EDDY CURRENT ESTIMATION OF STRUCTURAL CHANGES IN THIN SURFACE LAYERS ON NONFERROUS MATERIALS

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ABSTRACT

The new method to detect structural changes in thin surface layers is based on eddy currents with frequencies much higher than used traditionally. The method is used to detect and estimate gas-filled layers on the titanic alloys' surface, intercrystalline corrosion of the samples made of austenitic and austenitic-ferritic steels, to determine wear of alitized layers on surface of the blades made of high-temperature alloys. It is also used for crack detection in materials with low conductivity (graphite - based).

KEYWORDS

Non-destructive method, eddy current, structural changes, conductivity, gas-filled layers, titanic alloys, electromagnetic field, intercrystaline corrosion.

OBJECTS OF TESTING

The eddy current method is widely used for non-destructive evaluation of structural changes in the surface layers of metal products. In this case the instruments register changes of specific electric conductivity in effective zone of the probe. This conductivity is structure-sensitive parameter (Dorofejev, 1973). But traditional eddy current methods use alternating electromagnetic field with frequencies less than 25 MHz. On such frequencies the average value of specific electric conductivity in zone of eddy currents' distribution affect the readings of instrument. For main constructive non-ferrous materials this zone is more than 0.3 - 0.5 mm thick for frequencies less than 25 MHz which coincides with deepness of eddy current penetration on these frequencies. This value is even greater and can reach 1 mm for low conductive materials (titanic alloys, austenitic steels, graphite-based materials). In this case structural changes in thin layers (less than 0.1 mm) apparently would not affect the parameters of eddy current probe's output signal. But structural changes which affect operational properties of materials and products occur right in the surface layers up to 0.1 mm thick. The problem of detecting and evaluation of gas-filled layers on the surface of details made of titanic alloys is chosen as an example. Gas-filled layers appear during heat treatment in the air of the details made of titanic alloys. Since such layers are very hard and are low plastic, they have to be removed from the details which are exposed to changing loads. These layers are wear resistant, so in some cases they are specially placed on the details which are working in hard conditions. The detection of gas-filled layers usually is done by measuring of hardness of the samples which were exposed to heat treatment simultaneously with the detail. Such detection requires much labour and can not objectively assess the whole lot of details. More trustworthy is an X-ray method which is based on measurement of parameters of surface layer crystals. But it also is not widely used because it requires the expenditure of much work.

THE DEVICES FOR DETECTION OF STRUCTURAL CHANGES

In recent time an eddy current method is used to detect gas-filled layers, which is based on measurement of change of specific electric conductivity of gas-filled layer. In such a case boundary between layers is not sharp and specific electric conductivity is changing according to exponent. So to detect gas-filled layers up to 0.1 mm thick it was suggested to use higher working frequencies (more than 100 MHz), that are 10 times higher than usual for traditional eddy current method (Dorofejev, 1973). High frequency structurescopes "Alpha" and "Delta" were developed in the Karpenko Physico-Mechanical Institute for detection of gas-filled layers on the details made of titanic alloys (Uchanin et al., 1989). The base of an instrument is high frequency autogenerating transducer and its working coil include eddy current transducer's coil. When eddy current transducer is positioned on the surface of tested detail without gas-filled layer, autogenerator secures stable oscillation on frequencies 100 to 400 MHz. When gas-filled layer appears (its electric conductivity is less), occurs cease of oscillations, which is registered with the instrument. Instrument's threshold of sensitivity corresponds to layer which is 0.02 mm thick. Eddy current transducer's coil diameter is 0.5 mm. Test results are indicated with pointer indicator and LED which are placed on the front panel of the instrument and with sound signal when headphones are connected. The instrument requires such power supplies - 220 V AC (50Hz) or +12V and -12V DC. Overall dimensions of the instrument are 170*90*45 mm. Weight of the instrument is less then 0.5kg. The instrument has such specific features - automatic selection of the mode and instrument's zero setting. For this purpose the instrument has digital synthesizers of control voltages for autogenerator. Therefore the instrument is extremely simple in operation - an operator has only to place a probe on the surface of sample without gas-filled layer and press button "Adjustment". It is recommended to adjust the instrument immediately on the detail. For this purpose a layer, which thickness exceed thickness of gas-filled layer, is removed from part of the surface. Automatic adjustment also increases test trustworthiness, because it excludes subjective factors. Now the instruments are used on some industrial enterprises to test heat treatment of the details made of titanic alloys BT 3-1, BT-6, BT-14, BT-20 and others. The relation between thickness of gas-filled layer and hardness is determined, so it makes possible to use the instrument directly to test hardness of the details, which are made of such alloys. The instrument is also used to solve related problems - to detect micro cracks in titanic alloys, to estimate wear of alitized layers on the details made of super steel, to detect intercrystalline corrosion and other problems, where detecting structure changes in the thin surface layers of details made of non-ferrous materials is involved.

METHOD AND DEVICE FOR QUANTITATIVE TESTING

Sometimes it is necessary not only to detect changes in thin surface layers but to determine values of some parameters, for instance, specific electric conductivity of the layer or its thickness. Traditional solving of this problem with use of high- frequency technique is rather complicated because of technical problems which occur on high frequencies, such as distributed parameters affection and units' matching, and it would not solve the problem. Another technique appeared to be more fruitful - the technique, which do not use complicated high-frequency units. We use autogenerating transducer, which is already developed and applied in the shown above instruments and works in the mode of oscillations' stalling. The value of control voltage which enables oscillations stalling or feasible area of control voltages, enabling stable oscillations, depend on the parameters of test specimen (Uchanin, 1990). To confirm this statement we show experimental results after testing of samples made of titanic alloy BT-14 with different thicknesses of gas-filled layer. Thickness of gas-filled layer was determined by the way of measuring surface hardness. Fig. 1 shows relation between output voltage of autogenerating transducer and control voltage on the varicap for different thicknesses of gas-filled layer. Only the beginning parts of curves are shown.

Relations which are presented on fig. 1 show that control voltages values, enabling cease of oscillations, depend on layer thickness. This relationship is used as a base of eddy current testing technique of the parameters of thin surface layers when the difference between boundary values of control voltage in the cases when transducer is placed on test object or on the sample without gas-filled layer is used as diagnostic variable. The relation of the difference between boundary values of control voltages to layer thickness

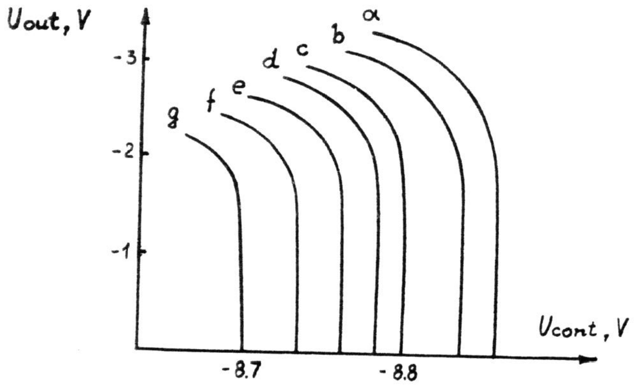

Fig. 1. Output voltage - control voltage characteristics for different thicknesses of gas-filled layers: a - 0 μm, b - 15 μm, c - 20 μm, d - 40 μm, e - 60 μm, f - 70 μm, g - 100 μm.

(obtained for specific sort of titanic alloy and transducer) is used to implement the technique. Fig. 2 shows relation between boundary values of control voltage on varicap and specific electric conductivity of the samples for different values of transistor supply voltage in autogenerator.

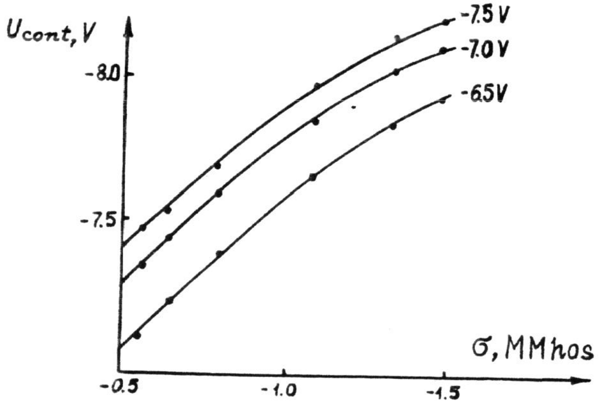

Fig. 2. Control voltage - conductivity characteristics for different transistor supply voltages.

To obtain this group of curves the transducer was placed on the samples made of titanic alloys with electric conductivity changing from 0.5 to 1.74 MMhos per meter and on every sample oscillations stall was enabled by changing control voltage. This relation shows the possibility to determine specific electric conductivity of thin surface layers with high-frequency autogenerating transducers, working in the mode of oscillations stall. To implement this technique an instrument was designed, which produces control voltage digitally and automatically registers threshold control voltage, used as diagnostic parameter. Also the instrument's modification was developed, which implements presented above technique with the help of usual PC. All methods and devices presented in this article are patented.

CONCLUSION

1. The eddy current structurescope "Alpha" and "Delta", developed in Karpenko Physico-Mechanical Institute and intended to detect structure changes of surface layers, is presented. These instruments are used as indicators to detect gas-filled layers of titanic alloys, to detect intercrystal-line corrosion, wear of alitized layers on super steels, and micro cracks.
2. The ways to solve a problem of parameters determination of surface layers on high frequencies and also the device and technique for quantative eddy current test on high frequencies, suggested by Physico-Mechanical Institute, are shown. This technique can be used for quantitative test of dimensional parameters of thin surface layers and related mechanical properties.

REFERENCES

1. Dorofejev A. L. (1973). Induktsionnaja strukturoskopija. Energija, Moskow (in Russian).
2. Uchanin V. N., Kalinin N. P., Zybov V. N., Grabskij Ju. S. (1989) The eddy current structurescope for detection of gas-filled layers on the details made of titanic alloys. Technicheskaja diagnostika i nerazrushajushij kontrol. N4. - p. 68 - 71 (in Russian).
3. Uchanin V. N. (1990). Eddy current testing using high working frequencies. Znanie. Kijev (in Russian).