ON LONGITUDINAL IMPACT I
FUNDAMENTAL CASES OF ONE-DIMENSIONAL ELASTIC IMPACT. THEORIES AND EXPERIMENTS
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Summary
Central longitudinal impact of slender bodies has a number of important technical applications. Theoretical treatment of these cases has, however, often been unduly scarce or crude, probably because available methods suitable for engineering applications have not been sufficiently well known. This is the first one of a series of papers intended to fill this gap by presenting theoretical solutions for a number of cases of various types, including hammers and bars of various fundamental forms, impact with elastic and plastic deformation and restraint by solid friction, and by suggesting some applications. This paper reviews known analytical, graphical and numerical methods for one-dimensional treatment of longitudinal impact and introduces a slightly modified version of the "graphodynamical" method which will be used in the following. Stress pulse measurements made with wire strain gauges on a bar impacted by cylindrical hammers of various diameters and materials are presented and found to agree reasonably well with corresponding theoretical pulse forms. Formulae and diagrams are given for the influence of the ratio of areas and material constants of hammer and bar on force, stress, energy transmission and other important quantities of the type of impact mentioned.

Principal notations

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Different symbol used in $^{17,18}$</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
<td>$F$</td>
<td>Cross-sectional area</td>
</tr>
<tr>
<td>$a, b, c...$</td>
<td>1, 2, 3...</td>
<td>Different states (points in diagram of state)</td>
</tr>
<tr>
<td>$E$</td>
<td></td>
<td>Young's modulus</td>
</tr>
<tr>
<td>$h$</td>
<td></td>
<td>Height of drop of hammer</td>
</tr>
<tr>
<td>$L$</td>
<td></td>
<td>Length</td>
</tr>
<tr>
<td>$m$</td>
<td></td>
<td>Mass = $\rho V$</td>
</tr>
<tr>
<td>$P, F$</td>
<td></td>
<td>Force</td>
</tr>
</tbody>
</table>

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Reflection constant \( \frac{(1 - r)}{(1 + r)} \)

Ratio of dynamic stiffnesses \( \frac{A_2E_2u_1}{A_1E_1u_2} \)

Displacement

Time

Duration of elementary pulse

Velocity of disturbance propagation (of sound)

Particle velocity

Volume

Energy (in (7) and figs 2 and 3: velocity)

Potential energy

Kinetic energy

Coordinate along bar

Directrix angles in diagram of state

Strain

Stress

Density

Length of elementary pulse

Numerical values for some materials are found in \( \text{18} \), e.g. for steel \( E = 21100 \text{ kp/mm}^2 \), \( u = 5150 \text{ m/s} \). For approximate calculations we use \( E \approx 20000 \text{ kp/mm}^2 \), \( u \approx 5000 \text{ m/s} \).

As units of force are used 1 kp (kilopond) and 1Mp (megapond) = 1000 kp where 1 kp = 9.80665 N (newton) is the force that gives a mass of 1 kg an acceleration of 9.80665 m/s².

Index 1 denotes hammer (before impact)

2 bar, pulse travelling along bar

4 reflection at fixed end of bar

5 reflection at free end of bar

6 hammer impacting stiff anvil (\( r = \infty \))

§ 1. Introduction. Engineering applications of longitudinal impact of slender bodies, such as pile driving, riveting, percussion rock drilling etc., are mainly due to the transformation of mechanical energy produced by the impact. As an example we show in fig. 1 how a steel hammer of 25 mm diameter and 1 kg weight accelerated by a force of 1 kp during 1 second (which can be achieved by dropping it from 5 m height) when hitting a long bar of the same material and diameter produces in it a travelling stress pulse containing a dynamic force of 10 000 kp but of very short duration (0.0001 s) and producing a particle displacement of only 0.5 mm. As is indicated in fig. 1 the same pulse can also be produced by accelerating the hammer with a greater force for a shorter time and distance; the latter values roughly correspond to the blow from a hammer accelerated manually and by a pneumatic tool respectively.