RECORDING STRAIN DIAGRAMS IN LOW-TEMPERATURE IMPACT BENDING TESTS

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UDC 620.178.74

The simplest and most widely used method of monitoring the tendency of metals to brittle fracture is the determination of the temperature dependence of the work of fracture from the results of impact bending tests. It is therefore highly advantageous when using pendulum-type and other impact testing machines to incorporate special sensors and devices for plotting strain diagrams. This apparatus can produce, in addition to impact strength, the characteristics of dynamic strength, plasticity, and ductility of fracture [1].

An apparatus of this type was developed at the Institute of the Strength of Materials of the Academy of Sciences of the Ukrainian SSR for a 10 kg pendulum impact testing machine used in low-temperature tests (from 20 to -196° C) and for a KN 30 kg pneumatic impact tester (for the temperature range from 20 to -269° C) Physicotechnical Institute of Low Temperatures of the Academy of Sciences of the Ukrainian SSR [2]. The KN testing machine can be used for recording load flexure graphs. The specimen with the anvil is placed onto the dynamometer operating as a load sensor; a photocell is provided for monitoring the flexure.

The apparatus developed for recording load and flexure as functions of time is highly sensitive to sensor signals, quick-acting, and insensitive to distortions. During tests the load signal can be amplified 50,000 times while the deflection signal can be controlled from 0 to 10 V.

An ac supply of about 47 kHz from a GZ-33 generator 4 provides more stable operation than a dc supply. The working frequency is controlled by the F-599 device 5 (Fig. 1).

Unlike other devices [1], the system being described records, in addition to the load – time graphs, also flexure versus time and load versus flexure diagrams. It can also be used with pendulum impact testers. In this device, as in the PSWO impact tester, a piezoelement placed under the striker knife edge is used as the load sensor.

The system, whose flow diagram is shown in Fig. 1, works as follows. From the strain gages of dynamometer 1 the unbalance signal proportional to load is applied to a USh-10 broad-band amplifier; the amplified signal is applied, after passing through filter F (transmission band width over 30 kHz) and rectifier R, to one of the inputs of the two-ray oscilloscope S1-34. A special tuning unit TU is used to improve the accuracy of load measurements by balancing the resistance and capacitance of the bridge. This is

TABLE 1

Temperature, °C	KN	Pendulum impact testing machine	
	diagram	diagram	scale
20	—	14,1; 14,7; 14,4 / 14,4	14,5; 14,8; 14,5 / 14,6
—196	8,6; 9,1; 8,7; 9,3 / 8,9	9,3; 9,2; 8,3; 8,6; 8,7 / 8,8	10,0; 10,0; 8,8; 9,2; 9,2 / 9,4
—269	6,6; 6,9; 6,7; 6,0; 6,8 / 6,6	—	—

Note. Numerator: impact strength of the specimen, denominator: average impact strength, kg-m/cm^2.

Institute of the Strength of Materials, Academy of Sciences of the Ukrainian SSR. Translated from Problemy Prochnosti, No. 12, pp. 55-57, December, 1972. Original article submitted March 1, 1972.

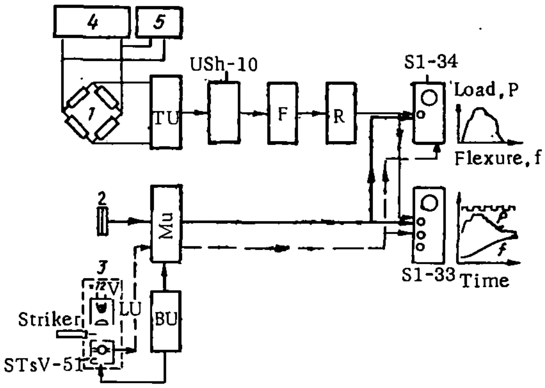

Fig. 1. Schematic diagram of the system for recording strain during impact bending tests.

necessary to compensate for the reactance and capacitance of cables, an operation which is essential when working on high carrier frequencies.

When working with a pendulum impact testing machine the load is monitored by piezoelectric sensor 2 whose signal is applied to the oscilloscope through matching unit MU.

On both machines the specimen flexure is monitored by photocell unit 3 incorporating a STsV-51 photocell and lamp LU.

Since both piezosensor and photocell have considerable internal resistances, the two-valve electronic unit MU is provided for matching the measuring circuits to the oscilloscope input. The power supply is from a 100 V stabilized ac source. One of the matching unit valves (6ZhZP) works under electrometric conditions with a grid voltage of 10^{12} A and a corresponding resistance of 10^{-14} which enables it to retain the charge formed on piezesensor plates after the application of a static load. This makes possible a static calibration of the piezosensor. The scale adjustment in recording the load is by means of a bank of scale condensers (from 1800 to 15,000 pF).

The flexure monitoring system was calibrated by means of a micrometric device. The changes in the light intensity were used to obtain a linear relationship during calibration, between the photocell signal and striker displacement. The load signal obtained from the photocell was applied to horizontal oscilloscope plates. The fracture diagram was photographed (Fig. 2).

By static calibration it is possible to obtain on the screen of a S1-34 oscilloscope the required beam position which was determined by static calibration.

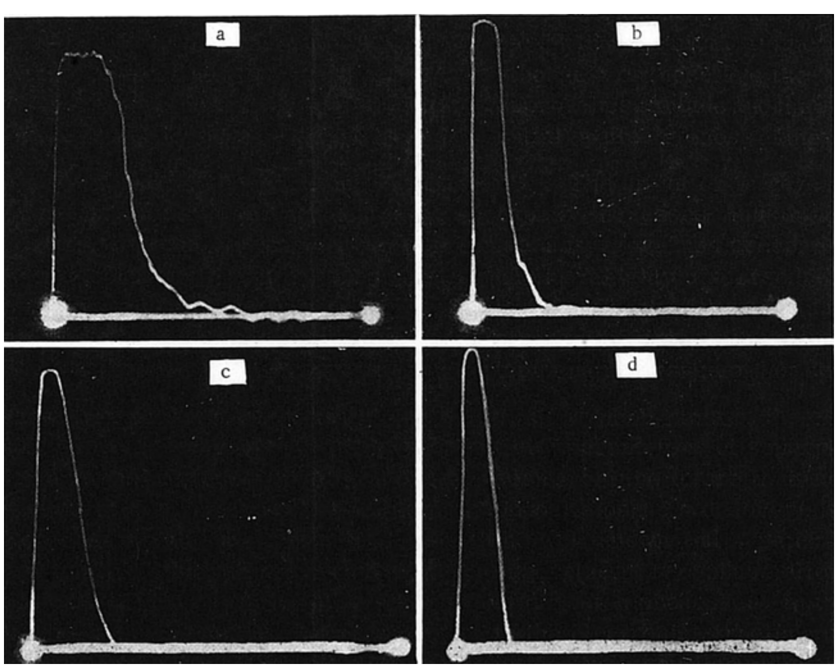

Fig. 2. Typical strain oscillograms "load–flexure" obtained for Kh·16N6 steel: a, b) t = +20 and -196° C, pendulum impact testing machine; c, d) t = -196 and -269° C, pneumatic impact testing machine.

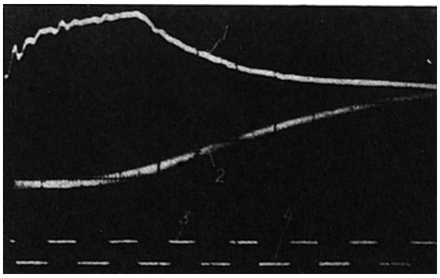

Fig. 3. Oscillogram (1) load–time, (2) flexure–time for impact bending of Kh18N10T steel at -196° C; time marks (3, 4) 0.0005 sec.

The fracture load and flexure were determined from the diagram by comparing the beam deviations determined during the test using calibration marks applied to the film before and after the test cycles.

The displacements of the beam in vertical and horizontal directions (load and flexure scales) can be adjusted (using units TU, MU, and amplifier) in a wide range according to the characteristics of the material concerned.

For plotting fracture diagrams in load–time and flexure–time coordinates the five-ray oscilloscope S1-33, receiving signals from the load and flexure sensors, is used. The third channel is used to record time (Fig. 3). The beams are controlled by the generator working on the slave sweep principle.

It should be noted that by this method the work of fracture is determined directly by measuring the area of the load–flexure diagram by means of a planimeter or from the load–time diagram by the method described in [1].

It may be seen from Fig. 2 and the data of Table 1 that the oscillograms obtained for given conditions (-196° C) on pendulum and pneumatic testing machines are practically identical in shape. Some differences in diagram widths and maximum deviations of the beam in a vertical direction are due to different load and flexure scales used.

The impact strength values determined by the conventional method (GOST 9454-60) and from strain diagrams are also practically identical (deviations 2-7%).

The testing machine scale produced slightly higher impact strength values than the values obtained from the work of fracture using strain diagrams; this is evidently due to energy losses in the anvil which are not associated with the specimen failure. This difference slightly increases (Table 1) with decreasing test temperature because of increasing energy stored in the elastically strained specimen. The system for recording strain diagrams during the impact considerably increases the volume of information gained in testing a single specimen. The use of the same recording and measuring apparatus on different testing machines makes the comparison of experimental results easier. Table 1 gives the data obtained in impact testing Kh16N6 steel specimens at 20, -196, and -269°C.

To maintain the specimen temperature at a constant level between +20 and -196° C during impact tests on pendulum machines the specimens are placed into paper containers or wrapped into a laminated fragile material (thickness 0.02 mm). The specimens are cooled in a seperate chamber by liquid nitrogen or its vapor and held at this temperature for 10-15 min. Measurements showed that the temperature of insulated specimens transferred into the machine remains constant over the entire length and cross section of the specimen (within measurement errors) for 20-40 sec which is sufficient for the test; insulation has no effect on the impact strength values obtained. For tests on the KN machine the specimens are cooled in a liquid cooling agent or its vapor (nitrogen or helium) in a cryostat which also contains the loading unit striker.

A good agreement between the results obtained in dynamic tests over a wide range of low temperatures (to -269°C) on different testing machines but with the same strain diagrams recording system, showed that it is possible to standardize the impact bending test conditions for temperatures below -100° C specified in GOST 9455-60.

LITERATURE CITED

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2. V. K. Chernetskii, Author's Certificate No. 270312, Byulleten' Izobretenni, Otkrytiya Izobreteniya, Promyshlennye Obraztsy, Tovarnye Znaki, No. 16 (1970).