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Some Experimental Results on Dynamic Properties of Rubber Cord under High-Speed Transverse Impact

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Abstract

Shooting the rubber cord transversely with a bullet, some remarkable phenomena are observed, which are different from those under the static testing. In short, the differences from the static properties are as follows:

(1) The breaking elongation under high-speed impact comes to three times of that under static loading;

(2) The propagation velocity of the transverse deformation along the cord is larger than that of the ealstic wave.

And some photographs of the deforming cords are given.

I. Method of Experiment

The arrangement of the experimental equipments is shown in Fig. 1.

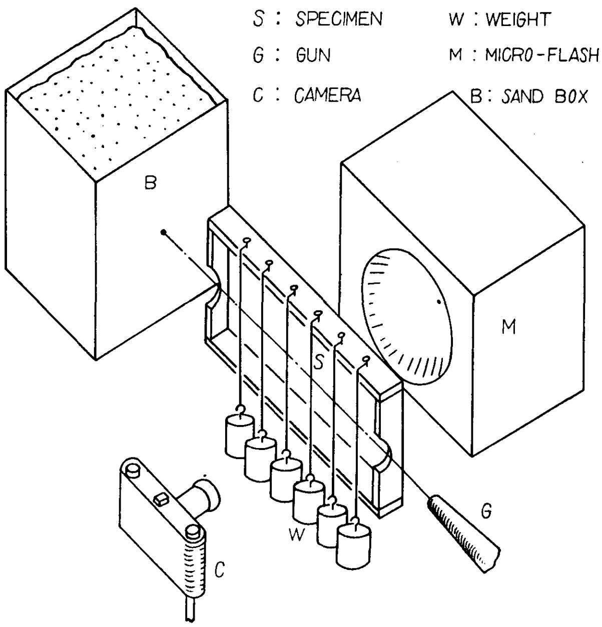

Fig. 1. Arrangement of Equipments

The process of the experiment is as follows:

(1) Specimens (dimension 1.3×1.3×250mm) are suspended equidistantly from

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the straight frame at 4cm interval, and weighted at their ends;

(2) These specimens are shot transversely by a cylindrical bullet (Dimension of the bullet $12.2\phi \times 25$mm and its velocity 130, 230, 300, 350 and 400m/sec, which are determined by the weight of the powder. The velocity of the bullet is measured previously by the ballistic pendulum.)

(3) The deforming specimens are photographed by the micro-flash lighting from transverse direction;

(4) Lastly, the bullet is stopped in the sand box.

And, from the photographs, the propagation velocity of transverse deformation along the cord and the elongation are determined. That is,

(1) Propagation Velocity of Transverse Deformation

In Fig. 2, the bullet, having struck the cord, flies the distance b, while the deformation wave propagates for the distance a, and therefore the propagation velocity of transverse deformation v is

$$v=\frac{V\times a}{b} \text{ m/sec}$$

where, V=velocity of bullet.

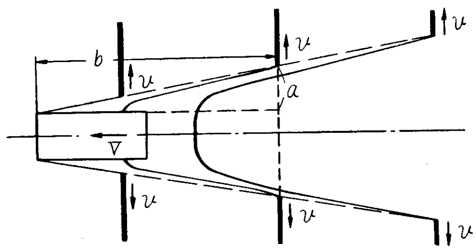


Fig. 2. Geometrical relation of deforming cords

(2) Elongation

As it is regarded that the specimen is drawn into extension by the bullet head, from the geometrical relation in Fig. 2, the elongation ε is

$$\varepsilon=\left(\frac{\sqrt{V^2+v^2}}{v}-1\right)\times 100\%.$$

II. Experimental Results

The photographs are shown in the next page, which are taken under various conditions. From these, we learn the following experimental facts:

(1) Elongation

Fig. 3 shows the relation between the impact velocity (=velocity of bullet) and the maximum elongation obtained at each velocity, and from this we see that the maximum elongation becomes larger with the increase of the impact velocity. On the other hand, when the cord is stretched under slow loading, (tested in a separate

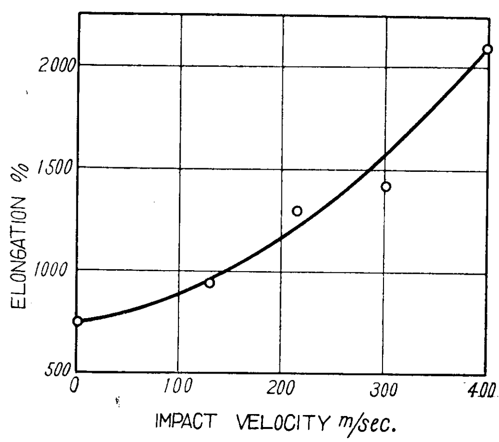
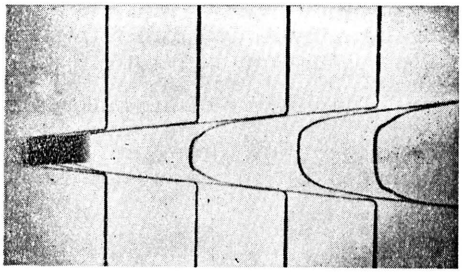
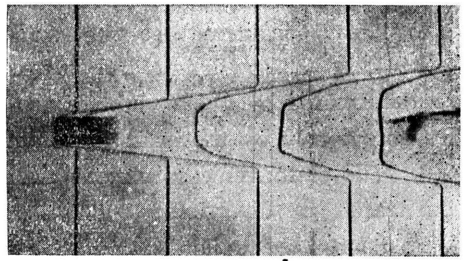


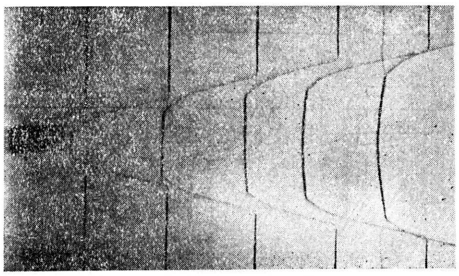
Fig. 3. Impact velocity and elongation



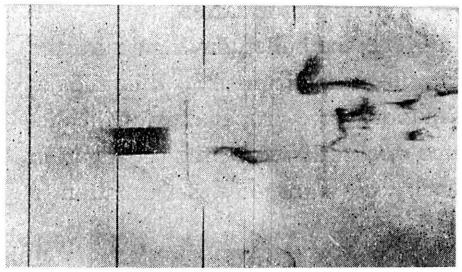
a) Impact Vel. =230m/sec
Initial Tension=21g



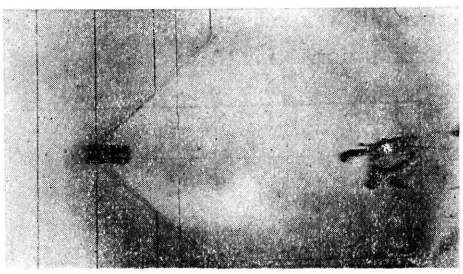
b) Impact Vel. =230m/sec
Initial Tension=63g



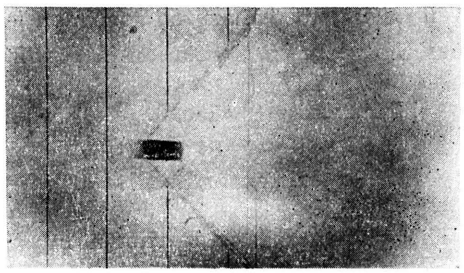
c) Impact Vel. =230m/sec
Initial Tension=105g



d) Impact Vel. =230m/sec
Initial Tension=252g



e) Impact Vel. =230m/sec
Initial Tension=350g



f) Impact Vel. =230m/sec
Initial Tension=700g

experiment by means of a weight) its breaking elongation is about 800%. This relation is a contradictory tendency to that of the common materials.

Fig. 4 shows the elongation at impact of different velocities under various tensions. In this figure, under the conditions of the zone above the dotted line, the cord is torn up at the impact point. So we should examine the elongation within the limits below the dotted line. From this, we see that the largest elongation is obtained under the lowest tension and becomes lower with the increase of the tension and thereafter increase slightly. And then, as is seen from the dotted line in the figure, the higher the impact velocity, the lower the tension will be where the cord is torn up at the impact point.

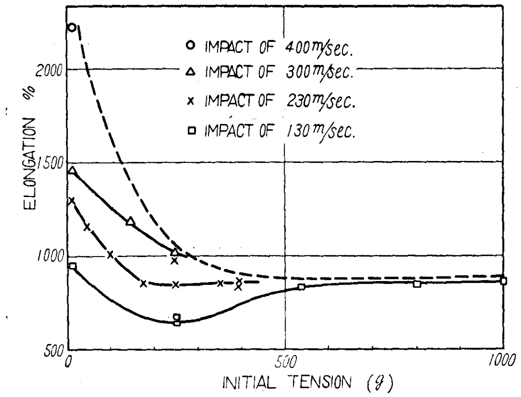


Fig. 4. **Initial Tension and Elongation**

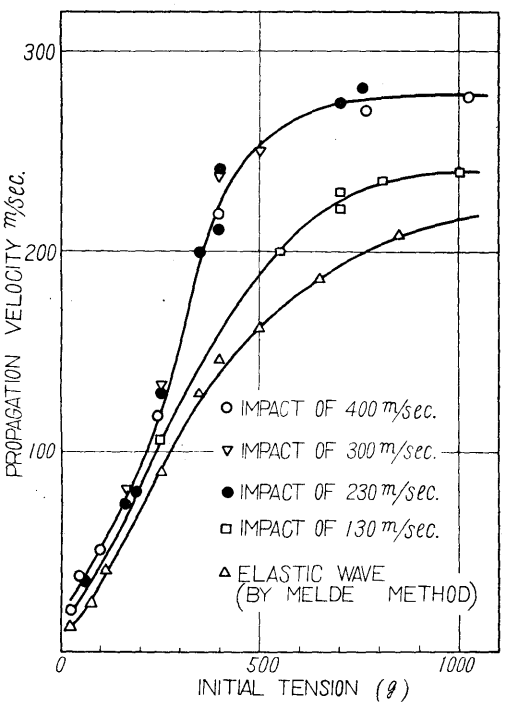


Fig. 6. **Initial Tension and Propagation Velocity**

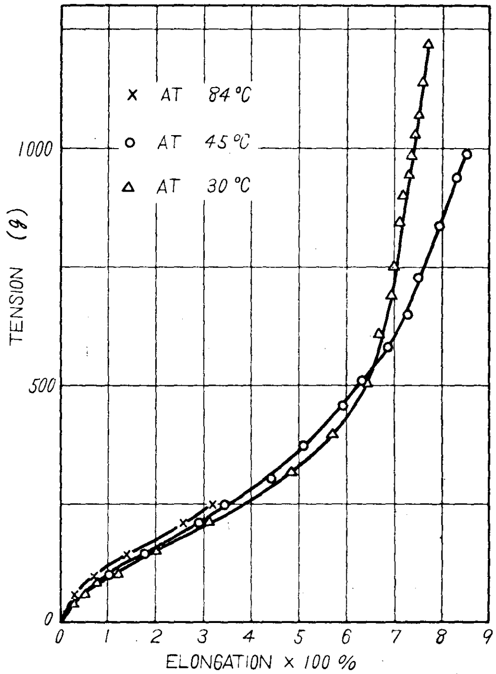


Fig. 5. **Tension-Elongation Curve under Various Temperatures**

(2) Shape and Propagation Velocity of Transverse Deformation along the Rubber Cord

As is shown in all the photographs, an abrupt transverse deformation wave along each cord is generated. It is considered that this wave may be called a kind of shockwave, for as seen in Fig. 5 the relation between elongation and tension at various temperatures[1] makes upward concave at larger strain, the value of $d\sigma/d\mathcal{E}$ becomes larger with the increase of σ (σ stress, $\mathcal{E}$ strain). Because of this

[1] As the temperrture rises in the rubber under adiabatic elongation, the tests under various temperatures are tried.

property of the elastic rubber, the maximum stress, which has the maximum velocity, may generate at the front of the transverse deformation. We see in Fig. 6 that the propagation velocity of this deformation becomes larger with the increase of the tension and under the tension over 700 g the curve flattens. In the same figure the propagation velocity curve of transverse elastic wave under various tensions in the same cord is shown, which is measured by Melde's method. We may recognize by this difference that the propagation of deformation by the high-speed impact is not the simple transverse wave.

Conclusions

So far as we have seen in this experiment, the following matters may be concluded:

(1) Under high-speed impact, the elongation of a rubber cord gets up to 2200%, while the static breaking elongation of the same rubber is about 800%;

(2) The elongation under high-speed impact becomes smaller with the increase of initial tension, and under the tension over a certain value it rises slowly;

(3) When the impact velocity from the transverse direction becomes larger, the rubber cord is torn up at the impact under lower initial tension;

(4) By the impact from the transverse direction the abrupt lateral deformation is developed and propagates along the rubber cord, which may be considered as a kind of shock wave;

(5) The propagation velocity of the lateral defomation along the cord is higher than that of the elastic transverse vibration measured by Melde's method under the same tension.

Although explanations for the particular behaviors of rubber under high-speed impact may be considered, I prefer to withhold them for the present. So the experimental facts only are reported.

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