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Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
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CONTRIBUTIONS TO DESIGN AND CARRY OUT AN UNIVERSAL DYNAMIC HARDNESS TESTER FOR METALLIC MATERIALS TESTING

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Abstract: *The paper focuses on a high accuracy measuring hardness tester of universal use, meant to metals hardness tests using static loads and IMPACT ones. With this end in view, an electromagnetic loading computer-controlled system is used allowing the tested material to be stressed by a spherical tungsten carbide penetrator, and force is measured by a capacitive sensor which consists of an oscillation resonant circuit, and depth of penetration is measured by an inductive displacement sensor. To perform a certain hardness test using this equipment requires the penetrator change and proper computer setting only.*

Key words: *hardness, static, dynamic, inductive, capacitive*

1.INTRODUCTION

To determine static load hardness by measuring depth of penetration, known standardized methods Rockwell, Martens, instrumental hardness test as well as other non-standardized methods are more or less used for informative hardness determination. As for impact load test the following methods are known: Shore, Poldi, Baumann-Steinrück, Leeb and other (Gutt,2000,2009), impact load test methods which are less standardized as compared to the static load ones because the stressing speed influences greatly hardness value, and companies produce a wide variety of stressing speed impact hardness tester.

The way the impact hardness value is expressed has also negative influence, depending on the method used leading to different reproductibilities even of the same tested material, thus in some impact tests, the test results are conversed into units of static hardness, using as basis the ratio between the stressing force and surface area deformed by penetrator (Poldi, Baumann –Steinrück) whereas in other tests elastic or impact recoil energy is used as expressing hardness value (Shore, Leeb, Hermann 2000,Gutt 2009 .

Mention should also be made about the fact that the way impact load hardness is expressed by energy values has better data reproducibility as compared to other methods as both kinetic stress energy and the recoil one include speed, thus being possible to eliminate an important error source by making it easier (Gutt 1995). At present, no matter the static or impact testing method used, a specific hardness tester is needed to put them into practice.

The authors have not been acquainted yet to any equipment allowing static and impact load hardness tests using the same apparatus. The device in question requires just a penetrator change according to the test type as well as test type setting.

2.EXPERIMENTAL

The hardness tester is meant to determine all types of static stress hardness tests as well as of impact ones wherein impact hardness IH is expressed by the ratio between recoil kinetic energy E_{cr} and impact kinetic energy E_{ci}.

$$HD = K \cdot \frac{E_{cr}}{E_{ci}} \quad (1)$$

The impact hardness value HD calculated this way should not be a sub unitary number that is why the K constant value is conventionally adopted as being equal to a thousand units. The use of the hardness tester in question makes possible to correlate impact hardness value to testing speed and eliminates the friction influence of guiding mobile equipment from the hardness measured value.

In this sense an electromagnetic loading system is used, the tested material *11* being stressed by a penetrator *10* moved from the mobile core *2* of an electric coil *1*.

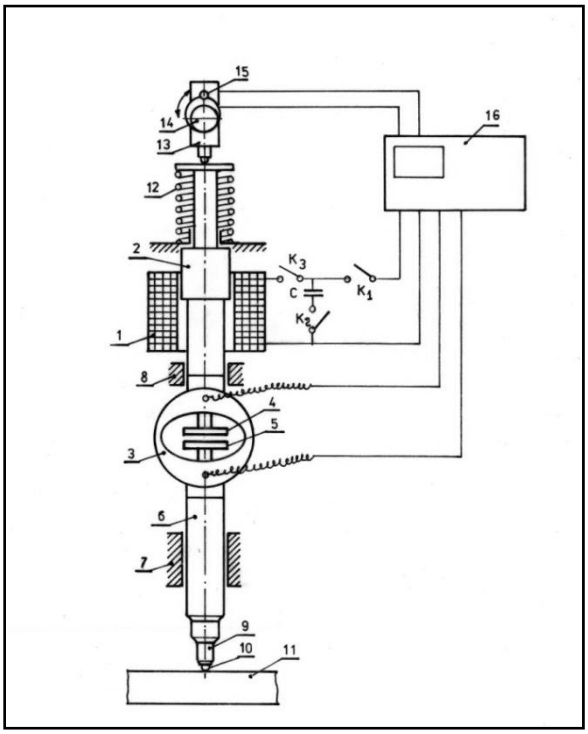

Fig.1. The basic diagram of universal hardness tester. 1-electric coil, 2- mobile core, 3-dynamometer cell, 4,5-condenser coatings, 6- guiding rod, 7,8- guides, 9- port penetrator, 10- spherical tungsten carbide penetrator, 11- tested material, 12- compression spring, 13,14-electric coils, 15- mobile core, 16- electronic unit, C_o- bank of capacitors, K_1, K_2, K_3 - switches

To make different types of static load hardness tests, the electromagnet coil *1* is fed by linearly increasing voltages, controlled by a microprocessor and to make impact load hardness tests; one or more condensers are suddenly discharged from a condenser battery *c* through the electromagnet coil. The static and impact stresses acting upon the penetrator*10* is made by a dynamometer cell with capacitative force sensor *3*, the condenser being composed of two plane cylindrical coatings *4* and *5* in series into static or impact stress flux of the tested material *11*.

To measure penetration depth of penetrator, both for static load hardness tests and impact ones, and impact speed and elastic recoil speed (in impact load hardness tests), a differential inductive displacement sensor is used, in contact to the mobile core of charging electromagnet coil, composed of two electric coils *13,14*, and a mobile core *15.*

3. RESULTS AND DISCUSSION

The operation and working mode is the following:

a) For load static tests the port penetrator*9* is tapped with the spherical tungsten carbide penetrator *10* according to the type of test, the hardness type is set electronically then switches K_1 and K_3 are automatically off, leading to the charging-discharging cycle of penetrator and continuous measurement of force values by the capacitive impact force sensor, composed of the two electric condenser coatings *4* and *5* as well as the measurement of penetration depth values of penetrator *10* into the tested material *11*, impact-speed and the speed after impact by the differential inductive sensor formed by the electric coils *13,14* and mobile core *15*. The use of hardness tester in static testing allows the determination of Martens hardness, values (HM) using a Vickers or Berkovich penetrator by the relationship (Ullner 2005, Fröhlich 1997, Oliver 1992, Weiler 1990):

$$HM = \frac{F}{A_s(h)} = \frac{F}{26{,}43xh^2} \tag{2}$$

Where:

- F - force applied on penetrator [N]
- A_s(h)- depth of penetration up to a distance (h) from the top [mm^2]
- h- depth of penetration under load, [mm]

b) For impact load tests the port penetrator *9* together with the spherical tungsten carbide penetrator *10* corresponding to the test type is tapped to the guiding rod *6*, then the hardness test type is electronically set, and the switches K_1 and K_2 are automatically off , fact that leads to the battery charging of condensers C_o , afterwards the switch K_1 is also automatically on whereas the switch K_3 is off, fact that makes the battery of condensers discharge through coil *4* by an electric energy E_e:

$$E_e = \frac{C \cdot U^2}{2} \tag{3}$$

Where: U-supply voltage of the battery of condensers

C- capacity of battery of condensers causing the displacement of mobile core *2* towards the tested material *11* by a speed v, with the kinetic energy E_c of mobile equipment at impact:

$$E_c = \frac{m \cdot v^2}{2} \tag{4}$$

Where: m- weight of mobile equipment

Discharge electric energy E_c at impact moment is equal in terms of value to kinetic energy of mobile equipment:

$$E_e = E_c \tag{5}$$

Or:

$$\frac{C \cdot U^2}{2} = \frac{m \cdot v^2}{2} \tag{6}$$

On the impact of penetrator10 to the tested material *11* the kinetic energy of penetrator is turned into energy of plastic and elastic deformation of the tested material and energy of elastic deformation of the dynamometer cell *3*.

The higher is cell deformation degree, the harder the tested material *11* is. The deformation of dynamometer cell generates at its turn a proportional reduction of the distance between coatings of the electric condenser which is part of an oscillation resonant circuit integrated into central electronic unit *16*, causing a frequency displacement of this one proportional to the capacity change of the condenser composed by coatings *4* and *5*. Expression of dynamic hardness can be done in three ways:

1. as the ratio of kinetic energies by using Equation 1, values of the two speed given by the inductive sensor 13,14,15 and the mobile equipment mass 2, 3,4,5,6,8,9,10,15
2. as the ratio of kinetic energy impact E_{ci} and the penetration depth using the impact speed value given by the inductive sensor 13,14,15, mobile equipment mass 2, 3,4,5,6,8,9,10,15 and depth of penetration given by inductive sensor also
3. as the ratio of dynamic impact force and depth of penetration using the frequency drift value given by capacitive sensors 3,4,5 and depth of penetration given by inductive sensor 13,14,15.

4. CONCLUSIONS

The universal hardness tester in question renders possible both hardness tests of static stress and impact ones using unique equipment, different types of hardness tests requiring only the penetrator and computer proper setting.

The use of universal hardness tester increases the accuracy determination of impact load hardness as, when this one is calculated, the value of impact speed is automatically taken into consideration being determined by differential inductive sensor.

The ratio between recoil kinetic energy value of mobile equipment and impact-kinetic energy results in an impact hardness value which does not include errors given by the friction forces mobile equipment of guides as the influence of friction forces may be found both in the fraction nominator and numerator and the result of simplifying the numerical values of these errors is one without modifying the measurement result.

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