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AEC RESEARCH AND DEVELOPMENT REPORT

Y-1619
Instruments

MASTER

VELOCITY READOUT SYSTEM
FOR AN IMPACT TEST MACHINE

J. J. Henry

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the ATOMIC ENERGY COMMISSION under U. S. GOVERNMENT Contract W-7405 eng 26

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Y-12 PLANT

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VELOCITY READOUT SYSTEM FOR AN IMPACT TEST MACHINE

J. J. Henry

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ABSTRACT

A noncontact velocity readout system for an impact test machine has been designed. This system measures velocity with an optical-electronic-generated, time-interval measurement from a distance template. An accuracy of ± 0.05 ft lb has been obtained. Calibration data for the system have been determined.

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SUMMARY

A noncontact optical-electronic velocity measurement system has been designed for a pendulum-type impact tester. The system measures the time required for the pendulum to traverse two known distances, one before and one after impact. The distances are established by two sets of reflecting marks on a template mounted on the pendulum hammer. Passage of the marks is detected by a photosensor and light-source combination, and the time of passage is measured by a counter-timer combination, providing for calculation of both the input energy and that remaining after impact. Calibration equations and fixed calibration measurement data have been determined as well as an error analysis and an expected limit of error.

INTRODUCTION

The impact breaking strength of various materials is measured using a machined specimen of the material which is broken in a test machine. The energy lost in the breaking process is measured and displayed. The Sonntag impact test machine uses a weighed pendulum hammer which is dropped from a fixed height, as shown in Figure 1. The energy left in the hammer after impact is found by measuring the peak angle of the follow-through swing with a friction-pointer, peak-reading attachment. The peak angle is related to the remaining energy. The difference in energy is indicated by a calibrated scale under the pointer.

Figure 1. SONNTAG IMPACT TEST MACHINE.

The accuracy of this test can be influenced by the hammer drop-release characteristic (where the drag and release rate can affect the input energy) and by friction and wind losses during the first swing.

The method that minimizes these errors has been devised using a noncontact velocity measurement before and after impact. The energy required to break the specimen is calculated from the kinetic energy formulas:

$$\begin{aligned}
 E_s &= E_{in} - E_{out}, \text{ or} \\
 &= \frac{1}{2}m(v_{in})^2 - \frac{1}{2}m(v_{out})^2.
 \end{aligned}
 \tag{1}$$

VELOCITY READOUT SYSTEM FOR AN IMPACT TEST MACHINE

DESCRIPTION OF THE SYSTEM

The velocity readout system is used with a Sonntag-type impact test machine to improve the precision of the readout over and above that obtained from the calibrated scale and friction-type peak-reading pointer. To use this system, a velocity measurement must be made both before and after the hammer strikes the specimen. A velocity determination is made by measuring the time required for two accurately spaced marks on the pendulum to pass a photodetector and light-source combination. The marks consist of two pairs of radial lines each spaced one inch apart at a 31.5-inch radius on a 0.020-inch-thick aluminum template. The template is mounted on the side of the impact hammer and aligned with the striking edge.

The detector assembly consists of a light beam focused on the surface of the template and a Photofet detector. A block diagram of the measuring system is presented in Figure 2.

Figure 2. VELOCITY READOUT SYSTEM FOR AN IMPACT TEST MACHINE.

Light reflected from lines on the template is detected by the phototransistor. The detector output signal is amplified and actuates a Schmitt trigger-level detector to provide an indication when the mirror line is in the light beam.

An integrated-circuit digital-counter control is operated from the Schmitt output and provides a signal that starts the first counter after the first accepted Schmitt output, stops Counter 1 after the second output, starts Counter 2 on the third output, stops Counter 2 and locks up to prevent further action on the fourth output. The circuit reset pushbutton must then be depressed to remove the lockup and allow any other counts. As a result, the control circuit causes the instrument system to take two consecutive counts and then disables the input to prevent further counting.

A 1.00 Mhz crystal oscillator provides an accurate time signal to the counters. Counter 1 (LH unit) indicates input time (T_1), while Counter 2 (RH unit) indicates the "after-break" time interval (T_2).

The counters and control circuit are mounted in the standard AEC module and bin system.^(a) The counters are commercial units with discriminator input.

Calibration

To calibrate the instrument for absolute energy measurement using velocity indications, it was necessary to measure the oscillator frequency, template line spacing at the point of light beam contact, mass of the hammer, and the radius of the pendulum at the centroid.

Oscillator frequency is crystal controlled with an accuracy and stability of better than one part in 10^5 . When counted with an Eput meter certified by Y-12 Standards Laboratory, the oscillator measured frequency was 1.000001 ± 0.000001 megahertz.

Template line spacing was measured by an optical comparator to an accuracy of ± 0.0001 inch per one-inch measurement. Each template line pair was measured independently and correction applied to the measurement to relate the moment arm to the measurement position, thereby calibrating for the velocity of the centroid.

The mass of the hammer was measured by the Y-12 Standards Laboratory using a level-beam technique centered on the center of the hammer's striking face. A moment correction must be applied to this measurement since the center of the striking face is not exactly the centroid of the pendulum.

The actual position of the centroid (centroid radius) must be determined from the pendulum period. To obtain the maximum accuracy, the electronic system was used with a single line mirror to determine the period. The period was found to decrease from 1.95 seconds at the normal (low) drop height to about 1.79 seconds at a swing of about ± 5 inches from center. A 10-period time interval was obtained by blanking the lamp to prevent intermediate signals and by counting overflows (1 sec) by visual observation. The measured quantities used to derive the calibration and the expected limit of error in these quantities are summarized in Table 1. The derived constants and the equations from which they were derived are given in Table 2. The system's general calibration equations are reported in Table 3.

(a) Costrell, Louis, Editor; Modular Nuclear Instruments, TID-20893; Atomic Energy Commission, Washington DC; July 1964

Table 1
MEASURED CALIBRATION DATA

Quantity	Symbol	Value	Limit of Error (%)
Period	T_p	1.7968 sec	0.03
Local Gravity ⁽¹⁾	g	32.143 ft/sec ²	0.0062
Mass (large hammer, moment included)	M_l at l_l	52.805 lb at 31.602 in	0.008 weight 0.03 length
Mass (small hammer, moment included)	m_s at l_s	13.254 lb at 31.539 in	0.03 weight 0.03 length
Striking Radius	l_b	31.486	0.01
Oscillator Frequency	F_o	1.000001 Mhz	0.001
Template Distance	d_1	Depends Upon Light Position (moment correct)	0.02

(1) Value interpolated from measured value at Y-12 Standards Laboratory

Table 2
DERIVED QUANTITIES

Quantity	Symbol	Equation	Value
Centroid Radius	l_c	$= \frac{gT_p^2}{4\pi^2}$	2.6286 ft 31.543 in
Centroid Mass (large hammer)	M_{cl}	$= M_l \frac{l_e}{l_c}$	52.904 lbs
Centroid Mass (small hammer)	M_{cs}	$= M_s \frac{l_s}{l_c}$	13.252 lbs

In practice, it is desirable to reduce the hammer equation to:

$$E_{bs} = \frac{K_1}{(T_1)^2} - \frac{K_2}{(T_2)^2}, \quad (2)$$

where:

$$K_1 = 0.20614 \times 10^{12} (dc_1)^2, \text{ and}$$

$$K_2 = 0.20614 \times 10^{12} (dc_2)^2,$$

as expressed in Table 3. In this case, T_1 and T_2 are in microseconds, and they are the numbers read directly from the counters.

Table 3
CALIBRATION EQUATIONS

$$E_{in} = 1/2 M \left(\frac{dc_1}{T_1} \right)^2$$

$$E_{out} = 1/2 M \left(\frac{dc_2}{T_2} \right)^2$$

$$E_b = E_{in} = E_{out} = 1/2 \frac{W}{g} \left[\left(\frac{dc_1}{T_1} \right)^2 - \left(\frac{dc_2}{T_2} \right)^2 \right]$$

$$E_{bl} = 0.82295 \left[\left(\frac{dc_1}{T_1} \right)^2 - \left(\frac{dc_2}{T_2} \right)^2 \right] \text{ for the large hammer}$$

$$E_{bs} = 0.20614 \left[\left(\frac{dc_1}{T_1} \right)^2 - \left(\frac{dc_2}{T_2} \right)^2 \right] \text{ for the small hammer}$$

Error Analysis

The contribution to total error in any term will add in proportion to the square root of the sum of the squares of the effective percent error in each individual determination. Where a term is squared, its error in the final answer must be doubled:

$$E = \left[(2ET_p)^2 + (E_g)^2 + (E_m)^2 + (EL)^2 + (2Ed_1)^2 \right]^{1/2},$$

where:

$E_s = 0.00067 = 0.067$ percent for the small hammer.

The limit of error (95% confidence) of 0.03 foot pound can readily be applied.

An additional error for an individual reading due to random noise, vibration, and $\pm$ one count error extends the limit to ± 0.05 foot pound as a conservative limit of error for the system using moment corrected distances measured to ± 0.002 inch for dc_1 and dc_2 .