

Energy absorption of a cylindrical tube with varying cross-section subjected to axial impact

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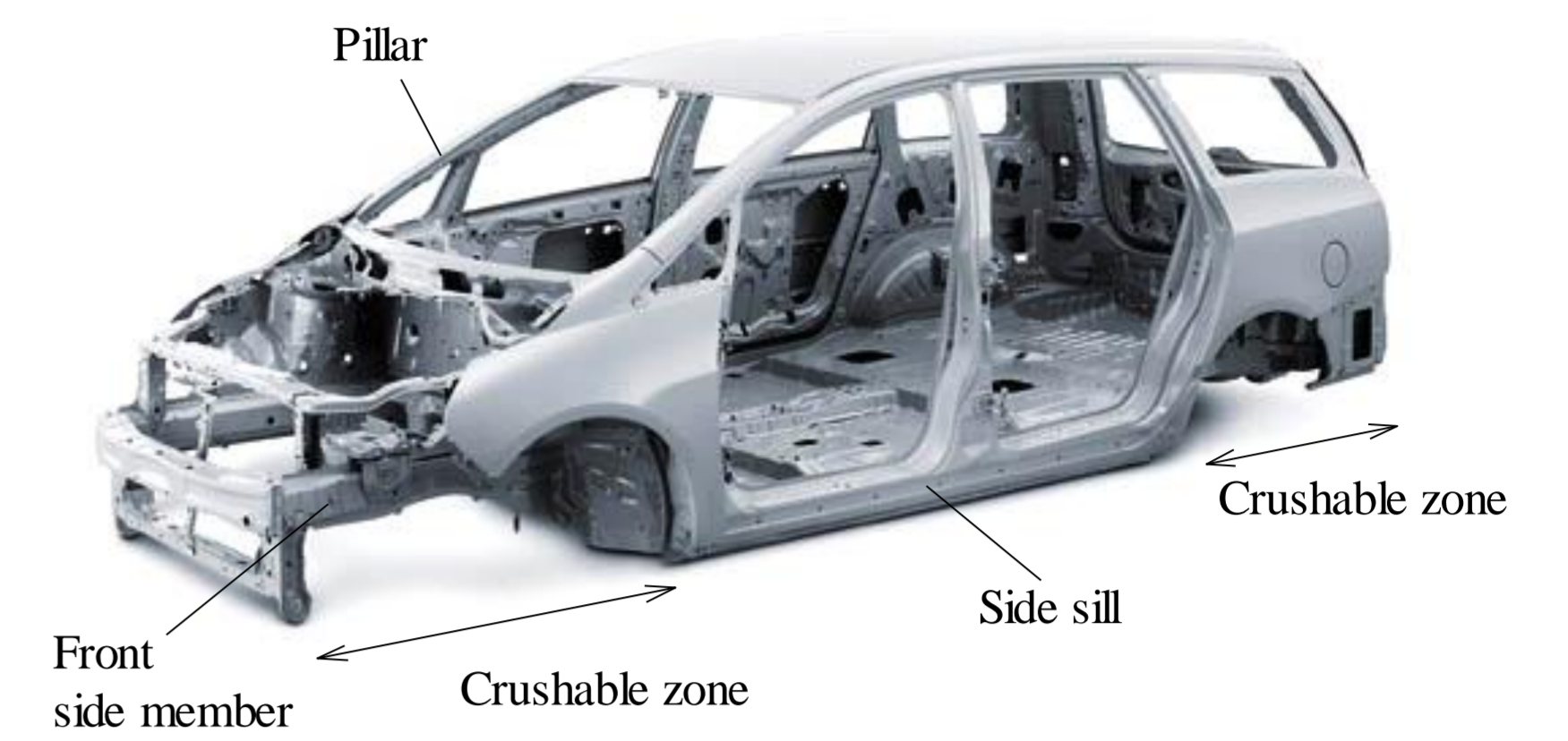
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Background & Objective

Safety is a vital issue in design of modern vehicles. When a vehicle collides, crushable zone of the vehicle collapses to highly absorb impact energy for safety of the passengers. To improve & control absorbed energy by the collapse, several structural elements with various shapes as well as uniform cross-sections have been investigated.

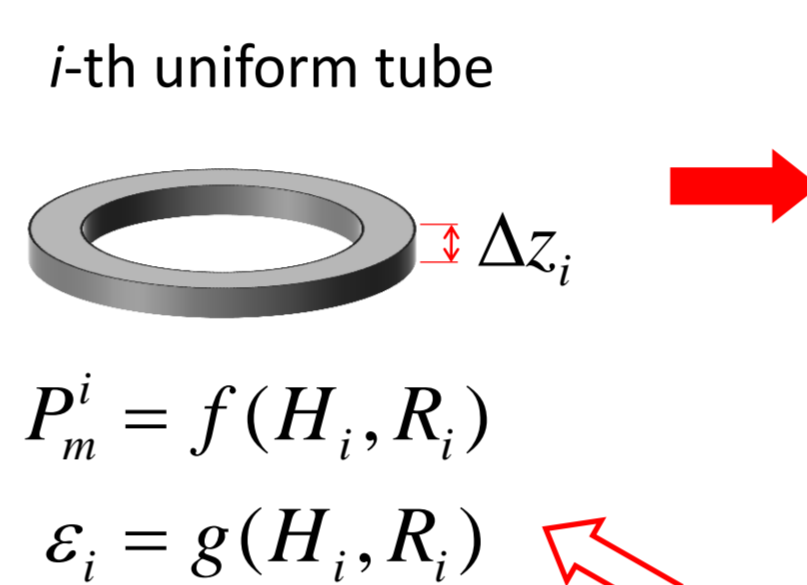
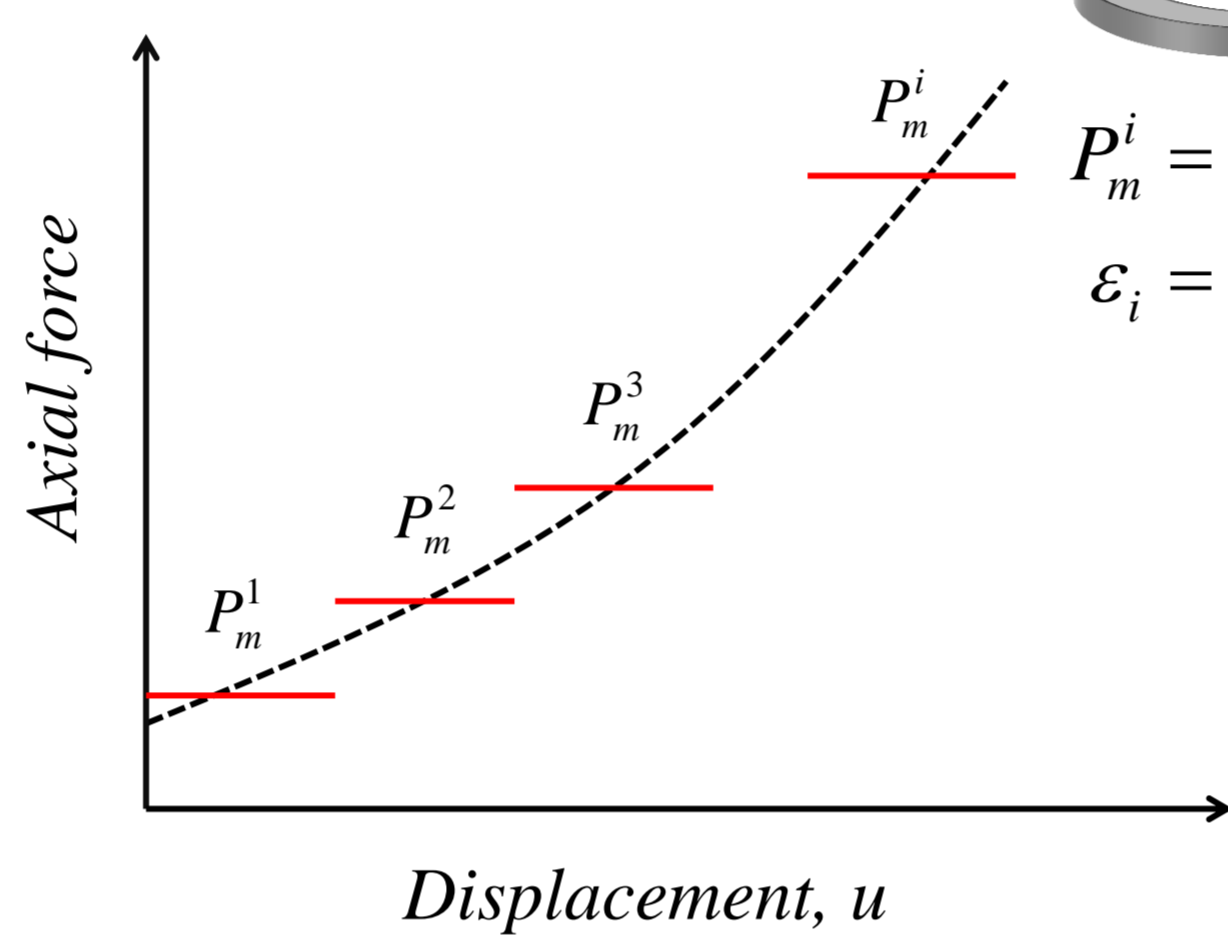
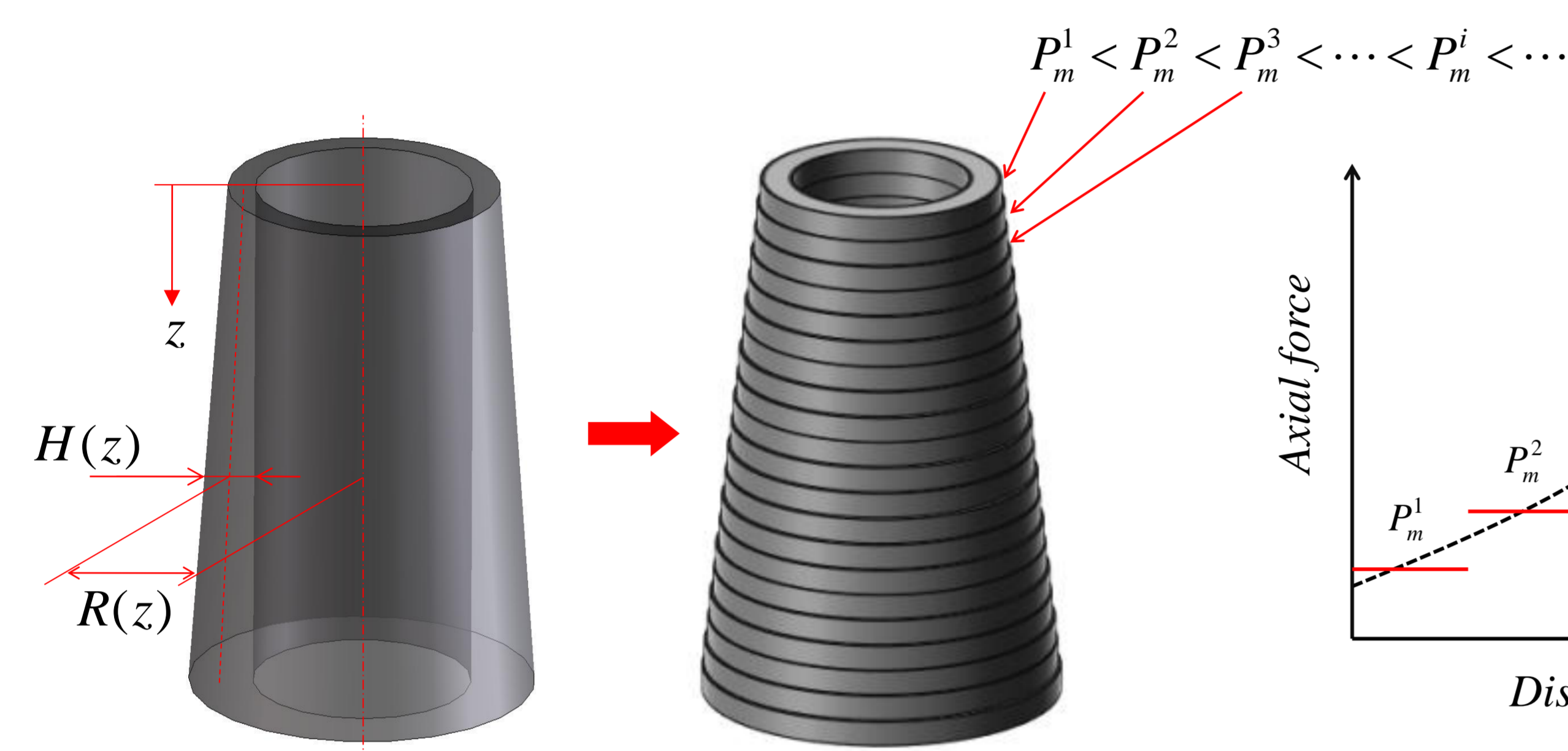
The objective of the study is development of **approximation method for evaluating the absorbed impact energy of a cylindrical tube with varying cross-section** subjected to an axial impact.



Approximation method

Cylindrical tube with varying cross-section is set down as a tube connected with infinitesimal uniform cylindrical tubes.

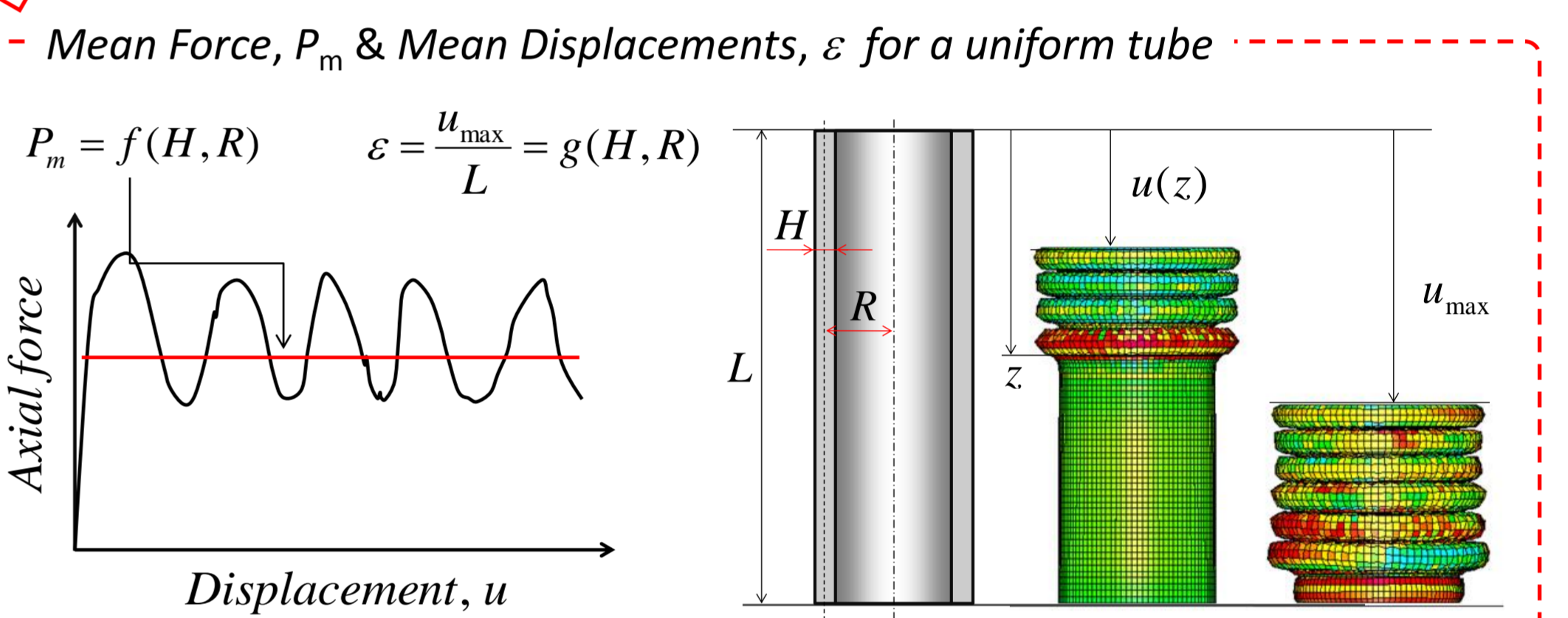
Crushing of the cylindrical tube with varying cross-section progresses due to minimum force of the infinitesimal uniform tubes.



Absorbed Energy, E_{ab} & Displacement, u for a cylindrical tube with varying cross-section are expressed by combination of results for the uniform tubes.

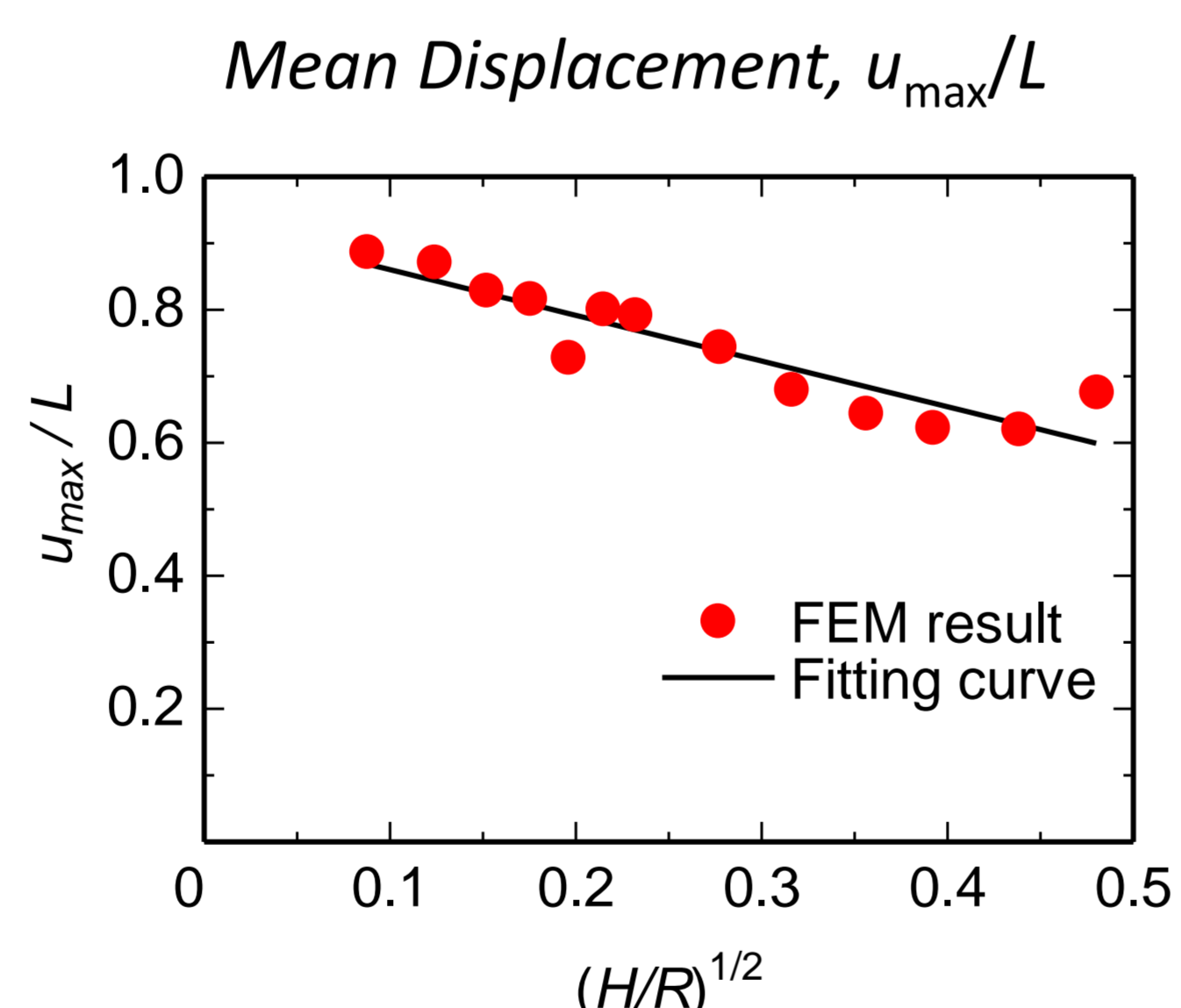
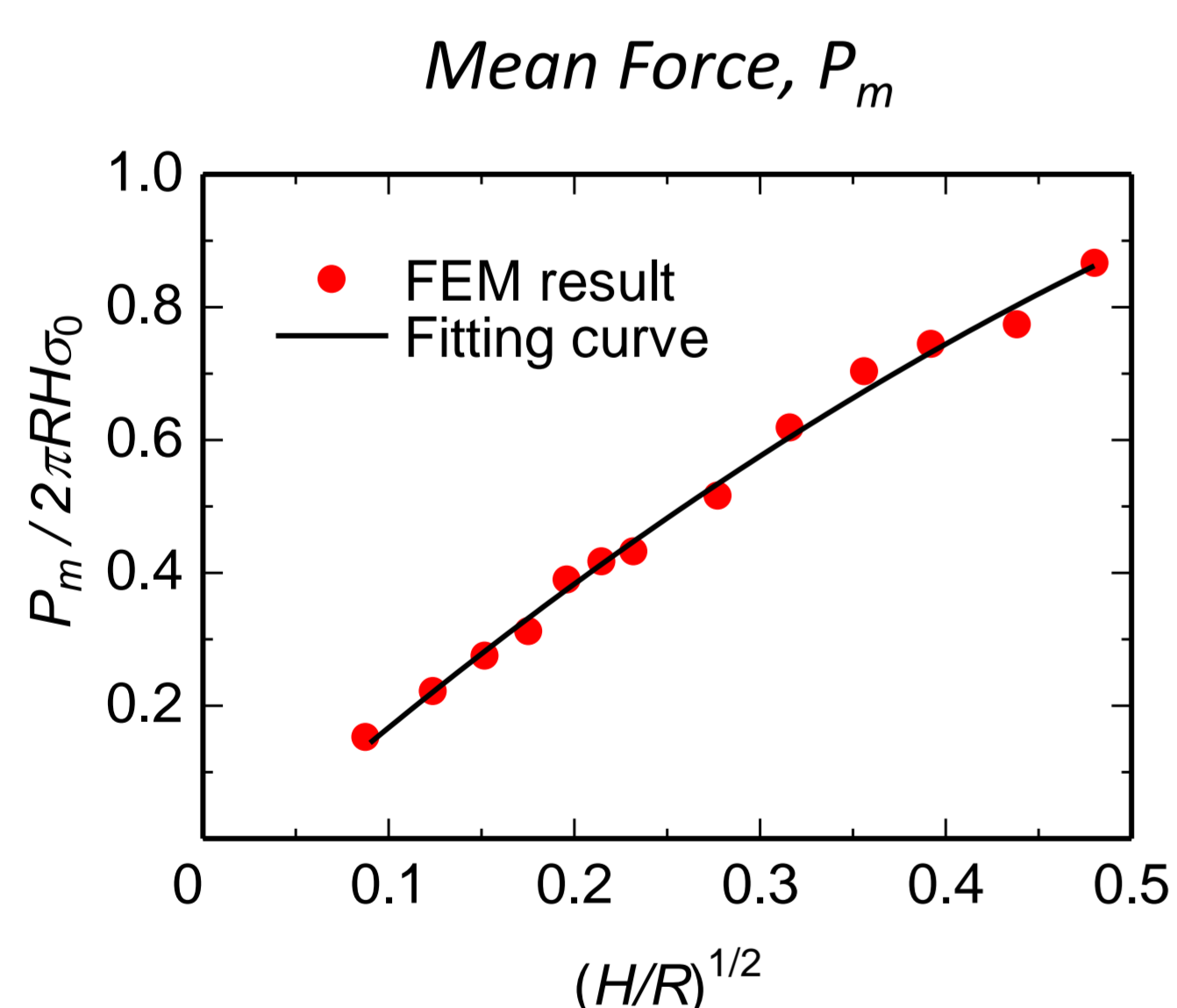
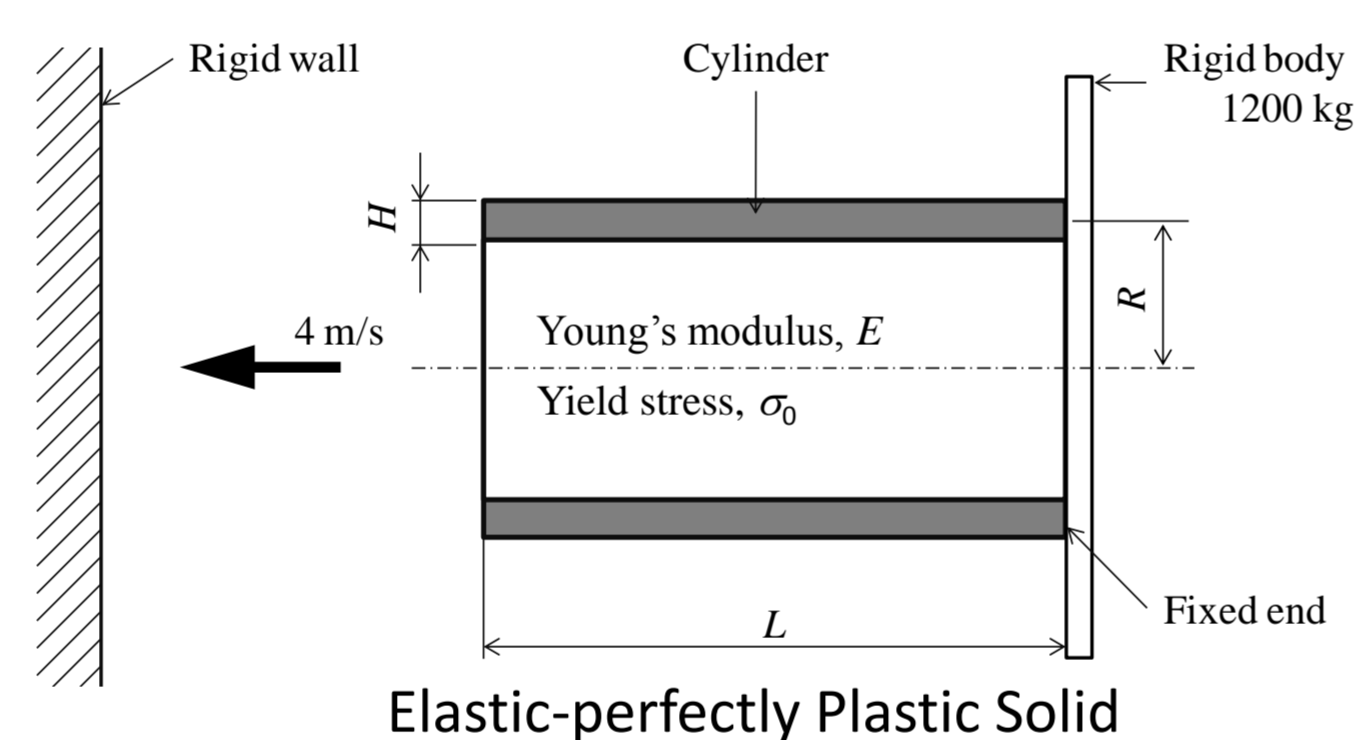
$$E_{ab} = \lim_{n \rightarrow \infty} \sum_i P_m^i \varepsilon_i \Delta z_i \rightarrow \int_0^u P_m du$$

$$u = \lim_{n \rightarrow \infty} \sum_i \varepsilon_i \Delta z_i \rightarrow \int_0^z \varepsilon dz$$



Demonstration of proposed technique

In this study, mean forces, P_m & mean displacements, u_{max}/L for uniform tubes were formulated by FEM (Radioss ver. 4.4q)



$$\frac{P_m}{2\pi RH\sigma_0} = -1.19 \left(\frac{H}{R}\right) + 2.52 \left(\frac{H}{R}\right)^{1/2} - 0.0731$$

$$\varepsilon = \frac{u_{max}}{L} = -0.687 \left(\frac{H}{R}\right)^{1/2} + 0.929$$

Formulation of Absorbed energy & Displacement for cylindrical tubes with varying cross-section

Mean Force & Mean displacement for uniform infinitesimal tube at position z

$$P_m(z) = 2\pi R(z)H(z)\sigma_0 \left[-1.19 \frac{H(z)}{R(z)} + 2.52 \left(\frac{H(z)}{R(z)}\right)^{1/2} - 0.073 \right]$$

$$\varepsilon(z) = -0.687 \left(\frac{H(z)}{R(z)}\right)^{1/2} + 0.929$$

Integrating with displacement u

Integrating with z

$$E_{ab} = \int_0^u P_m du$$

Absorbed Energy

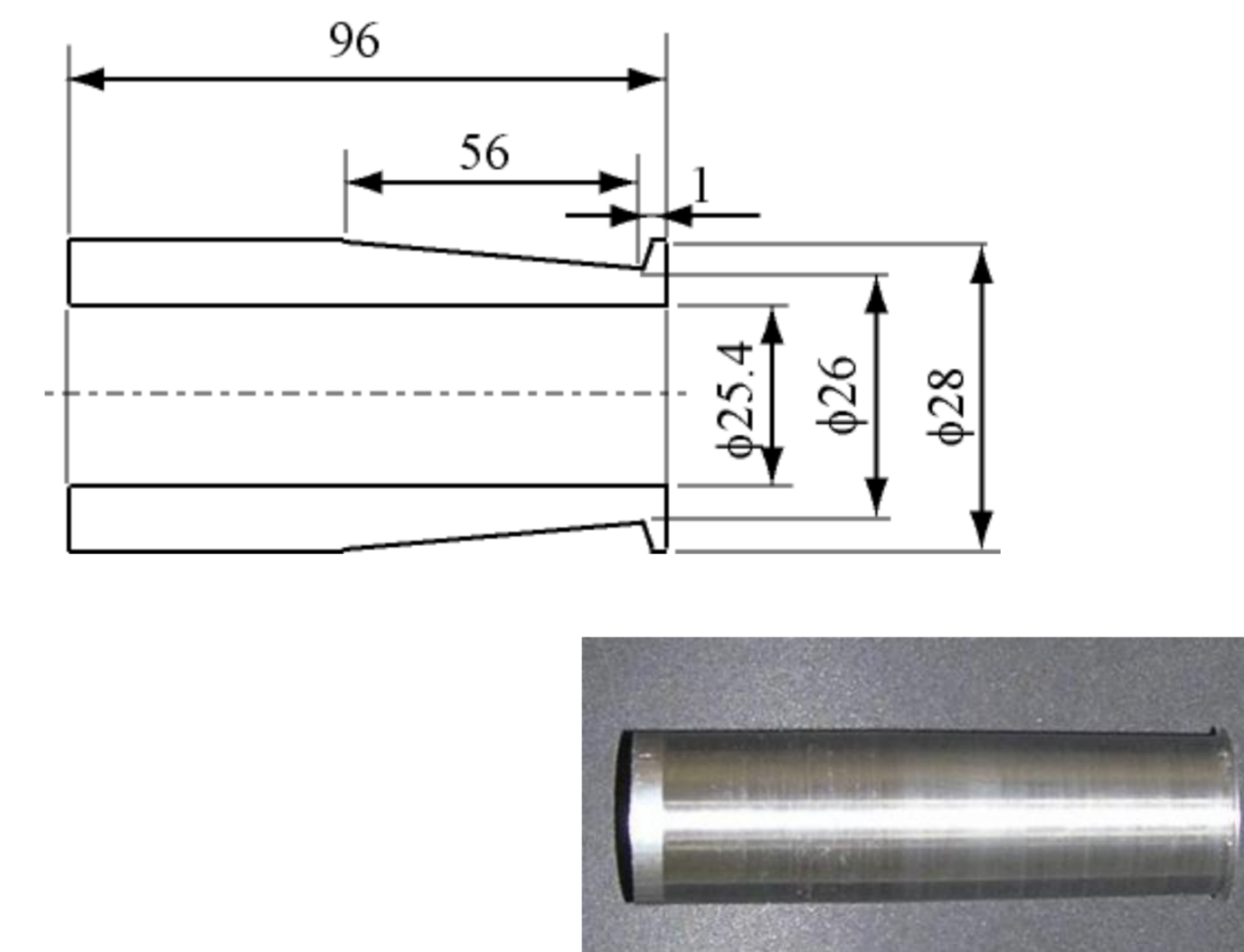
$$u = \int_0^z \varepsilon dz$$

Displacement

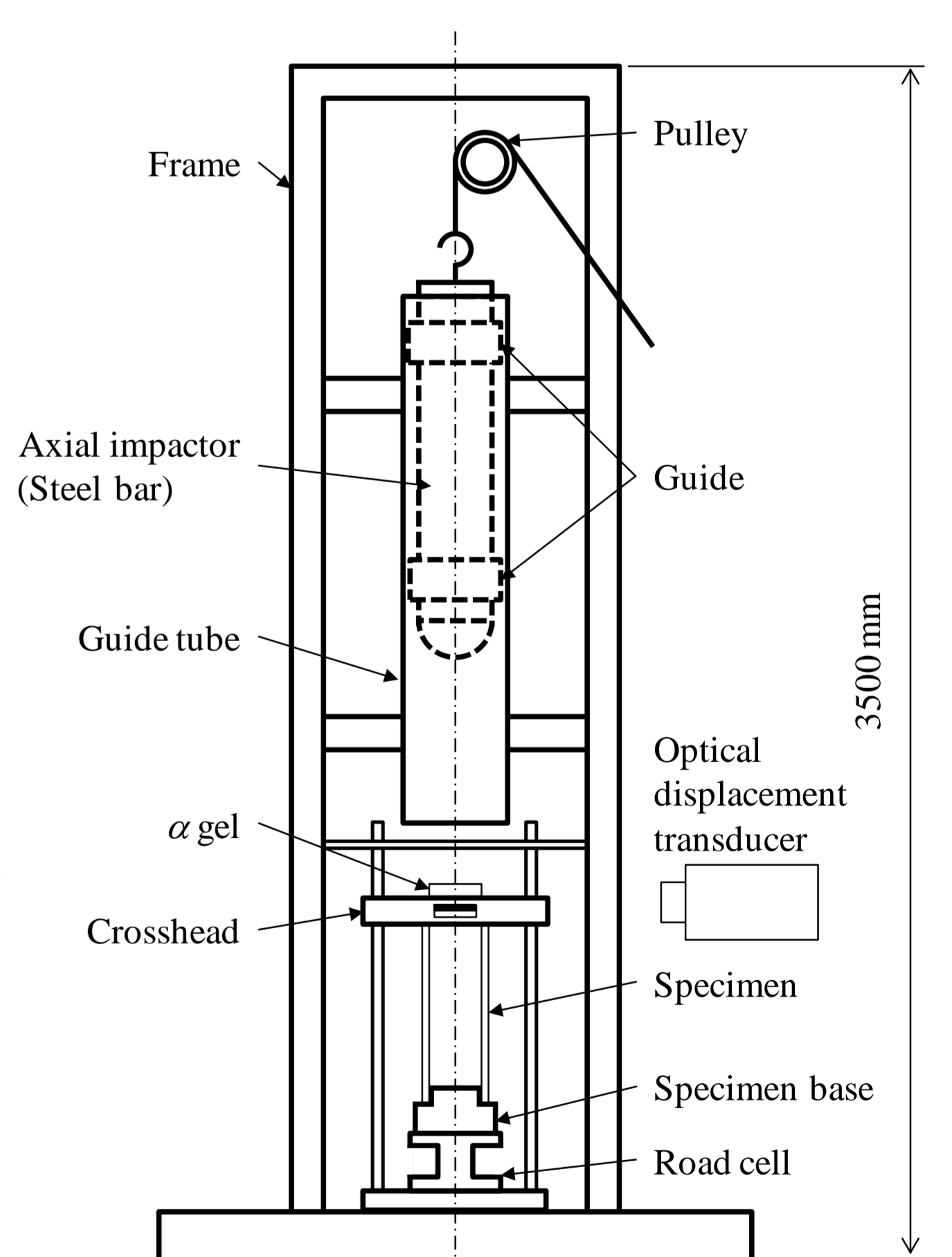
Drop weight impact test for tapered tube

To confirm the validity of the proposed method, the results of **drop weight impact tests for tapered tubes** were compared to those of approximation formula.

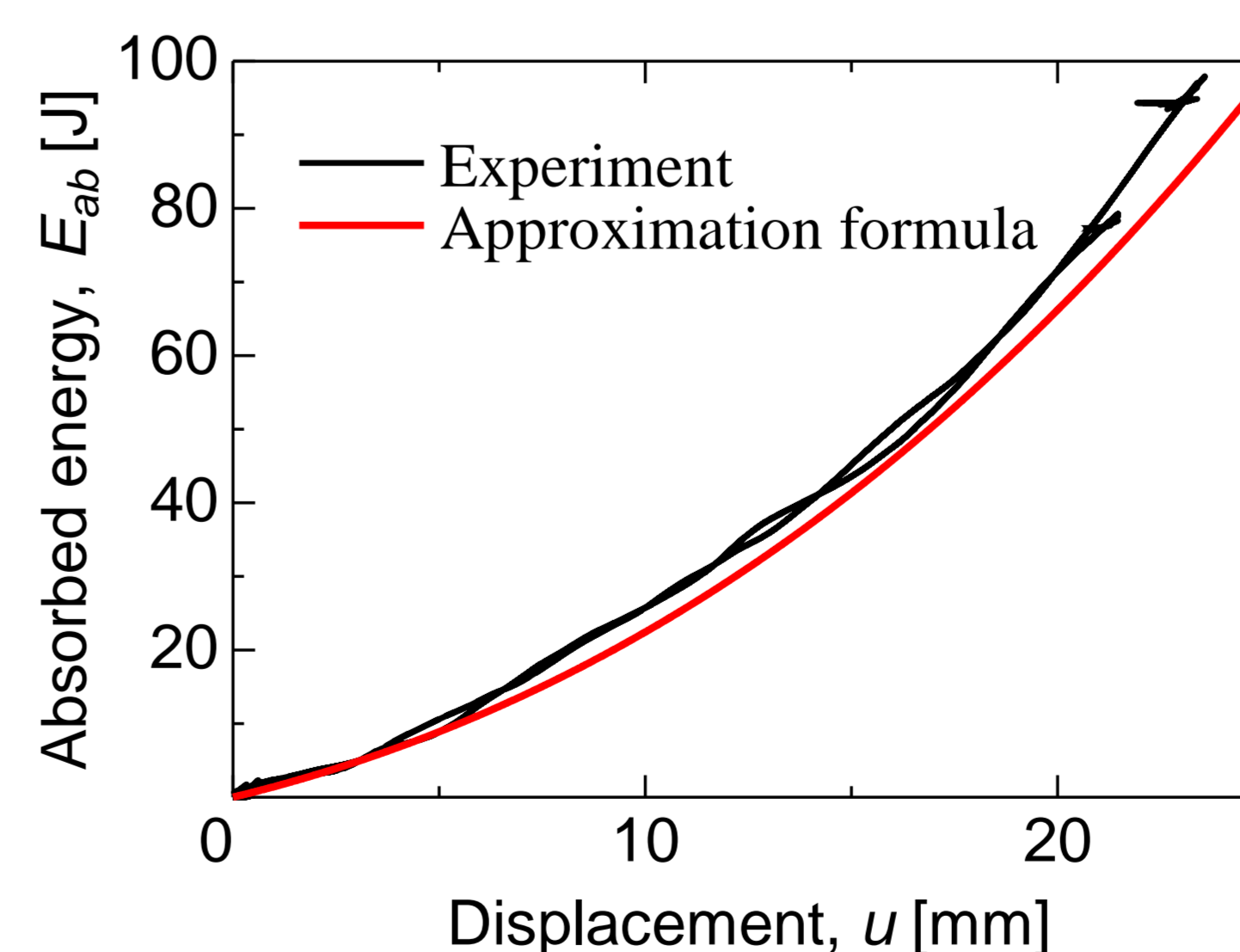
Specimen (Aluminum alloy, A6063)



Drop weight impact test machine



Absorbed energy-displacement curves



- Mass of the impactor is 10 kg
- Drop height of the impactor is 1.5 m

Conclusions

We developed an **approximation method for evaluating the absorbed impact energy of a cylindrical tube with varying cross-section** by using absorbed energy characteristics of uniform cylindrical tubes subjected to axial impacts.

Approximate absorbed energy-displacement curve for tapered tube showed good agreement with the experimental results.