The Effect Gorbunov In Practice

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***Abstract*—Practice of application of the device for remote non-destructive testing. The operation principle is based on the discovery that the effect of "Gorbunov". The process of measuring presents the level of the wanted signal from elastic to plastic loading for pair of samples of steel grade St4. The working distance from the microwave sensor and the steel sample is not less than 75 millimetres. During elastic loading (one ton) reset load with a subsequent increase above one ton. The results obtained in the form of the amplitude of the "spectral component at the output of the microwave sensor" not contrary to the known results of tests by Acoustic Emission method «summary account ". The main advantage of the new method is the possibility of remote (distance not less than 75 mm) of the definition of dangerous defects (before cracking) arising from mechanical loading of metallic object. The signal from the microwave sensor is maintained after the cessation of mechanical loading, which is impossible for the method of Acoustic Emission.**

Keywords—Effect «Gorbunov», « Doppler» radar, non-destructive testing, Acoustic Emission.

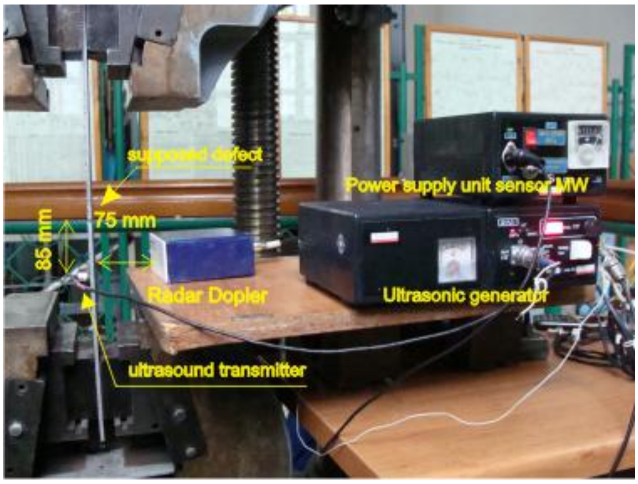
I. Initiation

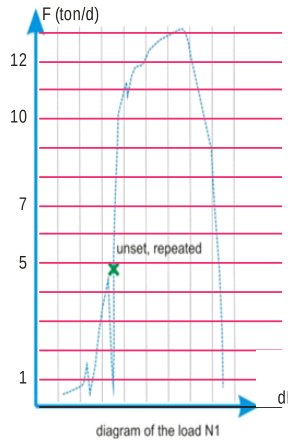
The NDT specialists strive to learn more about new methods of contactless microwave diagnostics [6,10]. One of them is the definition of dangerous defects using radar Doppler [2,4]. This method became possible after the discovery, made by a group of authors, under the guidance of Professor V. I. Gorbunov [3-5]. In his honor called "the effect Gorbunov» As a result of many experiments for the contactless detection of defects, by using microwave fields, we found an unusually large coefficient of the interaction of ultrasound with dangerous defects in the metal. The microwave field frequency 27-33 GHz reflected from the surface of the metal containing dangerous defects, was a phase modulated frequency of the exciting ultrasound. Virtual amplitude of the surface oscillations, on the calculation, unit is micron. Whereas the measured amplitude of mechanical vibrations did not exceed ten nanometer. The effect is almost not detected in samples without defects (cracks, delamination). Component of the ultrasound in the spectrum of the reflected signal exceeds the noise on 10-26 dB for metals with a defect. The working distance from the aperture of the horn antenna of the microwave sensor and the surface investigated is 90-180 mm. The speed of propagation of virtual fluctuations of the surface is a fraction of the speed of light, thousands of times exceeds the speed of ultrasonic waves. For this reason, almost the entire surface of the metal sample has a single phase change of surface conductivity [3]. The desired signal exists at any point on the surface. Unlike ultrasound signals, quickly damped for operating frequency of 200-300 KHz, the signal fluctuations in surface conductivity can be measured at a distance of several meters without attenuation. The frequency of the exciting ultrasound can be selected in the range of 20-300 KHz. The indexing device remote active metal defects (RIAD), developed by our group allowed to perform a lot of measurements for different metals and alloys. It was found experimentally that similar to the method of Acoustic emission device records the defect known as "active". They generate acoustic signals with the " summary account " is proportional to the first degree of mechanical loading [1]. In addition, "active" defects we may find after a full reset of the load. This options the theory and practice of Acoustic Emission does not know. Printed papers published by our team, describe in detail the principle of operation [4], results [3,5]. Unfortunately, unknown to us the theoretical work describing the observed phenomenon. Article of Professor A. Misra [10] describe the phenomenon of generation of radio emission band 16 MHz - 16 GHz in the destruction of brass and other metal materials. But there is no word about the unusual collaboration "exciting" ultrasound "active" defects before and after the appearance of mechanical cracks. The only work of Russian scientists Vasiliev Y, D and Lyuboshitz V, L published in 1994 [8] contains the theoretical justification of the possibility of the appearance of an electric charge inside a conducting body through mechanical forces. But the equation obtained, and the conclusions of the authors do not allow to find a practical application.Moreover, the conclusions of the article about the impossibility of practical use were incorrect, our group was discovered a long time of the existence of space charge inside the conductor, which is contrary to the system of Maxwell's equations [9]. For conductors can exist only surface charges (which change the surface conductivity) short-time existence of internal charges flowing to the surface at the speed of light in the conductor. These inconsistencies of theory and practice are to some extent "brake" make the faith of our results. Make us again and again to conduct experiments on the instruments RIAD. To investigate the processes of elastic and plastic deformation of metals, using microwave sensor in the form of Doppler [2]. To compare the results for registered parameters, obtained by the method of

Acoustic Emission (the dependence of the summary account from the effort of loading) and new method (the dependence of the amplitude of the useful spectral component from the same effort). **II. Experiment**

The discovery has produced several variants of the device, operating on the effect of «Gorbunov». The tests were carried out to detect fatigue cracks, weld defects after cooling, and the live time of defect . Part of the research published [2-4]. With the aim of attracting the attention of a wide range of NDT technicians who are familiar with tests of strength, our group performed the experiment for verification of the Kaiser effect on a tensile testing machine. Remote indicator active defects (RIAD) in the work allowed us to compare its operating parameters with a known method of acoustic emission [1]. The tests were carried out at the Department of theoretical and applied mechanics TPU, for pairs of identical samples steel (St4, 450x45x5mm). Breaking machine was GMS-50 1960 No. 663. (Maximum force of 50 tons). Primary fixation of samples of the screwing device the stretching process by the hydraulic method with smooth adjustment efforts. Fig. 1 shows the RIAD and the first sample. On the rear surface of the sample printed pattern for control of deformation during loading. The microwave sensor is installed at a distance of 75 to 90 mm from the front surface of the sample, at a distance of 55-60 mm from the intended destruction .The ultrasonic transmitter on the rear surface of the sample at a distance of 75 mm (half wavelength of ultrasound) from the scene of the alleged break (specimen a weakened specially made "neck"). Pre-installed, the oscillation amplitude of the ultrasound at the site of installation has the same meaning as in the break. This technique is made in order not to affect the transmission of ultrasonic power during plastic deformation in the area of destruction. The ultrasonic transducer is located opposite the area of irradiation of the microwave field, but had protected him from the metal of the sample (thickness 5 mm). The loading process is stored in the writing instrument on the surface of the paper cylinder that rotates together with the movement of the upper part of the clamp of the machine. In Fig.1 shows: breaking machine and set the RIAD, prepared for the experiment on the first sample. The ultrasonic transmitter on the rear surface, the sample in the profile (Fig.1). The microwave sensor (blue box), the ultrasound generator (dual black box) and the power supply sensor. This power supply contains a frequency mixer for converting the signal output at the frequency of the sound range. The frequency of the local oscillator 6 KHz differs from frequency ultrasound (50 KHz). This allows you to work with tablet PC sound card . This computer is not shown. Located right in front of the testing machine.

The beginning of the experiment consists in the preliminary tensile specimen a force of 100-150 kg. Then set the working distance of the microwave sensor to surface (75 mm). The distance can vary in the range of 60-90 mm with a period of a quarter wavelength of the microwave. The fact that the greatest sensitivity is achieved with a quarter wave phase shift of direct and reflected signals. The precise control of the distance along the device operating "current of the sensor, is determined experimentally when working on the simulator sets the RIAD. Useful signal in the experiment is measured periodically. Wherein the ultrasound generator is activated together with the "tape recorder" PC. The record is 3-4 seconds. The recorded file is marked. If necessary, calculates the spectrum.





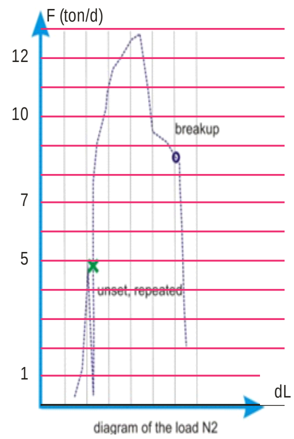


Fig.2 diagram loading TPU Fig. 3 diagram loading TPU0 Fig.1 Set of RYADS-1, tensile testing machine Fig. 2.3 route shown writing tracks of the first and second tests. The X-axis, the elongation along, the Y-axis is the conventional force break (ton/division). On the tracks of the applied point load shedding (green cross), the point of complete rupture of the second sample (oval). During the experiments were measured (saved file) to 7 points on each track. The first point after the preliminary stretching of 100-150 kg. the Second point is the force of one ton, the third point load shedding. Fourth-increasing loads up to five tons. The measured value of the useful signal for marked way manual effort gap is listed in table 1. In Fig.2, 3 and table 1 experiments indicated TPU. (first series) and TPU0. (second series)The total test time per sample is 78-80 seconds. Including 4 x 7 points=28 seconds (time readings), plus the time of load increase of 7 x 7 =49 seconds. Reading (7 times in 4 seconds) is carried without changing mechanical forces.

A sample of the first series Fig.4 was stronger because of the wider "neck". We managed to stretch his effort to 12.9 tons. The crack on the specimen Fig.4 b did not lead to complete failure of the load shedding. For the second sample of a crack resulted in a complete destruction.These tables indicate that when force is formed 12.9 tons crack contains active defects (the mouth of the crack), which leads to the appearance of the desired signal by 7 dB/noise.The signal remained after removal of the load (6 dB/noise) that is fundamentally different from experiments by the method of acoustic emission. When the load is removed after the formation of cracks "total score" is not changed – there are no signals of acoustic emission In Fig. 4 shows the sample mounted on a tensile testing machine at the beginning of testing and after the formation of cracks. Table.1 Signal/noise ratio in the steel loading images Steel 4 (St4)

Point loading	0 tons	5 tons	1 ton	7 tons	10,6 tons	12,9 tons	0,1 tons
The first series	TPU	TPU	TPU	TPU	TPU	TPU	TPU
Signal/noise ratio(dB)	0	8	4	12	4	7	6
Point loading	0 tons	5 tons	1 ton	7 tons	10.6 tons	12.9 tons	0
The second series	TPU0	TPU0	TPU0	TPU0	TPU0	TPU0	TPU0
Signal/noise ratio(dB)	0	2	0	8	7	0	0

Option (a) at a load of 5 tons, a part of the painting destroyed. Option (b) with a load of 12.9 tons. Option (a) at a load of 5 tons, some of the paintings were destroyed. The paint was peeling due to plastic deformation. Option (b) with a load of 12.9 tons. The formation of cracks. The reduction of the useful signal (table 1, columns 6 , 7 for option TPU). Works only "the mouth of the crack», where there are active defects.The destruction took place not symmetrical

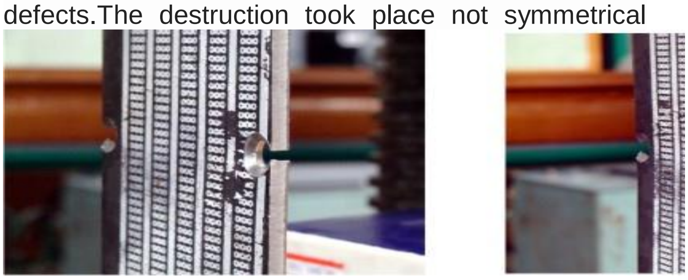


Fig.4 the sample before fracture (a), the sample after the formation of cracks (b)

(the formation of cracks just to the right). The difference of experimental results for "TPU" and "TPU0" the authors explain the imperfection of the laboratory sample RIAD.

The tuning of the microwave sensor for maximum sensitivity is not perfect. Tuning error is 2-3 dB.

III. Conclusion

Analysis of experimental results allows to draw some important conclusions.Laboratory layout RIAD stated demonstrates the ability to detect dangerous defects arising from mechanical loading of steel samples. Demonstrating the feasibility of a new method for remote detection of the beginning of plastic deformation once again proved the efficiency, usability and reliability of detected phenomena, "effect Gorbunov". Existing imperfections of the kit RIAD in part to the inconvenience of settings, necessary to use auxiliary ultrasonic signal, it is impossible to detect the defect, it is disposable and does not require sophisticated technical solutions.

Experience has shown major differences of the new method from the method is still based on the signals of acoustic emission. Demonstration of useful signals with increasing and load shedding has proved the justice of the law of Kaiser [7] for the second series. For the first series was that the microwave sensor detects a certain signal (4 dB/noise) even when load shedding. Ibid., first series detects the signal after the formation of cracks at full load (6 dB/noise). This confirms the known results, demonstrates new possibilities. It is now possible to detect dangerous defects related to the group "active", not only at the moment of their formation, but also for some time after the removal of mechanical loads. For example is the useful signal In this work not considered a method Brychkov [2], which allows to reactivate dangerous defects at any time. Therefore, the new method does not require complicated and costly re-testing to verify previously identified defects, generating acoustic signals.

Two variants of tests with sufficient accuracy has not proven the criticality of the place of installation of the

microwave sensor, Indirectly confirmed by the property differences of the velocity of the wave propagation surface conductivity and velocity of ultrasound. It is possible that an instrument on the effect Gorbunov , allowing not only to indicate dangerous defects, but also to find the place occurrence. When the difference in speed thousands of times, determining the phase difference of arrival of the microwave response from the beginning of the ultrasound radiation, you can determine the location of the defect triangulation method.

The material presented is not sufficient to demonstrate new, unusual properties of the method of diagnosis using the «effect Gorbunov». But the results obtained clearly demonstrate the difference of the two diagnostic methods. Demonstrate the inexplicable results of the modern theory of diagnostics of metals using microwave. This is a joint work of many specialists. We thank Professor. Doctor of technical Sciences, Tomsk Institute of nondestructive testing Kapranov Boris Ivanovich, associate Professor Tomsk university automated control systems of Khatkov Nikolay Danilovich, doctor of physics and mathematical Sciences Professor of the Tomsk Institute of strength physics and materials Siamoohin Boris Semenovich. for their active participation and useful comments, calculations and corrections. Separate gratitude to the head.DEP. The theoretical and applied mechanics of Tomsk Polytechnic University Ph. D. associate Professor Simankin Fyodor Abramovich for a favorable attitude to the performed experiments. Part of manufacturing of prototypes RIAD was held in the framework of the Federal programm "Start-10", small business development.

References

[1]. Acoustic Emission Measurement Technologies from Physical Acoustics. [Online] Available:

http://www.pacndt.com/index

[2]. Dopler Radar in Crack Testing, Vladimir Sutorichin, Sergei Brichkov, British Journal of Applied Science & Technology, 4(23), 2014, p. 3315-3321

[3]. Gorbunov V. I. & Sutorikhin V. A. Microwave Nondestructive Testing Method, Applied Physics Research, Vol. 4, No. 1; February 2012. P. 206-210

[4]. Gorbunov V. I., Sutorikhin V. A., & Ustinov B. F. (2008 b). Useful model patent No. 81677. The device for detection of active defects in metal products. Priority of Invention, August 04.

[5]. Gorbunov V, Sutorikhin V. Possible control of elastic deformation limits by the

microwave (MW) method. Defectoscopy. 1999; 7, pp.75-80.

[6]. Kerouedan J, Queffelec P. Detection of micro-cracks on metal surfaces using near-

field microwave dual-behavior resonator filters. Measurement Science and Technology. 2008;19(10):54

[7].http://universal_ru_en.academic.ru/ Kaiser effect [Free access]

[8]. Vasilyev YD, Lyuboshitz VL. The virial Theorem and some properties of the electron

gas in metals (Session RAS 23.02.1994 g.). The Successes of the Physical Sciences.1994; 4 (164), pp. 367-374.

[9]. Leontovich MA. Approximate boundary conditions for electromagnetic fields on

surfaces of well-conductive bodies. Research in Radio-wave Propagation; 1948.

[10]. Misra A., Kumar A. Some basic aspects of electormagnetic radiation during crack propagation in metals// Intern. J. Fracture. 2004. V. 127. № 4. P. 387-401