ВИСОКОЕФЕКТИВНІ ТЕХНОЛОГІЧНІ ПРОЦЕСИ В ПРИЛАДОБУДУВАННІ

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STRENGTH CONTROL SYSTEM UNDER DYNAMIC LOAD WITH ELECTROMAGNETIC ACCELERATOR

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The article describes the device to control the strength of brittle materials under dynamic load. A design was developed and an electromagnetic accelerator was manufactured. It allows to perform mechanical strength tests of brittle materials at speeds up to 10 m/s. It was defined that the device on the basis of the Hopkinson measuring cores can also be used while studying the energy characteristics of the solid alloys destruction and the investigation of the cutting process. The obtained experimental results on the strength of solid alloys can be used to predict the probability of incisors destruction.
Keywords: *automated system, strength, electromagnetic accelerator, dynamic load, superhard materials.*

Introduction

The research on the changes of metals and alloys under high-speed deformation has a great scientific and practical interest in connection with the development of a number of new technology branches, as well as in connection with the development and introduction of new perspective technological techniques of material cutting on the industry.

During the process of processing, the cutting tool receive both static and dynamic load. The presence of various structural elements in details: holes, slots, ledges, etc., leads to the impact load of the cutting tool during their processing. The dynamic component of cutting power can be 1.5-2 times higher than static. Such processing conditions are very dangerous for a tool equipped with hard-alloyed or diamond- hard-alloyed plates. To predict the working capacity of tools operating in such conditions, it is necessary to test an instrumental material withing conditions that are as close as possible to the actual process of cutting.

The strength determining system of metals and alloys under dynamic load conditions

For the determination of the strength of metals and alloys under dynamic load conditions (from 0.1 to 10 m/s), pendular and rotational coppers [1] are usually used, which differ in design features and methods of load-deformation diagrams handling. One of the most suitable devices for testing of small samples of brittle materials under dynamic load systems are systems based on the Hopkinson-Kolsky dimensional cores.

In the IHAM named after Bakul V.M. NAS of Ukraine the vertical "Copper" is used to determine the characteristics of the brittle materials strength under dynamic load. The basis of the "Copper" is the measurement cores of Hopkinson-Kolsky's. This type of device is one of the most suitable for testing of small samples of brittle materials under dynamic load. The speed that can be achieved under the load is from 0.5 to 3 m/s [2].

The basis of the Kolsky method is the one-dimensional theory of the elastic waves propagation in long thin cores [3]. The testing system consists of two long cores (load and support) with a rather high boundary of elasticity and a thin sample in the form of a disk that is located between their ends. With the help of a falling from a height of 1-2 m peen, the first core excites an elastic momentum of compression with amplitude proportional to the speed of peen. The corresponding deformation wave $\varepsilon^I(t)$ extends along the core with the speed of sound. When approaching the sample, the compression wave is separated due to the difference in cross sections and acoustic impedances of the materials of the cores and sample. In this case, the part of the wave reflects from the boundary and returns to the first core with a wave of tension $\varepsilon^R(t)$, and the other part passes through the sample into a supporting core with a compression wave $\varepsilon^T(t)$. Assuming the homogeneity of the stress-strain state of the sample along its axis (due to the long duration of the load impulse, in comparison with the time of the wave pass along the sample length), on the basis of these impulses of Kolsky`s formulas [3] it is possible to determine the parametric dependences of the voltage development (1), deformation (2) and the speed of deformation (3) of the sample during the test:

$$\sigma_S(t) = \frac{EA}{A_S}\varepsilon^T(t) \qquad (1)$$

,

$$\varepsilon_S(t) = -\frac{2C}{L_0}\int \varepsilon^R(t)dt \qquad (2)$$
,

$$\dot{\varepsilon}_S(t) = -\frac{2C}{L_0}\varepsilon^R(t) \qquad (3)$$
.

To obtain parametric dependencies $\sigma_S(t)$, $\varepsilon_S(t)$ i $\dot{\varepsilon}_S(t)$ the time *t* excludes as a parameter and a diagram of the sample deformation in the form of dependencies is constructed $\sigma_S \sim \varepsilon_S$ и $\dot{\varepsilon}_S \sim \varepsilon_S$ [4]. The second dependence is used to control the change of deformation rate in the process of deformation or to evaluate the influence of the change history of the deformation rate on the resulting diagram with a impulse load of complex form.

The device for strength tests with a dynamic load "Copper" and a pattern of wave propagation are depicted on the Fig. 1.

In the main version of the copper, the basis of the measuring system of the device was a two-beam digital oscilloscope C9-8, which was launched from the increasing amplitude of the measured signal that inleted at the input of the oscilloscope after the previous amplifier of the strain gauge signal. The maximum amplitude of the signal was about 2.5 V. But the system worked unstable because it was not possible to shield the strain gauges that were glued on the cored.

It would load the core and disrupted its efficiency. An additional source of interferences was the supply chain of an electromagnet that raises the peen. The peen was dumped while the break of the power supply circuit of the electromagnet, which led to the occurrence of injuries on to strain gauges.

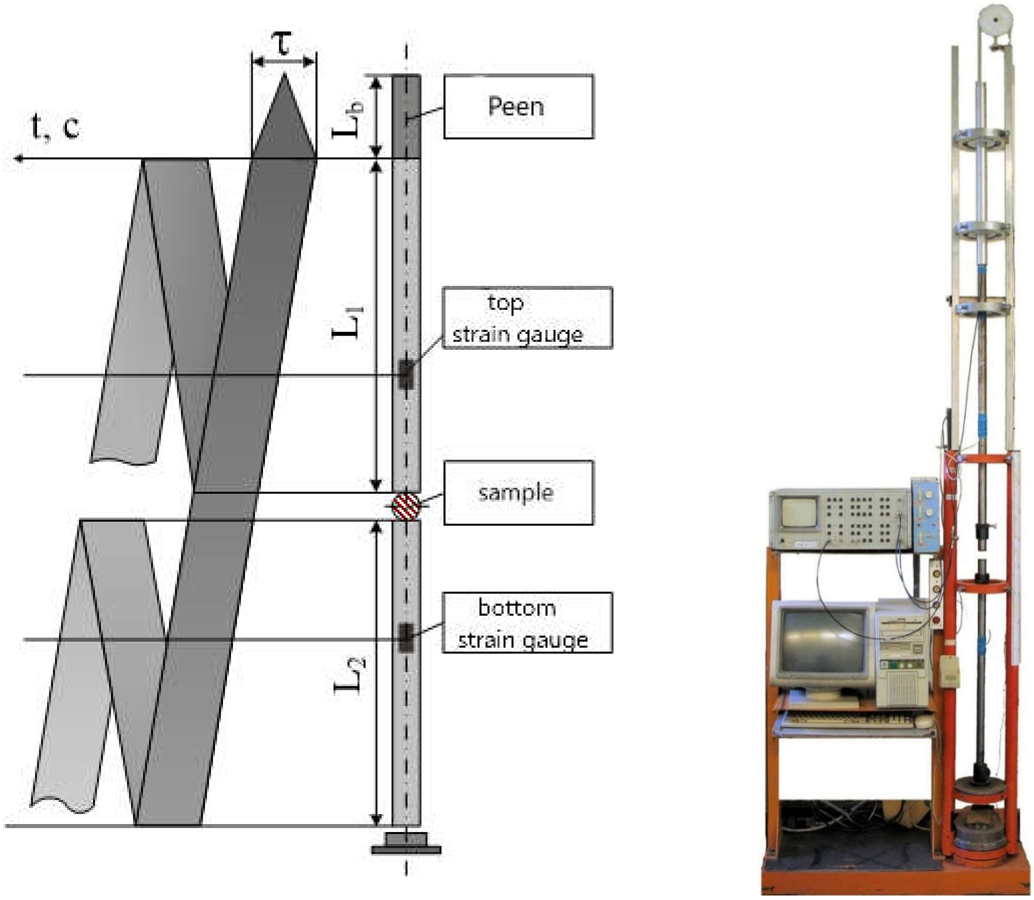

Fig. 1. « Copper» device and a pattern of wave propagation

To solve this problem, the measurement system was started with the help of independent source signal, namely a piezoelectric plate. The sensor was made of piezoceramic PCR-8, mounted on the side surface of the core, near the end, which perceived the impact. The design of the sensor is shown on the Fig. 2.

The epoxy lining 1 has a radius that is equal to the radius of the measuring core, which increases the contact area of the sensor with the core. On the foil glass textolite lining there are contact pads, where the outputs of the piezoelectric plate are soldered. The signal from the piezoelectric sensor was sent to the external oscilloscope input. This allowed to increase the reliability of the start of the measuring system.

The development of electromagnetic accelerator

Technology of sintering of hard alloys improvement has led to the manufacturing possibility of products of various shapes and sizes.

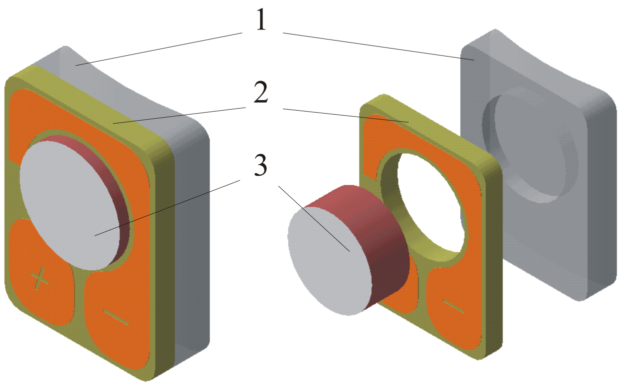

Fig. 2. Piezo sensor: 1 – epoxy lining , 2 – lining, 3 – piezoelectric plate

This allowed to expand the scope of the use of solid alloy from the cutting plates to the bushings in turbines at nuclear power plants. At the same time, the speed of dynamic loads increased to 10 m/s. It is very important to know what border strength has the solid-strength product from solid alloy precisely at those speeds at which the operation is foreseen. The "Kopper" device has a loading speed of up to 3 m/s [5]. Therefore, it was decided to increase the load speed on the vertical copper to 7-10 m/s. This will allow to test the product`s hardness from solid alloys in conditions that are as close as possible to the operating conditions. In this case it was decided to upgrade the copper to an electromagnetic accelerator, or Gauss gun.

The principle of Gauss gun action is based on the fact that the magnetic field created by the electric coil begins to push inside the solenoid iron cylinder, which begins to speed up. If at the moment when the cylinder appears inside the winding, the current is going to be turned off, then the pushing magnetic field will disappear and the speeding cylinder will freely flies through the other end of the winding. The stronger the magnetic field and the faster it is turned off - the stronger the cylinder flies out.

The parameters of the winding, mass and cylinder dimensions, the parameters of the condensers should be chosen in such a way that during the acceleration to the moment of the flight of the cylinder to the middle of the winding current in the last would have time to reduce to the minimum value, so the charge in capacitors would have been completely consumed. In this case, the efficiency of a single-stage magnetic accelerator will be maximal.

To increase the efficiency and the speed of the peen on the device for controlling the strength of solid alloys under dynamic load, a special control scheme was developed for electromagnetic accelerators [6, 10].

The electromagnetic accelerator can be divided into the following parts: start-up sensor, inductor coil, control unit and capacitor block.

To control the electromagnetic accelerator, a scheme based on a comparator was developed, which is implemented on a microcircuit LM311.

An important advantage of the control scheme on the comparator over the trigger is the noise immunity. This setting is important for devices that operate under industrial conditions where there are many sources of noise.

The sensor for switching on of the electromagnet is an optical pair K170P, which triggers on reflection. In optical pairs of this type, the light emitter and the receiver are made in the same frame. The monolithicity of the case eliminates the need for a mechanical adjustment of the optical system, a slight deviation of the peen from the vertical axis did not affect the operation of the optical pair. The foregoing is the advantage of the optical pair, which triggers on reflection, than the optical pair that triggers on the lumen. Reflecting element is peen.

The final principal electric circuit with all necessary nominal, power and protection circuits is shown on the Fig. 3.

At the initial moment, the phototransistor of the optical pair is closed and the potential at the inverting input of the comparator (output 3) is greater than the voltage of the hysteresis provided by the divider R6, R7 (Fig. 3) on the non-inverted input of the comparator (output 2). The negative voltage at the inverting input leads to a positive voltage at the output of the comparator (output 7), this positive voltage closes the transistor keys that are implemented on the transistors T1, T2. T3.

When the reflected beam of light appears, the phototransistor opens and starts the saturation mode.

Then the positive voltage through the chain R2 and the phototransistor enters the inverting input of the comparator. This voltage exceeds the voltage of the hysteresis and leads to the switching of the comparator. As a result of switching the negative voltage appears on the output of the comparator. Transistors T1, T2, T3 are opening and all accumulated charge on capacities C6 and C7 through T3 discharges to inductance L1. Each key has a local negative feedback on the current to exacerbate the fronts by reducing the Schmidt effect, and as a consequence of reducing the switching time of the transistor. For T1, T2, T3 the element which provides local negative feedback on current is respectively R11, R19, R120. T1 and T2 transistors should be medium power and high-frequency to reduce the time of operation, T3 of high power, also high-frequency, with the ability to withstand the impulse current up to 100A.

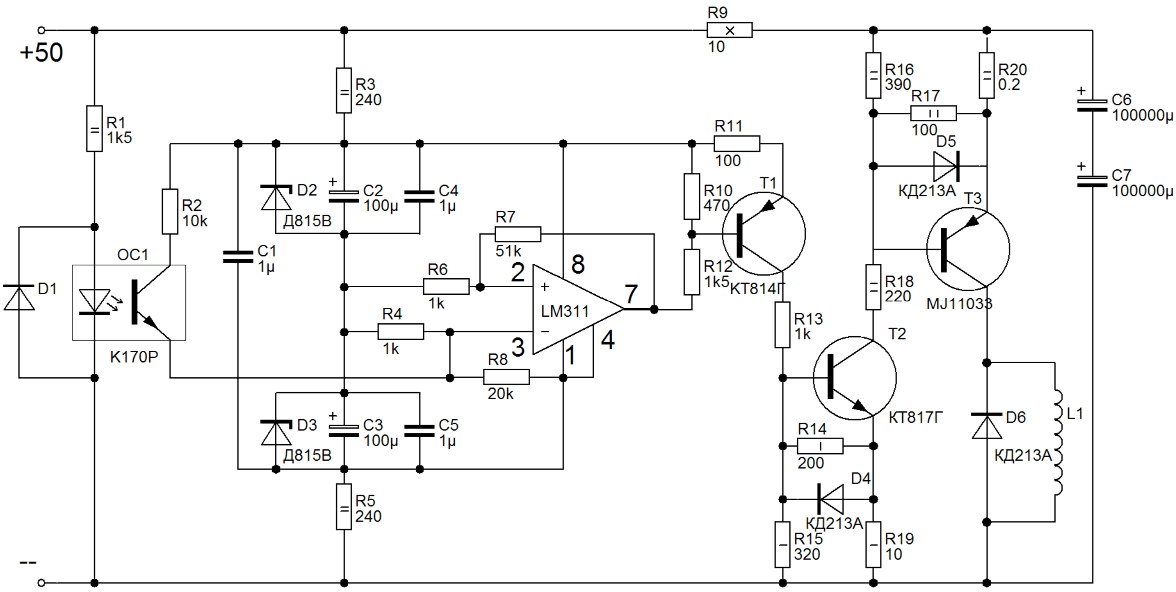

Fig. 3. Electromagnet control scheme

In the circuit base-emitter of the output keys on the T2, T3 transistors the diodes D4, D5 are installed (КД213А), to provide protection of transistors against pulse overload.

On the elements D2, D3, C1 – C5, R3, R5 the voltage stabilizers are connected for power supply of the chip LM311.

Particular attention was paid to the choice of type of capacitors C6 and C7 with the capacity of 100000μF and voltage up to 63V. They must have low parasitic inductance, operate in a wide range of frequencies (this enables to switch short pulses). According to these requirements the capacities Evox Rifa type PEH200MV6100M 100000 μF, 63 volt were selected. The L1 inductance coli was manufactured as a single element, with 250 turns of copper wire 2.5 mm in diameter in varnish insulation with additional insulation between layers.

The inductance coil was installed directly on the device. An optical pair of control circuit startup was installed before the coil, and optical pair was installed after the coil to measure the speed and start of ADC.

The electromagnetic accelerator was design and manufactured, it allows to conduct mechanical tests on the strength of brittle materials at speeds up to 10 m/s [6]. The device on the basis of the Hopkinson dimensional rods can also be used to study the energy characteristics of the destruction of solid alloys and to simulate the process of cutting the tool into a billet.

The application of the device to study the tensile strength at the diameter compression

The load diagram while determining the tensile strength at the diameter compression $\sigma_p^{\partial c}$ [7] is shown in the figure 4.

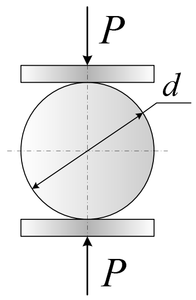

Fig. 4. Load diagram

Disc samples of one batch of VK3 alloy were tested on the modernized device for testing the strength of solid alloys under dynamic load. Before the start of the test, the dimensions of the samples were determined, namely, the diameter d and the thickness t.

The strength at the diameter compression was calculated according to the formula (4) [8].

$$\sigma_p^{\partial c} = \frac{2P}{\pi \cdot d \cdot t} \quad (4)$$

The strength at the uniaxial stretching was calculated according to the formula (5) [9].

$$\sigma_p = \frac{1.28\sigma_\kappa \sigma_c}{\pi\sigma_c - 5.93\sigma_\kappa}, \quad (5)$$

where σ_κ – contact strength, σ_c – strength limit at uniaxial compression.

Geometric sizes of samples d = 7,8 mm, t = 2,95 mm.

The results of the tests depicted that all 10 samples were destroyed according to the classical scheme (Fig. 5) and there was not any failure of the measuring system.

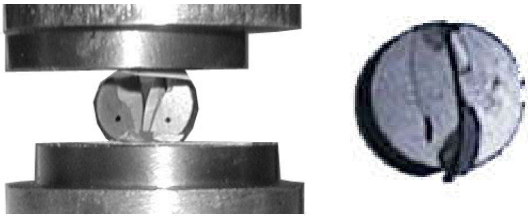

Fig. 5. Type of sample destruction

Test results VK3: $\sigma_p^{дс} = 576 \pm 95$ MPa, $\sigma_p = 620 \pm 165$ MPa with confidence probability 0,9.

Samples tests of experimental hard alloys obtained by vacuum sintering during 40 minutes at temperature 1550 °C were also carried out [11]. The blend before sintering was subjected to intense grinding during 120 hours with bullets 5-10 mm. Alloys of the first group included except **WC** up to 19% **Ni_3Al**, and the second - except **TiC** up to 19% **Ni_3Al**. Test results: the strength limit of alloys of the first group, $\sigma_p^{дс} = 435 \pm 28$ MPa, of the second group $\sigma_p^{дс} = 290 \pm 15$ MPa [10].

Thus, solid alloys obtained by vacuum sintering with an additive **Ni_3Al**, have high mechanical characteristics, although their strength under dynamic loads is less than the strength of solid alloys WC – Co - group.

Conclusions

The modernization of the control device of the solid alloys strength under dynamic load was carried out. A design was developed and an electromagnetic accelerator was manufactured, which allows to perform mechanical tests on the strength of fragile materials at speeds up to 10 m/s.

The basic scheme was developed and a control and synchronization unit for the start of an electromagnet was manufactured.

It was defined that the device on the basis of the Hopkinson measuring cores can also be used while studying the energy characteristics of the solid alloys destruction and the investigation of the cutting process.

The obtained experimental results on the strength of solid alloys can be used to predict the probability of incisors destruction.

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СИСТЕМА ДЛЯ КОНТРОЛЮ МІЦНОСТІ ПРИ ДИНАМІЧНОМУ НАВАНТАЖЕННІ З ЕЛЕКТРОМАГНІТНИМ ПРИСКОРЮВАЧЕМ

В статті описано установку для контролю міцності крихких матеріалів при динамічному навантаженні. Розроблена конструкція та виготовлено електромагнітний прискорювач, який дозволяє проводити механічні випробування на міцність крихких матеріалів зі швидкістю до 10 м/с. Встановлено, що установка на базі мірних стриж-

нів Гопкинсона може бути також використана для вивчення енергетичних характеристик руйнування твердих сплавів та дослідження процесу врізання. Отримані експериментальні результати про міцність твердих сплавів можуть бути використані для прогнозування вірогідності руйнування різців.
Ключові слова: автоматизована система, міцність, електромагнітний прискорювач, динамічне навантаження, надтверді матеріали.

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СИСТЕМА ДЛЯ КОНТРОЛЯ ПРОЧНОСТИ ПРИ ДИНАМИЧЕСКИХ НАГРУЗКАХ С ЭЛЕКТРОМАГНИТНЫМ УСКОРИТЕЛЕМ
В статье описана установка для контроля прочности хрупких материалов при динамической нагрузке. Разработана конструкция и изготовлен электромагнитный ускоритель, который позволяет проводить механические испытания на прочность хрупких материалов со скоростью до 10 м/с. Установлено, что установка на базе мерных стержней Гопкинсона может быть также использована для изучения энергетических характеристик разрушения твердых сплавов и исследования процесса врезания. Полученные экспериментальные результаты о прочности твердых сплавов могут быть использованы для прогнозирования вероятности разрушения резцов.
Ключевые слова: автоматизированная система, прочность, электромагнитный ускоритель, динамическая нагрузка, сверхтвердые материалы.

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МЕТОД ПІДВИЩЕННЯ ДОСТОВІРНОСТІ ДІАГНОСТИКИ СТАНУ РІЗАЛЬНОГО ІНСТРУМЕНТУ ПРИ АВТОМАТИЗОВАНІЙ ОБРОБЦІ ДЕТАЛЕЙ

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Дана стаття пояснює необхідність розробки методів підвищення достовірності діагностики стану різального інструменту, описуючи процес різання на мікроструктурному рівні, за допомогою якого визначається проблема зношення різального інструменту та можливий шлях її вирішення. Запропоновано метод діагностики стану різального інструменту в умовах автоматизованого виробництва, який базується на вимірюванні сигналу акустичної емісії та потужності різання. Цей метод дозволяє контролювати інтенсивність зношування різального інструменту та прогнозувати його стійкість, що дає можливість підвищити точність, якість та ефективність механообробки.
***Ключові слова**: діагностика, процес різання, автоматизація, різальний інструмент, зношення, стійкість різального інструменту.*

Вступ

При серійному автоматизованому виробництві деталей дуже важливо проводити діагностику різального інструменту, так як найчастіше за все, а саме 63% від загальної кількості несправностей, які виникають в технологічно-оброблюваних системах (ТОС), припадають саме на відмову різального інструменту. При цьому для виявлення та усунення відмов необхідно затратити біля 10% від загального часу роботи верстатів. З відмови інструменту на одній операції часто слідує і вихід з ладу інструментів на інших позиціях, що спричиняє відмови інших вузлів верстата та випуск бракованої продукції [1].

При відсутності достовірної інформації про всі види впливу навколишнього середовища на різальний інструмент та без моніторингу його стану може