Name of the scientific solution / development/ methodology, tool, prototype

Creating a wideband acoustic emission sensors.

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Problem Description

Piezoelectric sensors are key elements of systems of diagnostics and monitoring of performance critical parts based on the method of acoustic emission, acoustic leak detection, vibration monitoring, etc. Acoustic emission (emission of elastic stress waves) contains information about the fine physical processes that occur during friction, deformation and fracture of materials. This method is widely used for early detection of earthquakes, analysis of complex objects in the state of nuclear energy, missiles and space technology. In this area the most famous scientists are from the United States. Among them, Professor Ono from the University of California (Los Angeles). at Berkeley (California) using acoustic emission to diagnose the processes involved in cutting, Prof. David Dornfield with his disciples.

Research in the field of acoustic emission are carried out in Japan under the leadership of Prof. T. Morivaki (Tokyo Society of Nondestructive Testing). In Ukraine, such studies are carried out mainly at the E.O. Paton Institute of Electric Welding by Prof. A.J. Nedaseka, in Karpenko Physico-Mechanical Institute (Ukrainian Academy of Sciences) and the National Aviation University under the leadership of S.F. Filonenko.

Prof. Marvin Hemstadt of the U.S. National Institute of Standards, Boulder, is engaged in design and development of acoustic emission sensors . In Russia, work on creating sensors are actively conducted in the Laboratory of piezoelectric transducers under the leadership of V. Shikhman at the Institute of Mechanics and Applied Mathematics, Rostov State University.

The widespread use of acoustic emission is largely constrained by the narrow bandwidth and irregular frequency response of acoustic emission sensors. Today, with the advent of new materials and designs of acoustic emission sensors, field of application of non-destructive control methods, such as acoustic emission expands. In the V.N. Bakul ISM NASU, and the National Aviation University wideband acoustic emission sensors are developed, their characteristics are not inferior, and in some cases, surpassing foreign analogues.

The way of problem solving

At V.N. Bakul ISM NASU has developed a radically new design of acoustic emission sensors through science-based method of damping the rear side piezoplate, including selection of optimal sensor and material damping.

In this work we developed a new system of grading AE sensors, communications system calibration is made with the PC, a special software that allows you to semi-automatically obtain the frequency response of each sensor. We studied the amplitude-frequency characteristics of the sensors of various designs, selected the best option of acoustic emission sensors with a linear frequency response range from 200 kHz to 1200 kHz.

The developed sensors were tested in the study of friction and wear of cutting tools on CNC machines.

The design of the sensor is shown in fig. 1.

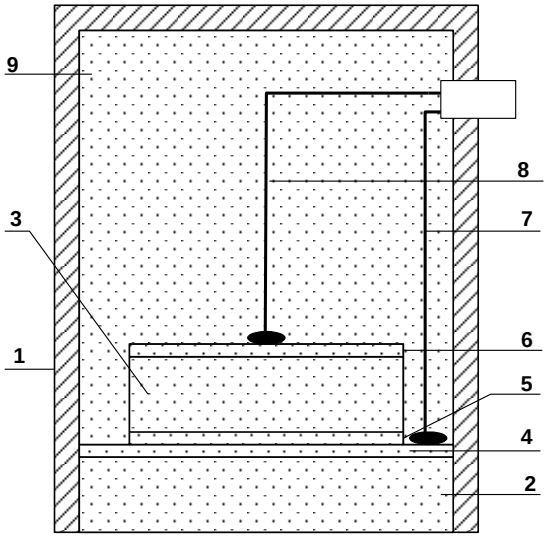

Fig. 1. AE sensor design

1 - body, 2, 3 - piezoelectric, 4 - a non-working electrode, 5, 6 - working electrodes, 7, 8 - wire, 9 - the body of the damper (a composite of tungsten carbide, titanium nitride and epoxy resin).

As the damper the original material (protected by a patent of Ukraine), consisting of particles of WC and TiNi, bonded with epoxy resin and hardener is used. The composition of the damper is selected in such a way that its acoustic impedance is the impedance of the piezoceramic, damping properties of the martensitic transformation of TiNi with the absorption of energy. Due to this, we managed to improve the damping properties to a damping factor of 1.5-2. Taken it together, it is possible to significantly reduce the resonant peaks, exclude parasitic signals reflected from the back side of the plate and the sensor body, to reduce the unevenness of the amplitude - frequency response from 23 dB to 8.5 dB.

Specifications of wideband acoustic emission sensors:

Input R, Ohm 2.3·1011
Range, MHz 0.3-1.2
irregularity of the AFC dB 8.5
sensitivity, mV/m·s^{-2} 125
capacity, nF 1.45

Fig. 2. Exterior view the AE sensor

Basic publications

1. N. Novikov, L. Devin. Wideband acoustic emission sensors to diagnose the state of cutting tools. Technical diagnostics and nondestructive testing, № 4, 2008 - p.81 - 85.

2. Devin L., Naidenko A., Nimchenko T. Piezoelectric transducer. Patent № 86818 on 25.05.09.

3. Devin L., Nimchenko T., Osadchy A. Acoustic - Emission Measurement System for monitoring the condition of cutting tools. High Tech in mechanical engineering: Collected Works of NTU "KPI". - Kharkiv, 2008. - Vol. 2 (17). - 508 p.

4. Devin L., Naidenko A., Nymchenko T. Piezoelectric transducer. Patent of Ukraine № 23804 of 6.11.07.

5. Devin L., Nedosyeka A., Stahniv M., Yaremenko M., Nimchenko T. Material for the damper ultrasonic transducer signals. Patent for utility model № 26259, Bul. № 14, 10.09.2007.

6. Devin L., Naidenko A. Using the method of acoustic emission for searching diagnostic features in the analysis turning process of aluminum alloy by PCD cutters. Superhard materials. - 2005. - № 6. - p. 77 - 82.

7. Novikov N., Devin L., Lysenko O. AE method to study fracture and wear of cutting tools made of polycrystalline superhard materials. Report 2. Progress in Acoustic Emission VII, Sapporo, Japan 1994, p. 631 – 636.

8. Novikov N., Devin L., Lysenko O. Testing of Polycrystalline Superhard Materials by the Acoustic Emission Method. 7th International Conference on Mechanical Behavior of Materials. Netherland, 1995 pp. 797 – 798.

9. Novikov N., Devin L., Lysenko O. A Model of the Energy Capacity of AE in the Precisions Turning by Cubic Boron Nitride Tools. Progress Acoustic Emission VIII, Nara, Japan, Proceedings of the 13th Int. AE Symposiums, Nov. 27 - 30, 1996.

Innovative Aspects of the solution / development/ methodology, tool, prototype

The developed sensors have the following characteristics:

1. Patented a new design of wideband acoustic emission sensors with working frequency band from 200 kHz to 1200 kHz.

2. Scientifically based method of damping the rear side piezoplate - sensor of acoustic emission sensors. Due to this reduced the unevenness of its amplitude-frequency response from 23 dB to 15 dB.

3. We used a new material damper consisting of tungsten carbide particles held together by epoxy resin and hardener. The composition of the damper is selected in such a way that its acoustic impedance is the impedance of the piezoceramic. Due to this significantly reduced the resonance peaks are excluded parasitic echoes from the back side of the plate and the sensor body.

Main advantages of the solution / development/ methodology, tool, prototype

1. The band of operating frequencies from 200 kHz to 1200 kHz.

2. Through the application of TiNi damping properties increased by 1.5-2 times.

3. The charge amplifier circuit provides optimum inclusion of the sensor and preamp with a minimum ratio of "signal - noise."

4. The new system allows the calibration of AE sensors in a semi-automatic promptly investigate the frequency response of the sensor of AE and its characteristics have been certified.

5. The developed software allows an objective grading of AE sensors.

Financial and Economic Parameters

The most simple wideband acoustic emission sensor (with amplifier) costs $1000.

The most complex wideband acoustic emission sensor (with management system, electronic units and software) costs $10000.

Intellectual Property Rights *(please, select)*

The wideband acoustic emission sensor is copyright.

1. Devin L., Naidenko A., Nimchenko T. Piezoelectric transducer. Patent № 86818 on 25.05.09.
2. Devin L., Naidenko A., Nymchenko T. Piezoelectric transducer. Patent of Ukraine № 23804 of 6.11.07.
3. Devin L., Nedosyeka A., Stahniv M., Yaremenko M., Nimchenko T. Material for the damper ultrasonic transducer signals. Patent for utility model № 26259, Bul. № 14, 10.09.2007.

Collaboration Details (Type of collaboration sought; *more than one option can be selected*)

Technical co-operation.

The possibility of producing broadband acoustic emission sensors.

Collaborative research.

Application of the developed sensors and signal processing systems AE.

Technology Key words

Acoustic emission sensor, damper, piezoelectric ceramics, titanium nickelide, frequency response, non-destructive testing.