INVESTIGATION OF FRICTION AND ABRASIVE EFFECTS IN ENGINEERING STEELS WITH MICROMAGNETIC MEASUREMENTS

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Abstract

Friction and abrasive surface treatment of engineering steels - is the new effective tool for surface material strengthening and improving the resistance to fatigue damage. The specific abrasive machining of medium-carbon steel yields formation of surface hardened layer with super dispersed nanocrystal structure which increase the fatigue damage resistance in times. The present study aimed to establish the correlation between the metal structure at successive stages of abrasive machining and post machining heat treatment, from one hand, and the Barkhausen noise intensity, from the other. Experimentally investigated the influence of a depth of abrasive removal in the range 0 - 0,8 mm on the BNI. At the second group of experiments the behavior of BNI under the variation of heat treatment drawback at various temperatures in the range 20 ^{o}C - 600 ^{o}C was investigated. The results give the background to create the non destructive technique to evaluate the strengthening parameters after friction and abrasive effects on engineering steels.

Keywords: friction and abrasive effects, surface strengthening, Barkhausen noise.

1. Historical background

The attrition of surface layers is the result of frictional and abrasive action [1-2]. From the other hand, friction and abrasive surface treatment of engineering steels - is the new effective technique for surface material strengthening and increase of the resistance to fatigue damage. As an example, the specific abrasive machining of medium-carbon steel yields formation of surface hardened layer with super dispersed nanocrystal structure which increase the fatique damage resistance in times. The frictional texture is also changes [3-4]. At the same time after such treatment of ferromagnetic steels the domain structure and domain walls dynamic properties in surface layer undergo sufficient transformation. This should provoke the changes in magnetic properties, particularly in Barkhausen noise. The present study is the first step to develop the procedure for non destructive evaluation of surface quality after surface abrasion. It is aimed to establish the correlation between the metal structure at successive stages of abrasive machining and post machining heat treatment, from one hand, and the Barkhausen noise properties (BNP), from the other.

Two groups of experiments have been undertaken. Within the first one the BNI was measured in the specimens, made from low alloy high strength steel, after the abrasive machining by grinding to different depth in the range 0 - 0,8 mm. The intensive (several times) growth of BNP was observed at the depths less than 0,5 mm. The appearance of burns was avoided. Within the second family of tests the medium-carbon steel after quenching was treated by dry friction with the help of counteragents from copper and ceramics respectively. After this kind of abrasive action the low temperature drawback was done at various temperatures in the range 20 ^{o}C - 600 ^{o}C. The BNP was measured at each stage of treatment. With the help of specific signal processing the monotoneous dependence of BNP upon heat treatment temperature, and thus the level of tempering, was reached. The concomitant nano structure changes have been investigated.

The results give the background to create the non destructive technique to evaluate strengthening parameters after friction and abrasive engagement in engineering steels.

2. Investigated materials and experimental procedure

Two groups of experiments have been provided. In the first group the high strength steel 300M disks were investigated by Barkhausen effect as to its sensitivity to a thickness of abrasive wear by grinding with abrasive tool. Two 300M steel disks of 30 mm thickness and 200 mm diameter were quenched and 3 times tempered to release residual stresses. Then they were placed into the center of the plane grinding machine and layers of incrementally increased thickness were removed after turning the disk into a new position. Thus about 60 strips were machined on the disks having their width from 3 to 20 mm. The thickness of removed layers varied from 0 to 0,8 mm. According to different thickness the surface hardness, residual stress and strain values, surface geometry were modified simultaneously influencing the surface integrity.

After this kind of machining the BNP were measured with the help of the instruments "Intromat" and "IMSH" [6-8] which measure BN intensity value within the spatial spot with about 3 mm diameter. The integrated results are shown in the fig. 1. It is clear that the increase of abrasively removed layer thickness yields the monotonous growth of BNP up to the layer thickness close to 0,5 mm. Then the saturation comes and the further growth stops. This kind of function indicates that after some critical level of abrasively removed layer the traceable BN does not change any more. In other words, the plastic deformation, surface geometry, surface hardness residual stresses and microstructure reach saturated level at some removed layer thickness. The temperature during abrasion was less than critical level for structural transformations. Also metallographic investigation showed that the martensite microstructure did not change after all removed layer thickness excluding very large ones.

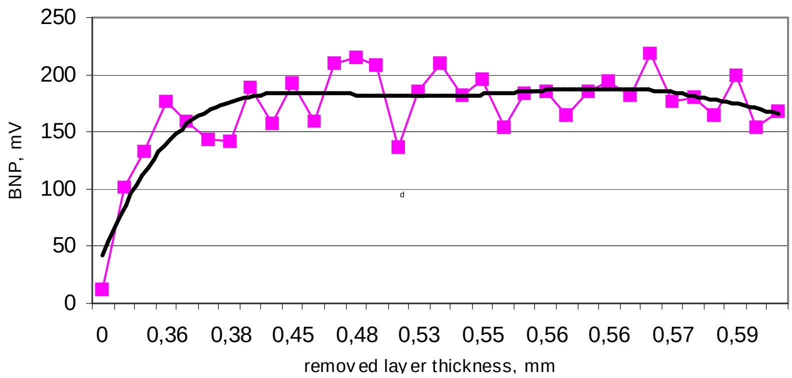

Fig.1. The dependence of Barkhausen Noise parameter via the thickness of the layer removed by grinding.

As it is known from [3-4], during successive abrasive wear the carbon steel first strengthens and then softening takes place. Watching the diagram in fig.1, we assume that the main contribution to the BNP growth is provided by longitudinal tensile residual stresses and plastic deformation in a very thin surface layer. Due to equilibrium condition the compression appears underneath. The last is not so sensible to BNP as tension on top. At very small removals an under layer compression yields increase of integrated surface hardness and strength, but BN feels it like tension stress growth. At larger removals tension covers larger thickness and yields softening. The BNP growth stops. The previous conclusion can be made that two competitive mechanisms control the abrasive treatment of steel: strengthening and softening due to compression and tension respectively. Particularly these mechanical characteristics most influence the changes in magnetic and micromagnetic BN parameters. But the last has many advantages as to its usability, adaptation to computer control, conformity to surface geometry and negligible magneto-elastic hysteresis. The traditional shortage is the demand for false data tune-out entered by other mechanical and structural parameters concomitant changes [5,7,9-10]. In spite of this shortage the shown results confirm the principal ability of the BN technique to be used for evaluation of the changes appear during wear.

For the second group of experiments the specimens from spring and tool medium-carbon steels were used after friction engagement with a contracting agents made with copper, ceramics and hard metal respectively. This kind of dry friction frequently appears in the majority of mechanical machines. As a treatment result after friction of the pairs: tool steel-copper, spring steel-ceramics respectively the treated zones of 7-8 mm width and 60-80 mm length were created on the surface [9,11]. Ten specimens had the shape of parallelepiped 4,3 x 6,8 x 19,7 mm [11]. One of the sides of each specimen after mechanical cutting was electro polished to avoid residual stress. The opposite side was subjected to micro deformation by friction. Before abrasive engagement the specimens were quenched from the temperature 950^{0}C. The abrasive treatment was done by back-and-forth motion of semi-spherical indenter 2,5 mm radius made from highly rigid alloy in noncorrosive medium of nitrogen at normal load 980 N.

Some of the results are shown in the fig. 2 and fig. 3. Several first of them are as follows:

- the level of BNP in the friction zone several times larger than in a non treated region. This means that the deflected mode in the surface layer is quite sensitive to abrasive wear, thus the tempering of the specimen becomes relevant;
- the non uniformity (volatility) of BNP in the friction zone is much more meaningful than in the outer and depends upon the intensity of abrasive treatment;
- surface hardness after friction engagement grows from 7,8 to 10,9 GPa, the reached level does not depend upon the load applied to the rider [4].

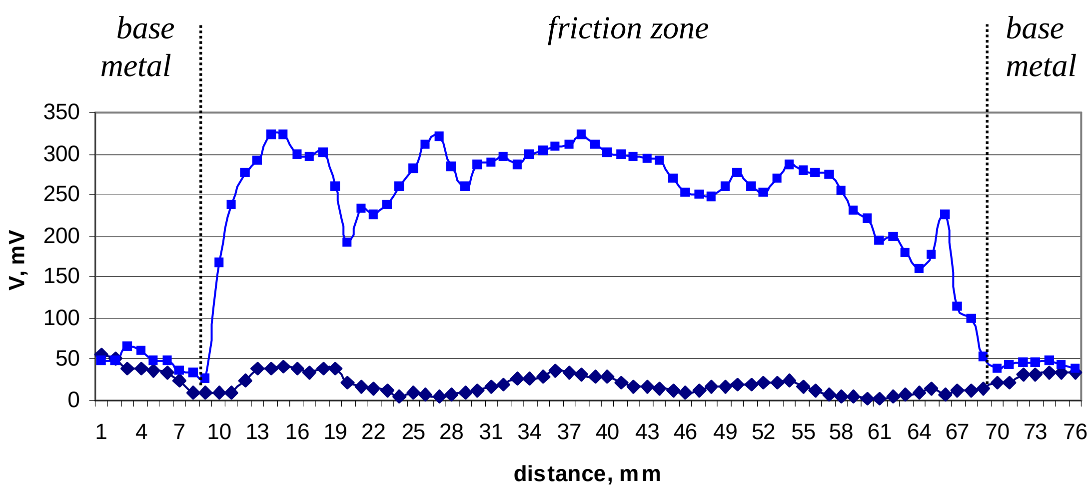

Fig.2. Spatial distribution of BN parameter along the specimen from tool steel after its abrasive treatment by the copper rider

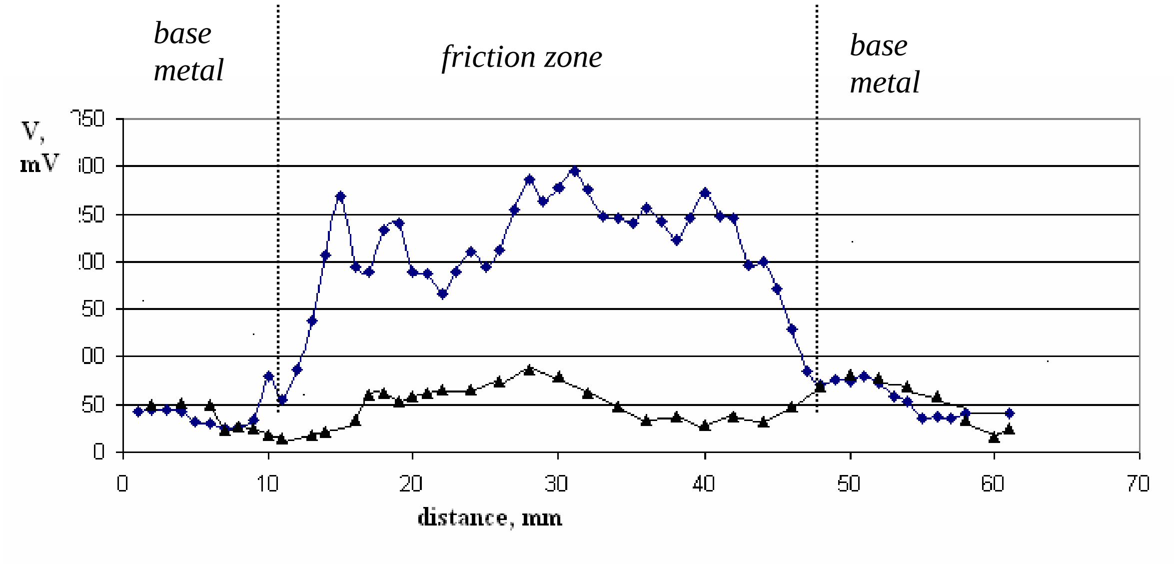

Fig.3. Spatial distribution of BN parameter along the specimen from spring steel after its abrasive treatment by the ceramic rider

Due to the first result in the p. 1 the investigation of the tempering influence on the abrasive layer properties were undertaken. After BNP measurement the specimens were subjected to the drawback in the temperature range 100-600 ^{o} C with aging time 1 h.

Fig. 4 shows the experimentally acquired dependence of BNP upon the tempering temperature for the specimens with initial microstructure (curves 1 and 2) and after friction treatment (curves 3 and 4). Curves 1 and 3 correspond to the longitudinal (relative to friction) direction of magnetizing field and curves 2 and 4 correspond to transversal direction. It is seen that abrasive treatment yields the fluctuation in BNP: the increase being different

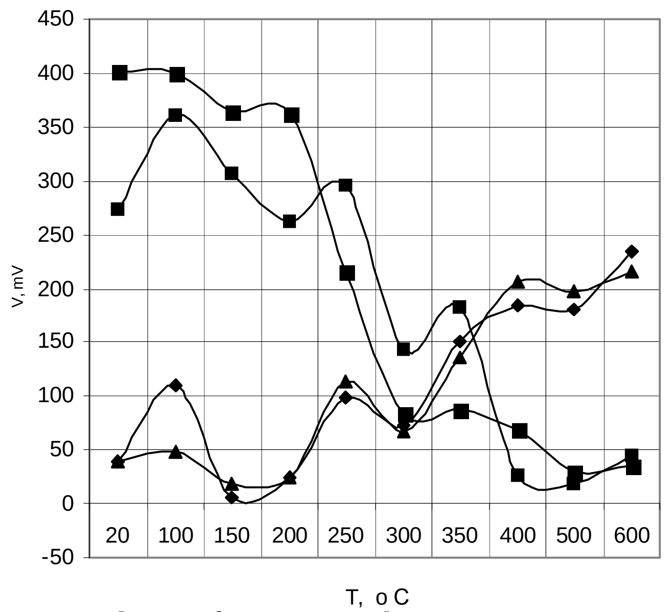

Fig.4. Dependence of BNP upon the tempering temperature of hard quenched medium carbon steel before (curves 1 and 2) and after abrasive treatment (curves 2 and 4) at longitudinal (curves 1 and 3) and transversal (curves 2 and 4) magnetizing field directions.

depending upon the temperature. The largest growth appears in the temperature range 20 ^{o}C - 200 ^{o}C. It is best seen in the fig. 5 where the differences between respectively curves 1 and 3 and also 2 and 4 in the fig.4 are shown as curves 1 and 2 respectively.

The monotonous decrease of the BNP via heat treatment temperature is observed.

The integrated results show that the BNP growth after friction engagement with an external indenter is caused by the creation of a film with superfine microstructure and high hardness on a surface. The trend to decrease changes in BNP after heat treatment is caused by increase in dispersity of α-martensite in the iron matrix and decrease in hardness. We checked the possible corruption of this conclusion due to the influence of unaccounted variation of the hardened layer thickness, which actually changed in the range 0,056-0,112 mm, but any influence was not mentioned. The correlation coefficient on the diagrams in the fig. 5 is o,98.

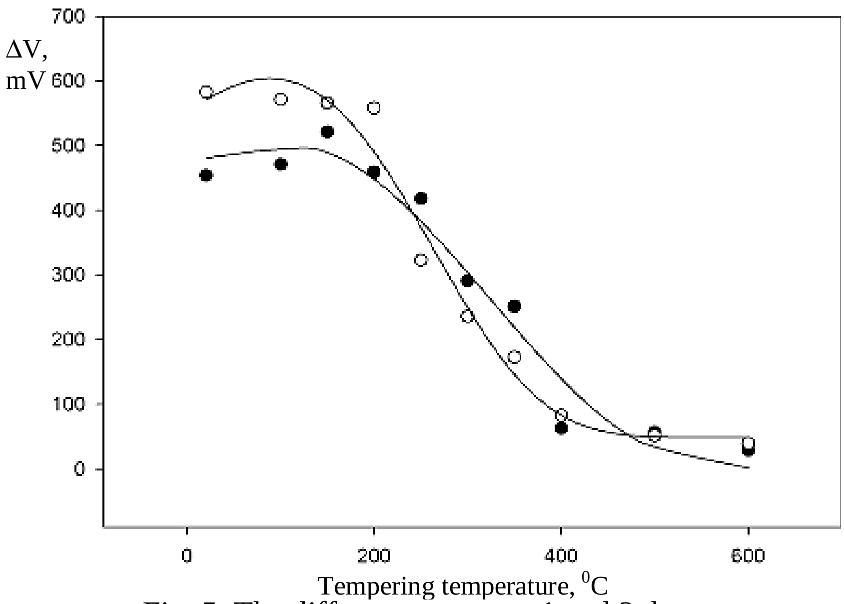

Fig. 5. The differences, curves 1 and 2, between respectively curves 1 and 3 and also 2 and 4 in the fig.4, which show the real influence of tempering effect on the abrasively treated surface.

Conclusion

(1) In the high strength martensitic steels the increase in the level of mechanical abrasive wear in the range up to 0,5 mm yields surface hardening effect which is accompanied by an essential growth of Barkhausen noise.
(2) In the specimens made from spring and tool steels the correlation between Barkhausen noise level and the level of dry abrasive wear by the counter agents from copper and ceramics is observed, the Barkhausen noise parameter growth reaches several times
(3) Friction and further heat treatment of the medium carbon engineering steel subjected to dry friction yield the creation of a film with superfine microstructure and high hardness on a surface of a specimen. This is resulted in strong growth of Barkhausen noise parameter after abrasive wear and further decrease after heat treatment.
(4) The results give the background to create the non destructive technique to evaluate the strengthening parameters after friction and abrasive wear of engineering steels.

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