1.1.10. NEW APPROACH TO FATIGUE DAMAGE EVALUATION VIA BARKHAUSEN NOISE

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The report relates to the field of material Non-destructive Evaluation (NDE), namely to the fatigue damage NDE, considering also the complexity of fatigue phenomena and alternative approach to fatigue damage assessment.

The fundamental approach to the conventional fatigue damage NDE via various physical characteristics like conductivity, permeability, Barkhausen noise (BN), optical or X-ray reflection, etc. is based on fitting the corresponding measured values of these parameters to calibration diagram, preliminary acquired experimentally by variation the number of cycles. Unfortunately the prediction of fatigue damage, going this way, is frequently useless mainly due to three reasons: 1) fatigue is too complicated phenomena to have the monotonic calibration diagram. E.g. fatigue degradation is usually defined ambiguously via magnetic characteristics; 2) the irrelevant material characteristics like microstructure, residual plastic deformation, surface condition, etc. are usually mask the influence of structure variations provided by fatigue; 3) the fatigue, particularly at early stages, is commonly associated with changes in fine sub microstructure, characterized by behavior of vacations, dislocations, micro cavities, glide lines, etc., while the micro structure variations, provided by fatigue, are usually negligible, similarly to measured physical characteristics associated with them. Therefore the way to fatigue characterization via absolute values of measured parameters should be complemented and elaborated. Last time there appeared several reports (J. Schreiber, V. Filinov, V. Vengrinovich and V. Busco) on volative behavior of BN parameters due to fatigue damage. This report is resulted from experimental study of spatial non uniformity of BN behavior in space and in depth in the specimen under investigation.

The cycling experiments were provided with the intermediate-alloy steel 40Cr (0.4% C and 1% Cr) and high strength martensite-ageing alloy VNS-2. The specimens (in the fig.1, right) were cycled by bending until crack appearance. The measurements were done with the BN analyzer "INTROSCAN". Scanning along the specimen across specimen's neck were done with the sensor which measurement area was about 1 mm^2. The scanning results are shown in the fig. 1.

Each pare of scans on (a) and (b) diagrams corresponds to two undersurface layers: respectively 50 and 170 μm depth. The measurements were done after electro polishing removal of respective layers from the specimen surface. Therefore 50 μm depth corresponds to the layer close to surface while 170 μm depth corresponds to the ground material. The results, from one side, clearly show the growth of an average signal value due to fatigue damage, and from the other side they reveal the growth of the spatial non uniformity in the damaged layer.

The growth of the spatial non uniformity is also illustrated by the BN signal distribution with depth resolution shown in the fig. 2 respectively before cycling (0), after 18000 and 40000 cycles.

The step-by-step removal of surface layers was provided by electro polishing. After each layer removal from the surface of the fatigue damaged specimen scanning measurements of BN signal were done. The scanned results confirmed the ambiguous correlation between magnetic parameter and number of cycles (fig. 3).

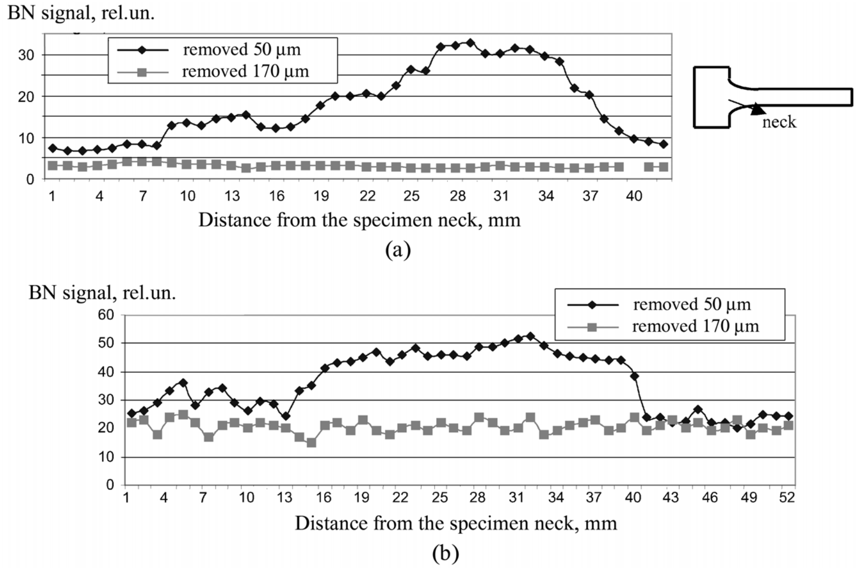

Fig. 1. BN signal distribution in the fatigue zone after removal of 50 and 170 µm relatively after cycling of the:
(a) martensite-ageing steel VNS-2; 2) intermediate-alloy steel 40Cr

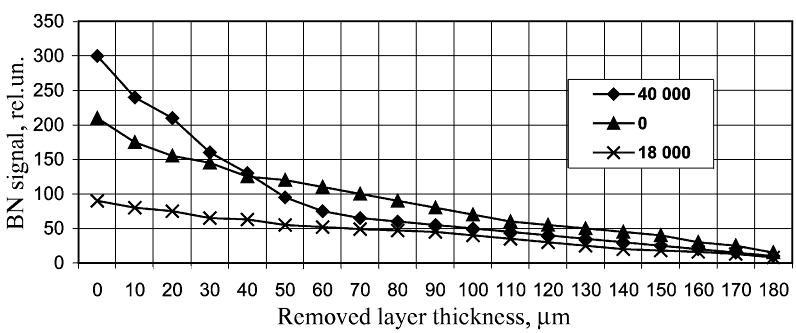

Fig. 2. BN signal value vs removed layer thickness after cycling of the martensite-ageing alloy VNS-2

The dependence of BN signal over removed layer thickness until reaching the ground material displays strong signal reduction while moving off the next surface layer (fig. 2). It is interesting that the behavior of BN signal in the immediate surface region is ambiguous. At the early fatigue stages the signal is dropping while at the later stages it is increases. Thus just before crack appearance at 40,000 cycles the BN signal value on the surface increases in times. But the main conclusion is that the difference between BN

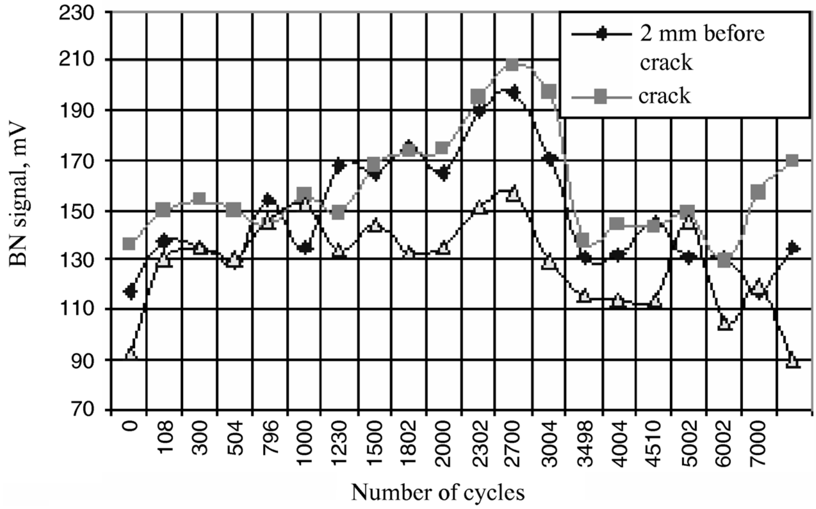

Fig. 3. Initial part of the dependence of BN signal over number of cycles for intermediate-alloy steel 40Cr

value on the surface and under the damaged layer increases for about one order. This result is in qualitative compliance with well known fatigue damage origination from the surface layer. The ambiguous dependence of BN signal over number of cycles for intermediate-alloy steel 40Cr is clear from fig. 3 for three positions of sensor location relatively to the crack initiated by fatigue.

Finally the report stresses on the need to reset the approach to fatigue damage NDE using the parameters of non uniformity of BN signal rather then its absolute values.