AN APPROACH TO
THE TESTING OF THE DYNAMIC FRACTURE TOUGHNESS

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THE METHODS OF TESTING AND THE IMPROVEMENT OF APPARATUS

Method I

Fig. 1 is the diagram of the experimental apparatus of the first method. Its working principle is as follows.

Connected with the mains, the electronic beam of the oscillotron is waiting outside the screen to scan. When the impact button switch is pushed, the hammer starts to go down and the sheet iron bolted to the tup first approaches the oscillator, stops it from oscillating and causes the trigger generator reverted, the trigger generator produces a trigger signal which makes the horizontal scanning system of the oscilloscope begin to work. At this time, the electronic beam enters into the screen and moves at a certain rate. When the tup strikes the specimen, the striking force is transmitted to the load sensor through the specimen. Then the load sensor gives out a voltage ΔE, which is proportional to the striking force. This voltage ΔE is magnified by the dynamic strainmeter and transmitted to the inputting end of the Y axis. Thus the oscilloscope shows the P-t curve (the load-time trace). The picture of its wave taken by camera serves the base for calculation of K_{1d}.

Fig. 2 shows a typical load-time trace obtained in the experiment. The pulse duration T is the time interval of striking. In order to control the degree of distortion of the wave shape, it is required that the deviation of the frequency response curve from its average value should be smaller than 3 db in the whole frequency range varying from $\frac{0.01}{T}$ to $\frac{10}{T}$.

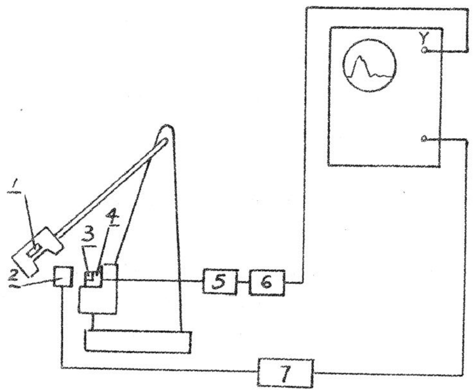


Fig. 1

1. sheet iron 2. oscillator 3. specimen 4. load sensor 5. box bridge 6. dynamic strainmeter 7. tgigger generator 8. oscilloscope SBT-5.

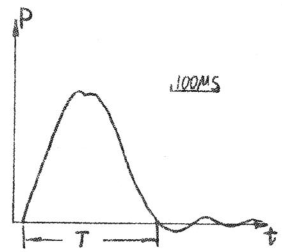


Fig. 2

This requirement can easily be fulfilled with common apparatus. The frequency bandwitch of the oscilloscope SBT-5 is 10 HZ—10MHZ. After the improvement, the frequency bandwidth of the dynamic strainmeter has reached

15HZ—35KHZ. The minimum striking time T is 300 μs in all experiments, so that the demands for the test of K_{1d} are well fulfilled.

Fig. 3 is a sketch of a load sensor. Four strain gages are stuck on both side surfaces of the prop. Eight strain gages of two load sensors are connected to form a complete bridge.

In some experiments, the load-time trace is obtained as Fig. 4. With this trace it is very difficult to determine the accurate maximum load P_{max} on the specimen. This load-time trace can be interpreted as follows. Because there is a gap between the specimen and the load sensor when the the specimen is stuck by hammer, it is accelerated rapidly, then the specimen strikes the load sensor at high speed, the sensor will give out a voltage corresponding to the striking force which makes a

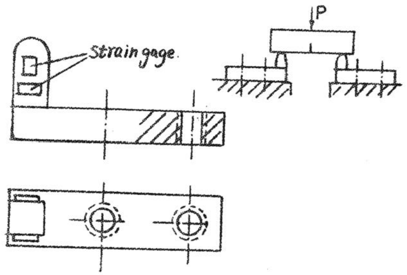


Fig. 3

peak in the wave picture, and the reaction of the striking force will decelerate the specimen. This peak can be considered as the inertial peak. In order to eliminate the gap between the specimen and the load sensor, the specimen is stuck on the load sensor tightly be stickers 502. Thus the load sensor does not give out the inertial peak, and the subsequent oscillations are decreased because the unloading process at the failure of the specimen is relaxed.

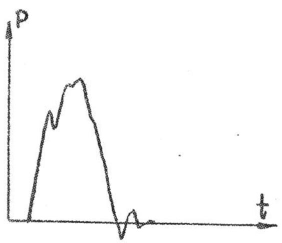


Fig. 4

Fig. 2 is the load-time trace obtained in such a test.

Method II

Fig, 5 is the diagram of the experimental apparatus of the second method. Here the scanning and triggering apparatus are exactly the same as those in the first method. A piezoelectric acceleration sensor is fixed on the tup, so that when the tup strikes the specimen, the striking force decelerates the hammer, in the meantime, the acceleration sensor gives out a voltage ΔE which is proportional to the deceleration a and is transmitted to the input end of the Y axis of the oscilloscope through the impedance converter and band-pass filter. In this way, the a-t trace (acceleration-time trace) is obtained.

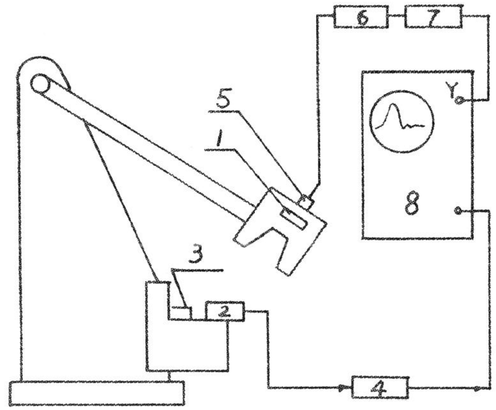
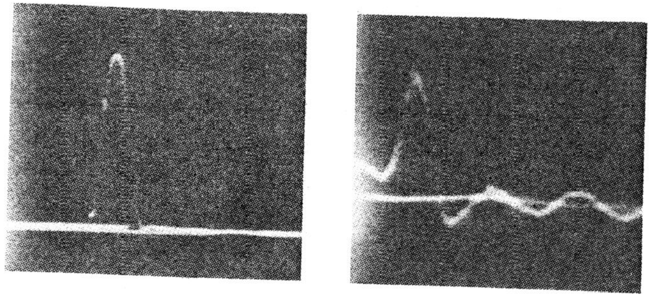


Fig. 5

1. sheet iron 2. oscillator 3. specimen
4. trigger generator 5. acceleration sensor
6. impedance coverter 7. band-pass filter
8. oscilloscope SBT-5

In order to reduce the influence of the resonance of the acceleration sensor on the wave shape, it is required that the natural frequency of the acceleration sensor should be higher than $\frac{30}{T}$.

The resonance of the hammer has more significant influence on the a-t trace. By installing a load-pad between the specimen and the anvil this influence is decreased, but at the same time the loading rate is decreased.



(a) (b)

Plate 1

Plate 1 is the wave picture of the same specimen with two methods (of which Plate 1 (a) refers to the first method, Plate 1 (b), to the second).

Comparing method 1 with method 2, it is obvious that the former is preferred.

THE DETERMINATION OF P_{max}

To calculate P_{max} with the P-t trace, we have proposed the impulse method, whose fundementals are as follows.

During the striking, the variation of the momentum of the hammer is equal to the impulse obtained by the hammer, therefore we have

$$m\,(v_1-v_2) = \int_0^T P(t)dt \tag{1}$$

where T denotes the time of the striking duration, m denotes the mass of hammer (approximately supposing that the mass of the hammer is lumped at the striking point), v_1 and v_2 denote the initial and final velocities of the hammer, respectively. If w_0 denotes the energy of the hammer before the striking, ΔW denotes the lost energy of the hammer during the striking, we

can easily get

$$v_2 = v_1\sqrt{\frac{w_0-\Delta w}{w_c}} \tag{2}$$

On the right side of the equation (1), $\int_0^T P(t)dt$ is the area under the P-t curve, which can generally be calculated as follows.

a) P-t trace is nearly a half sine pulse as Fig. 6 (a). Thus

$$\int_0^T P(t)dt = \int_0^T P_{max}\ \mathrm{Sin}(\frac{\pi t}{T})dt \tag{3}$$

Substituting into equation (1), we obtain

$$P_{max} = \frac{\pi m}{2T}(v_1-v_2) \tag{4}$$

b) P-t trace is such as in Fig. 6 (b) the area approximates to the sum of the area of the half sine pulse and the area of a triangle. If let $K = \frac{P_2}{P_{max}}$, we can easily get

$$P_{max} = m(v_1-v_2)/(\frac{2T_1}{\pi}+\frac{KT_1}{2}-\frac{KT_2}{2}) \tag{5}$$

c) P-t trace is as in Fig. 6 (c). Let $K = \frac{P_2}{P_{max}}$, we can easily get

$$P_{max} = 2m(V_1-V_2)/[T_2+(1-K)T_1] \tag{6}$$

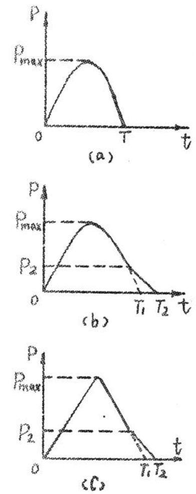


Fig. 6

The standardization of P axis has been set up. The P_{max} measured from standardized P-t trace agrees quite well with the P_{max} calculated by the impulse method.

THE RESULTS OF THE TESTING

The K_{1d} values of two kinds of steel at room temperature has been examined. Analysing the results of examination, the following conclusion may be drawn.

a) The relation between the sizes of the specimens and the K_{1d} values is shown in Fig. 7. The reason why the K_{1d} values are higher when the sizes of specimens are smaller is that the specimens are not in the plane-strain condition. Similar to the examination of K_{1c}, the sizes of specimens for K_{1d} should fulfill the following condition:

$$\left.\begin{array}{l} B \\ a \\ w-a \end{array}\right. \geq 2.5\left(\frac{K_1}{\sigma_s}\right)^2$$

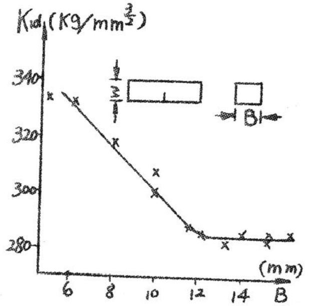


Fig. 7

Here K_{1d} is substituted for K_1 and σ_{sd} for σ_s. The K_{1d} values of common materials are generally smaller than their K_{1c} values and the σ_{sd} values are higher than their σ_s values, so that the sizes of specimens for K_{1d} can be much smaller than those for K_{1c}. The calculation of results of experiments shows that the dividing point for two regions — the region in which K_{1d} values are higher than usual and the region in which K_{1d} values are stable is critical point of plane-strain condition.

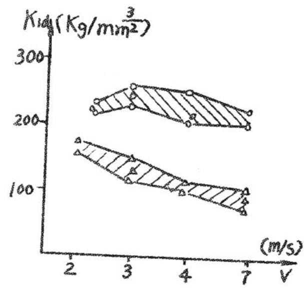


Fig. 8

b) The relation between K_{1d} values and the loading speed for two kinds of steel is shown in Fig. 8. It can be seen that the loading speed increases with decreasing K_{1d} values. But the susceptibilities of K_{1d} values of two kinds of steel to the loading speed are not the same.