USE OF ACOUSTIC PARAMETERS MEASUREMENTS FOR EVALUATING THE RELIABILITY CRITERIA OF MACHINE PARTS AND METALWORK

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These investigations were carried out at the Institute of Strength Physics and Materials Science, Siberian Branch of Russian Academy of Sciences, Tomsk. The method developed is based on the experimentally established correlations between ultrasound propagation rate on the one hand and chemical composition and structure-sensitive properties of metals and alloys on the other. We have modified the well-known self-circulation method of ultrasound rate measurement to achieve the desirable accuracy. Of great interest is the strain dependence of the ultrasound propagation rate that was investigated in situ from yield point to failure. Our attention was focused on the existence of a linear relation of ultrasound propagation rate to strain and stress. This linearity is common to all the materials investigated. This can be used to calculate some mechanical characteristics of metals and alloys without their rupture in the course of traditional tests conducted on test machines.

We used a specially developed method whose physical principles and some practical applications will be also discussed. These investigations were carried out at the Institute of Strength Physics and Materials Science, Siberian Branch of Russian Academy of Sciences, Tomsk.

The method developed is based on the experimentally established correlations between ultrasound propagation rate on the one hand and chemical composition and structure-sensitive properties of metals and alloys on the other. It is well known that the response of a medium to cycling action is generally described by the first and second Debye functions. In the framework of the above approach the first Debye function is related to damping of ultrasound. It is internal friction, of course.

The second Debye function describes the changes of ultrasound propagation rate, which are related to the modulus effect. This function has an extreme; hopefully, it would enable one to find the critical conditions of deforming solids changes. Using the theory initially developed by Tokuoka and Ivasititzu and modified later on by us, we have obtained the results: ultrasound propagation rate is directly proportional to elastic stress in solids. The above changes of ultrasound propagation rate are very small; they do not exceed approximately 10 meters per second. Actually, it is much less than ultrasound rate, which is about 3 to 5 thousand meters per second for different metals. For this reason one has to have a device, which would measure the ultrasound propagation rate to a relative accuracy of 10^4. We have modified the well-known self-circulation method of ultrasound rate measurement to achieve the desirable accuracy. The fatigue tests were the first example in which the above considerations were used to solve the problem of failure prediction. It was found experimentally that ultrasound propagation rate drops off during a fatigue test. The dependence of ultrasound rate on the number of loading cycles consists of three stages. The analysis of metal structure showed that microcracking occurs at the third stage of the process so that the latter stage threatens failure. We have proposed to introduce the criterion of fatigue failure based on the above dependence. Formally, the beginning of the third most dangerous stage corresponds to the condition that the second derivative of rate with respect to the number of loading cycles would be a negative one. Of great interest is the strain dependence of the ultrasound propagation rate that was investigated in situ from yield point to failure. Here our attention was focused on the existence of a linear relation of ultrasound propagation rate to strain and stress. This linearity is common to all the materials investigated. This can be used to calculate some mechanical characteristics of metals and alloys without their rupture in the course of traditional tests conducted on test machines.

Tthree applications of the ultrasound method in different fields

The first is construction of steel bridges. In 1997 we were faced with the problem of monitoring residual stresses in weld joints during the construction of a bridge over the Tom River in Tomsk. To solve this problem, a modification of the method for residual stress estimation was developed. This modification is based on our understanding of the nature of ultrasound rate dependence on stress level. The second application is connected with the production of items for the nuclear energetics. It is well known that fuel element cladding tubes for the water-moderated water-cooled power reactor are fabricated from Zr-based alloys by cold rolling. For example, billet failure often occurred in a certain cross-section of the billet and the cause could not be defined. The structure and mechanical characteristics of the specimens cut from this and other portions of the billet were found identical. However, ultrasound investigations of billets allowed one to establish that a jump exists in the residual stress distribution. This jump in the stresses occurred at the preceding stages of cold rolling and the location of failure coincides with this jump. The optimization of profiles of the rolls precluded billet failure altogether. The third application is railway transport. Ultrasound units were used to estimate the residual stress level in locomotive trolley frames during repair. A criterion has been developed, which is applicable to trolley frames manufactured from various low carbon steels.

Of interest is another application of the ultrasound method for inspection of railcar spring quality. This procedure consists in measuring ultrasound rate by spring contraction. It can be seen that a spring contracted by force, F, shows two variants of behavior:

(a) ultrasound rate increases in reliable springs or

(b) ultrasound rate decreases in damaged springs.

Conclusions

1. The physical principles of the new method of non-destructive testing have been developed.
2. A new family of devices has been created to measure ultrasound propagation rate to high accuracy.
3. The above method has found successful applications in

- steel bridge construction,
- weld quality monitoring,
- cladding tubes manufacture for the nuclear industry,
- railway transport.