics, U_6 – energetics] called external factors, by their action can change some superficial layer parameters X_i, i=1 – 6. In our experimental program the evolution of the X_2, X_3 and X_5 was shown by changing U_1 (type of steel: OL 52) and U_5 (testing frequency: ν_1=20 cycles/min, ν_2=40 cycles/min., testing deformation: ε_1=2000 μm/m, ε_2=2500 μm/m, ε_3=3500 μm/).

2. Experiment

We have conducted the examination of material features in fatigue process for two steels used in pressure vessel engineering: OL 52 and 10TiNiCr180. Using laminate samples, the investigations have been performed at variable solicitations of pure bending on a patented machine [1].

The tests have been developed in a symmetrical alternative regime at two frequencies: f_1=20 Hz, f_2=40 Hz.

The deformation domain was established in an experimental program of tests using the resistive tensometry. The deformations of samples were imposed at the superior limit of elastic domain, evaluated from characteristic curves. The deformations imposed in case of OL52 were: ε_1=2000 μm/m, ε_2=2500 μm/m, ε_3=3500 μm/m and in case of 10TiNiCr180: ε_1=1500 μm/m, ε_2=2000 μm/m, ε_3=2500 μm/m, respectively.

In the present paper we presented the experimental results only for OL52 steel. The experiments were performed in steps of two thousand cycles until a limit of 10^4 cycles. In every step, we investigated the lattice parameter and texture level [2, 3]. For this investigation we used an X rays diffractometer, DRON-3.

3. Results and discussions

In figure 2 and 3 the evolution of the lattice parameter for OL 52 steel tested to fatigue process for three imposed strains, ε_1, ε_2 and ε_3 at two frequencies are respectively presented.

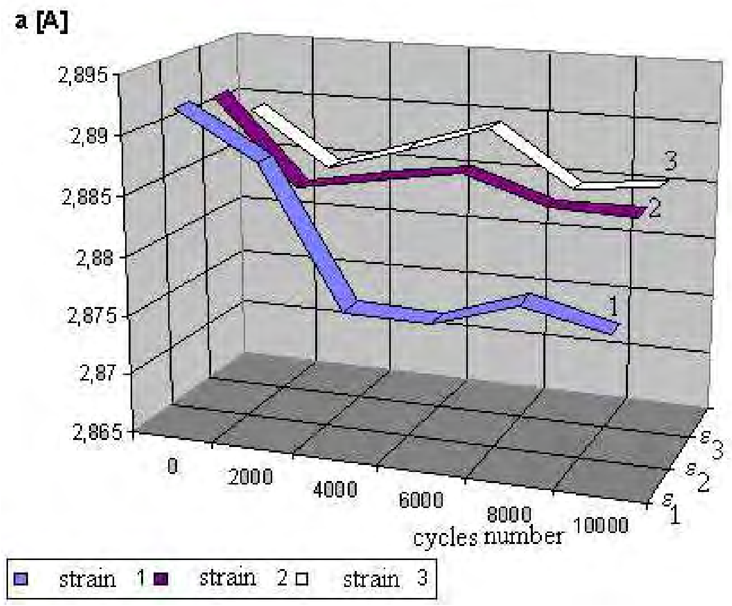

Fig.2. *Evolution of lattice parameter for f = 20 cycles/min*

Analyzing those two figures, a general tendency of decreasing of the ferrite phase lattice parameter, is evinced, when the number of the testing fatigue cycles increases. This occurs for the all imposed strains. A strong decreasing is revealed for small strains and frequencies, respectively for high strains and frequencies. The change of the lattice parameter can be explained by supposing that a migration process of some alloyed elements occurs during fatigue tests. This fact presents validity by a soft increasing of the lattice parameter during the fatigue test for an established testing cycle number. This increase appears earlar when the strain is bigger. The migration process of atoms in and from elementary cell of the ferrite phase shows the existence of a high kinetic of atoms in the superficial layer during fatigue tests. This kinetic can have negative effects if the material is tested in corroding media.

The migration process is more slowly in case of the small strain and more intensive at high frequencies and big strains; at small strain the process is more intensive at small frequencies. The presented data show that there is the possibility to command from exterior the durability of the tested material by changes of the imposed strain and testing frequencies in a certain range.

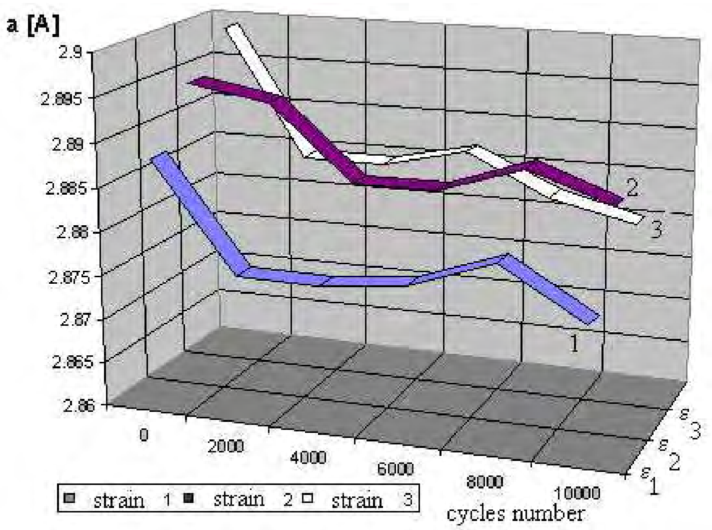

Fig. 3. *Evolution of the lattice parameter for f = 40 cycles/min*

In figure 4 and 5, for 20 cycles/min and 40 cycles/min, the evolution of the texture parameter, measured by ratio I_{max}/I_0, where I_{max} and I_0 are, respectively, the maximum intensities of the X-ray diffraction line (220) of the ferritic phase, for tested and non-tested samples, are presented. From figures, an inverse texture (IT) process of material is evinced. The higher degree of the IT occurs in the case of the bigger strain, ε_3.

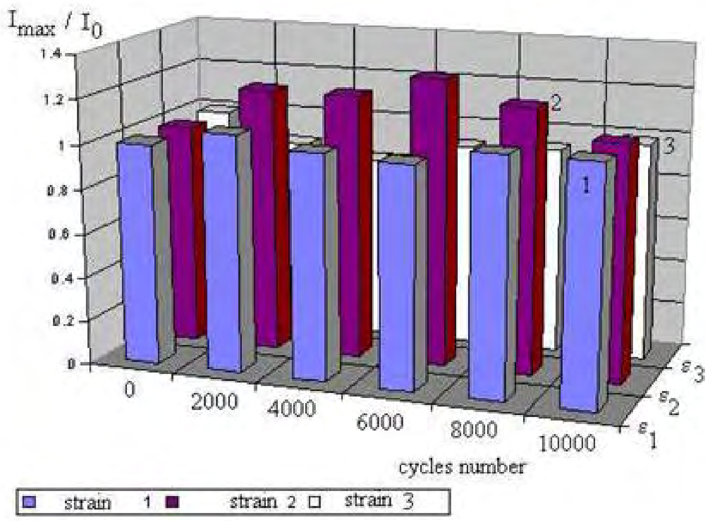

Fig.4. *Evolution of texture level for f = 20 cycles/min.*

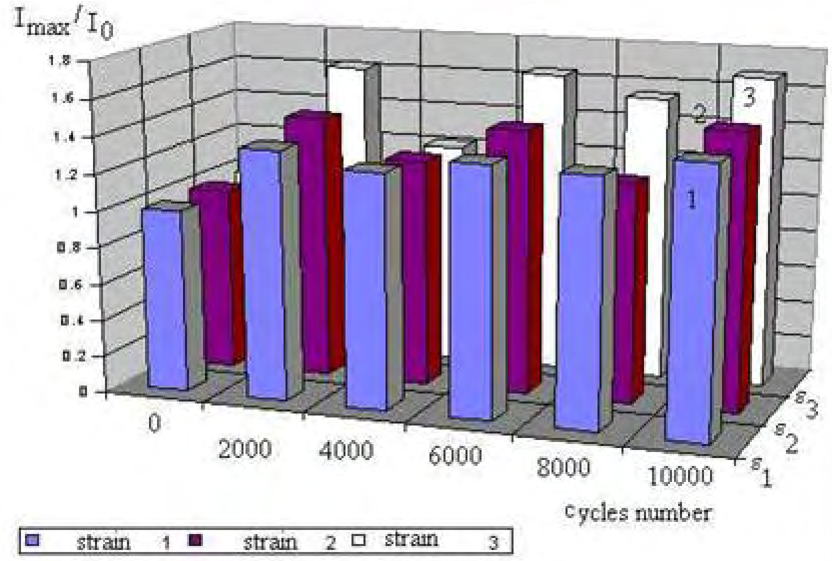

Fig.5. *Evolution of texture level for f = 40 cycles/min*

This IT can be associated to some mechanical micro-processes that lead to a preferential orientation of the crystalline planes in [220] direction in relation to laminated state of material, when $I_{max}/I_0 = 1$.

From the view of the presented histograms, can be analyzed the distribution of the texture degree of steel during fatigue tests and a relationship with plasticity properties can be established.

At small frequencies the material presents a normal hysteresis, but at high value the inertial properties of material are smaller.

Conclusions

1. During fatigue tests, the lattice parameter presents a general tendency of decreasing when the number of the cycles increases, for those three strains and those two frequencies. The decreasing occurs in jumps and can be associated to a migration of alloying elements from steel. The migration process is strongly influenced by number of fatigue cycles and level of strain.

2. During fatigue tests, a texture process of ferrite phase occurs and it is influenced by level of strain and frequencies. The texture process, evinced by X-ray diffraction method, shows data about inertial properties of fatigue tested material. The steel looses the elastic properties when it is tested at high frequencies, the influence of strain not being very important.

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