Regularities of Acoustic Emission in the Freight Car Solebar Materials

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Abstract. Acoustic emission results which were obtained during tests of the samples, which were made from foundry solebars with the developing fatigue crack, are presented. The dependences of the acoustic emission event count, the force critical value during the stationary acoustic emission process, and the growth rate of the event count from the cycles number are determined. The amplitude signal distributions relating to the crack growth were received. It is offered to use the force critical value and the amplitude threshold in the rejection criteria.

1. Introduction
Eddy current and magnetic methods of nondestructive testing are applied to diagnostics freight car solebars and bolster beams during planned types of repair on the Russia railroad. Bogies cast details, which resource is carried out, are testing by acoustic emission [1] method. The existing acoustic emission testing technique is directed on prevention refusals connected with old suitable details using. The rejection criteria are the most rigid and directed to the selection of faultless details from obviously unsuitable to operation on service life.

The acoustic emission control during planned types repair demands other approach in which it is necessary to minimize not only defects admission probabilities, but also false rejection probabilities. Necessary dependences of diagnostic signals critical values with errors probabilities can be received only in the course of acoustic emission testing of the samples with the real defects.

2. Experiment description
The samples for mechanical testing were prepared from solebar material (steel 20ГЛ in GOST 3240). Samples thickness varied in the range from 8 to 13 mm as samples were made from the real details with the foundry defects. The sources of the cracks development were the longitudinal slots 45 mm long.

The tests of the samples were carried out according to the similar scheme to the operation and repair process of the freight cars. The samples were loaded in the MTS electrohydraulic machine with the stretching cyclic force (figure 1) with amplitude 25 kN. Loading were stopped through out 5...20 thousand cycles and the samples were testing by acoustic emission method using monotonously increasing force to the maximum value 30 kN. The sufficient cycle quantity for samples destruction was varied from 60 to 250 thousand and was depended on thickness, foundry defects number and their extent. The detailed metallographic analysis result of the destroyed fragments is provided in [2].
The cracks development was controlled by the regular MTS disclosure sensor (position 4 on the figure 1), which time of measurements was synchronized with acoustic emission system. Acoustic emission signals were registered by the acoustic emission transducers with a pass-band from 0.1 to 0.7 MHz and the discrimination threshold equal 20 μV. The transducers were installed on the one side of the samples in the rectangle corners (position 1, 2, 3, 4 on the figure 1). The acoustic emission system SDAD 16.02/03 [3] was used for signals registration, filtration and preprocessing. Final signals processing was carried out in the specialized developed software. A plane source location was realized by the difference time of the signal arrival to the transducers. The transducer coordinates were used for definition and location of a crack top and signal filtration, which are arising in the places of the interaction between the samples and the loading device captures.

3. Experimental results

The increase crack disclosure was fixed already during the initial testing stage and the disclosure speed was monotonously increased for all testing samples. Similar regularities are typical for the low-cyclic fatigue testing and are caused with repeated-plastic material deformation.

During the testing of the samples No. 5 and No. 6 the sharp increase of the crack disclosure (more than twice) before the destruction are fixed. But such regularity was not found in a sample No. 2. The crack development unevenness is caused by the different foundry defects in the samples.

In the conditions of the low-cyclic fatigue the basic process of the acoustic emission signals generation is the plastic deformation of the vicinity of the stress raiser. Any obvious regularities which would allow to establish the dependence between the event count and the cycles number or the crack disclosure were not revealed. For example, for the sample No. 2 the considerable increase of the event count is characteristic not long before the destruction, for a sample No. 6 the existence of the event count maximum at 80 thousand cycles is characteristic, and for the sample No. 5 event count is fixed at the constant level from 20 to 40 acoustic emission impulses. First of all the acoustic emission event count depends from the plastic deformation value and material volume [4]. The lack of the regularity depends with the composite crack path and the existence in the sample material defects which influence on crack development. Therefore the plastic current in the crack mouth change in a random way in the course of the crack moving. It is defines the event count dependence from the cycles number.

The graphics of the dependences the test force and the acoustic emission activity during the static test on the time are submitted on the figure 2 for the sample No. 6 after 83000 cycles. These dependences are typical for all samples. Acoustic emission signals are registered in the course of the test force value. It testifies that plastic deformation for both directions test forces change. The acoustic emission signals arising during loading and unloading was analyzed separately.

Acoustic emission signals were registered in the certain force range. On the figure 2 it is shown the behavior of acoustic emission activity. The acoustic emission signals arise when the force increase above the critical value $F_i$ and when the force decrease below $F_d$ [5]. Critical values can be
characterized by dimensionless coefficient $K_F$, which is equal to the relation critical value and cyclic force amplitude.

**Figure 2.** The graphics of the dependences the test force (1) and the acoustic emission activity (2) during the static test on the time, the sample No. 6 after 83000 cycles, where $F_i$, $F_d$ – critical force when increase and decrease, respectively.

The graphic dependence of the coefficient $K_F$ from cycles number are shown on the figure 3. Sharp decrease force critical value $F_i$ is observed after 5...10 thousand cycles (5...10% total of cycles) destruction in all tests. The distinctive feature of the sample No. 2 is the existence of the tendency to decrease $F_i$ at all stages of crack development. The critical value decrease to 90% is observed for 30 thousand cycles (20%) before the destruction. The force value $F_d$ has considerable fluctuations, as shown on the figure 3, therefore it can’t be effectively applied for using as single rejection criterion.

**Figure 3.** Dependence schedules of relative forces critical values $F_i$ (1) and $F_d$ (2) from cycles number for samples No. 2 (a) and No. 6 (b); 3 – amplitude of cyclic loading force; 4 – the average value of $F_d$.

The critical value $F_i$ divides the dependence of acoustic emission event count from increasing force on two parts (figure 4). In the force field less than $F_i$ (about 20 kN) separate impulses are registered, acoustic emission has non-stationary character. The non-stationary acoustic emission event count didn’t exceed 20 for all tests. Loading with a force more than 20 kN causes emergence stationary acoustic emission and event count linearly depends from force:

$$N = a(F - F_i) + N_0,$$

(1)

$a$ – the coefficient determined by least-square analysis, kN$^{-1}$; $F$ – the force value, kN; $F_i$ – the force
critical value, kN; \( N_0 \) — non-stationary acoustic emission event count.

Figure 4. Schedules of event count dependence from force for various cycles number.

Coefficient \( a \) in the equation (1) describes event count growth rate. Stationary acoustic emission appears at force above the amplitude cyclic loading before cycle quantity less 87 thousand. The crack length increasing leads to reduction force critical value \( F_i \), which equal 40% force amplitude before destruction. Emergence of stationary acoustic emission before cyclic amplitude force testifies about Kaiser effect violation and fatigue defects develop actively. In the course of crack growing the coefficient \( a \) from 12 to 21 kN\(^{-1}\) in the cycles range from 110 to 130 for the sample No.2.

Acoustic emission signal amplitude distribution [6] for various cycles is presented on the figure 5. The high-amplitude signals number with an amplitude more than 300 mV increase before 10...20 thousand cycles (for a sample No. 2 before 40...50 thousand) destruction for all samples increase. It testifies about plasticity stock exhaustion and fragile destruction beginning. In the sample No. 2 relative quantity of high-amplitude signals doesn't exceed 5%, thus the average amplitude during tests monotonously increases from 40 to 75 \( \mu \)V (figure 6).

Figure 5. The dynamic of the amplitude distribution at static tests.

Figure 6. Average amplitude at static tests.

In the course of fatigue crack growing the concentration coefficient increases and, therefore, a stress increases close to crack top. Thus the average signal amplitudes increase. For example, in the sample No. 2 the growth rate of acoustic emission signals amplitude equal 23 \( \mu \)V divide on 103 thousand cycles (figure 6). Amplitude threshold equal 200 \( \mu \)V will allow finding fatigue cracks 10...20 thousand cycles before destruction in the course of control.

4. Conclusion
Solebars rejection is based on the event count analysis in the course of tests in the specialized test desk for loading. At the same time weak sites, in which plastic deformation develops, are found in details. It leads to the high level rejection (5–10%) of new details. It is offered to use critical force value, event
count growth rate coefficient, amplitude threshold in acoustic emission rejections for increasing test reliability. The recommended relative force threshold equal 80% of average working force and amplitude threshold equal 200 μV.

The executed tests of the samples, which was made from solebar material, showed that composite processes crack development in foundry molded material defines weak dependence between event count and crack disclosure. Monotonous growth event count in crack development is observed only in one of the samples. Force critical value allows observing a crack in the sample (5–20) % cycles total number before destruction. Using for rejection high-amplitude signals allows observing transition from viscous destruction to fragile destruction (10–40) % cycles total number before destruction.

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