

Programmable Stopping Device Design for Sled Test

Himmatrao Nalawade & L.B.Raut

Dept. of Mechanical Engineering, SVERI's College of Engineering, Pandharpur, Solapur, Maharashtra, India
E-mail: heemmatnalawade@gmail.com, lraut@rediffmail.com

Abstract – Full vehicle crash testing is used to reproduce the dynamic conditions of real world car accidents. The complex and destructive nature of these crash tests make them very expensive. For these situations, sled testing becomes preferred evaluation for occupant injury. Sled test is simulated crash test facility used to test components like seats, seat belts, child restraint systems, seat anchorages on body shell etc. the crash condition is simulated and the components are subjected to these conditions. The crash condition includes the velocity of crash and the deceleration level at the time of crash. There are number of international standards such as ECE regulations (Europe), FMVSS (USA) and ARAI testing standards (India) etc, which specify the conditions and limits for various parameter for above mentioned tests.

I. INTRODUCTION

Vehicle safety considerations have become increasingly important in recent years. As a result of this considerable research has been undertaken on automobile crashworthiness in past few years. Automobile crashworthiness can be define as the capability of motor vehicle structure to prevent adequate protections to its occupants from injury and its cargo from damage, and crashworthiness calls for various kinds of tests such as full vehicle crash test, body shell crush test, sled test for components like seats, seat belt, child restraint system, static strength test, energy dissipation tests of various interior fittings etc. test platform is in the form of trolley, which travels over steel rail fitted in concrete bed. The component to be tested is mounted on the trolley with suitable fixture simulating actual condition. The trolley is given a velocity through gravity feed arrangement making use of PE of falling weight and decelerated as per predefined deceleration pulse demanded by the test. The required deceleration of trolley is achieved with the help of energy absorption device called stopping device which is positioned between trolley and rigid concrete barrier available at distal end of the rails.

II. REQUIRMENT

To obtain various standard deceleration pulse demanded by standards and any non standard pulse required for development testing a programmable stopping device is felt necessary.

2.1 Types of Stopping Devices

Oversized olive head piercing internally tapered polyurethane tube

Hydraulic shock absorbers

Nitrogen cylinder

Axial compression of thin walled metal tubes

Out of all above mentioned devices Axial compression of thin walled metal tubes is used as it has low cost and it is more feasible.

2.2 Various Deceleration Pulse Required For Different Test

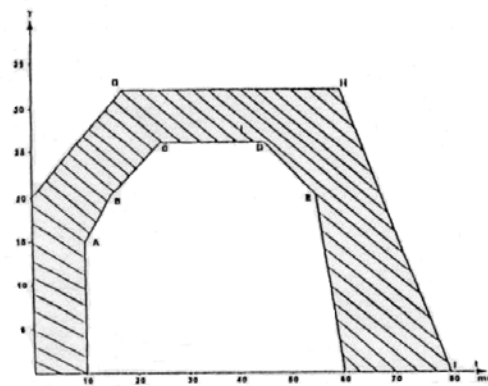


Fig. 1: Deceleration Pulse Specified in AIS 005 for testing of seat anchor.

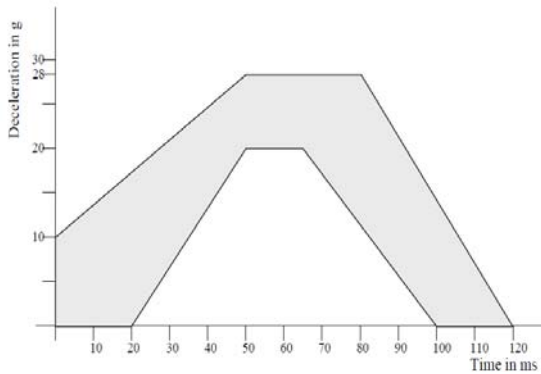


Fig. 2 : Deceleration Pulse Specified in AIS 016 for testing of seats, their anchorages and head restraints for category M1. For Frontal Impact

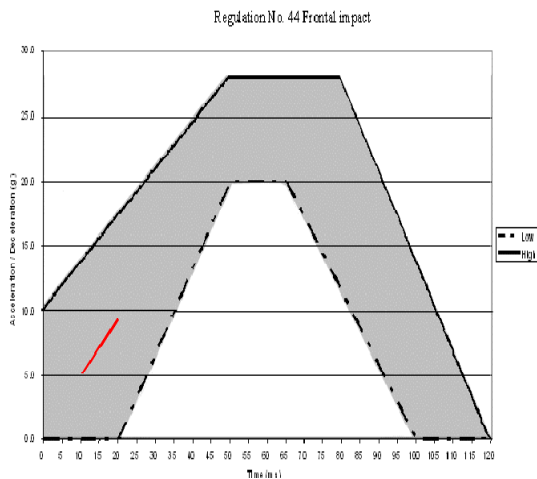


Fig. 3 : Deceleration pulse specified for frontal impact.

2.3 Energy absorption mechanisms for metal crush tubes

An energy absorber mechanism is a system that converts, totally or partially, kinetic energy into another form of energy. Energy converted is either reversible, like pressure energy in compressible fluids and elastic strain energy in solids, or irreversible, like plastic deformation energy [8].

Thin walled circular tubes compressed axially provide a number of particularly efficient energy absorbing mechanisms. Because of their high frequency of occurrence as structural elements, tubes are considered to be the most common shape and probably the oldest shape utilized in energy absorption. Plastic energy can be dissipated in thin metallic tubes in several modes of deformation, including:

1. Inversion;
2. Splitting;
3. Lateral indentation
4. Lateral flattening and
5. Axial crushing

From above energy absorption mechanisms, inversion of tube found to be the most suitable modes of failure [5].

2.4 Inversion

One of the interesting energy absorber columns is the tube inversion or invertube that basically involves the turning inside out or outside in of a thin circular tube made of ductile material, as shown in fig. 4. Inversion of thin-walled tubes using a die is characterized by the axial compression of a tube over an appropriate die of circular profile [1].

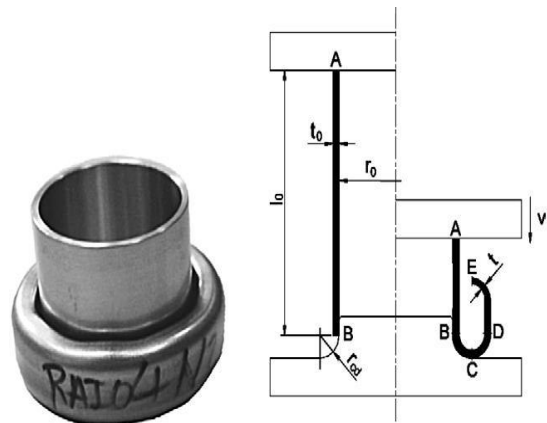


Fig. 4 : Schematic representation of the external inversion of tubes using a die. (AB) Undeformed region, (BD) plastically deforming region, and (DE) deformed region.

The process can be utilized for end forming and clamping operations of straight and bended tubular parts for automotive and aerospace industries as well as for designing mechanical devices for dissipating kinetic energy in a controlled manner (e.g. impact-energy absorbers in the column of a steering wheel).

The external inversion of a tube using a die is characterized by the axial compression of a tube over an appropriate radiused die (Fig.4). The plastic deformation of the tube is the result of three different mechanisms: bending, stretching and friction. Bending takes place at point B, where the tube contacts the die, and at point D (unbending) placed at the free region facing point B. Stretching along the circumferential direction, θ , progresses while the tube turns around the corner of the

die (BD). The influence of interface friction occurs between points B and C.

During external inversion of tubes using a die material submitted to both strain hardening and ductile damage. These two competing mechanisms control the feasibility of the forming process as well as the final mechanical properties of the tubular parts. For small values of the die radius formability is usually limited by the occurrence of plastic instability (local buckling) while for larger values restrictions are normally set by ductile damage (fracture) in the regions that are highly strained due to extensive material flow. This means that external inversion is only achievable within a compact range of process parameter [1-3]

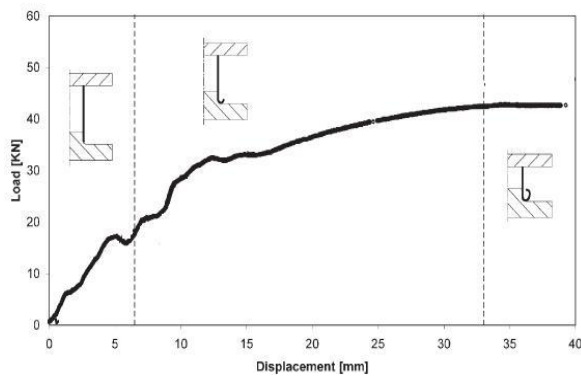


Fig. 5 : Typical Load Vs displacement Curve – Stages of Inversion

The steady state forced inversion can be obtained by following equation which is derived from the expression for free inversion load is given by T. Y. Reddy and A. Colocoglu [6].

$$P_{sei} = 2Py \left[\left(1 + \frac{3b}{2r_o} + \beta \frac{t_o}{16b} \right) \frac{1}{z_o} \frac{t}{4b} + \frac{1}{\sqrt{3}} \ln z_o \left(1 + \frac{\beta}{2} \ln z_o \right) \right] \quad (1)$$

III. THE METHODOLOGY

Inversion mode of collapse can be use for energy absorption in stopping device. The inversion mode of collapse for its efficient and constant load deflection characteristics except for the initial transient phase forms an ideal energy absorption element for stopping device. The slope in the transient phase can be used to advantages in obtaining the slopes required in the deceleration pulse.

3.1 The General Method to Obtain Deceleration Pulse

The required deceleration pulse is decided by using the array of tubes which when incorporated in stopping device will decelerate the trolley as per the pulse.

Following procedure is to be used for deciding the array of tube.

Velocity and deceleration pulse is known to us. We can obtain the velocity pulse and displacement pulse by numerically integrating the deceleration and velocity pulse respectively. Load Vs time pulse can be obtained by multiplying the deceleration Vs time pulse by mass. By cross plotting load Vs time and displacement Vs time we can get the load Vs displacement characteristic that the stopping device should exhibit.

An array of inverting tubes is decided on the basis of Load Vs Displacement characteristic. Following rules can be used while deciding the array of tubes.

1. Height of the pulse can be adjusted by deciding the number of tubes in parallel.
2. The slope of the pulse can be adjusted by deciding the number of tubes in series.
3. The length of the curve can be decided by the total length of the inverting tubes used

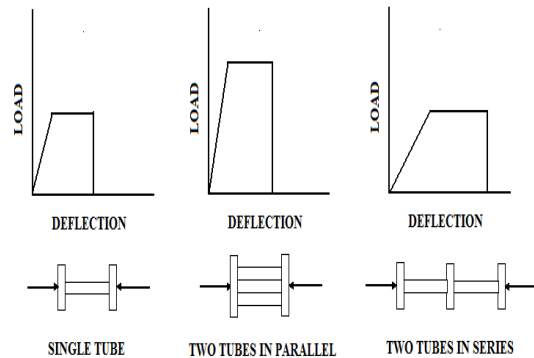


Fig.6 : Rules for Deciding Tube Array

3.2 Stopping Device

Stopping device consists of the two main components

1. The energy absorbing members
2. The fixture to hold the energy absorbing member.

The energy absorbing members are the crush tubes and the holding fixture is shown in fig 3.2. The fixture comprises of three rigid box type members. These members have five equispaced holes of Ø22 mm on either sides, which are used to mount the dies and the tube and the tube holding adaptors

The well assembled stopping device is mounted on rails of the sled test rig. One rigid body is fixed to the barrier and the other two are able to slide on the rails. The two sliding members are guided on the rails by

guide plates welded to the guiding members. The trolley makes impact on the free rigid block. The sliding blocks slide on the rails and the tubes mounted between the blocks are pressed over the dies. The inversion of tubes takes place which absorbs the K.E. of the trolley.

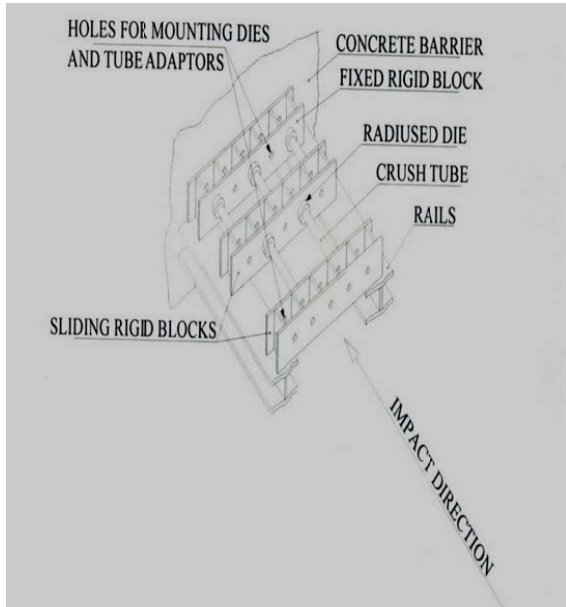


Fig 6 : Schematic Metal Crush Tube Stopping Device

IV. CONCLUSION

This paper presents sled test programmable stopping device design by use of metal crush tubes which is of low cost and it is more feasible over other stopping devices. But we cannot say whether tubes will invert, tear or buckle during dynamic testing because dynamic conditions are different than static. So to develop data bank of inverting tubes it is require to conduct large number of experiments on tubes of various dimensions, material and with variable die fillet radius.

REFERENCES

- [1] Pedro A. Rosa, Rui M.O. Baptista, Jorge M.C. Rodrigues, Paulo A.F. Martins, "An investigation on the external inversion of thin-walled tubes using a die", *International Journal of Plasticity* 20 (2004) 1931–1946.
- [2] P.A.R. Rosa, J.M.C. Rodriguez, P.A.F. Martins, "External inversion of thin-walled tubes using a die: experimental and theoretical investigation", *International Journal of Machine Tools & Manufacture* 43 (2003) 787.
- [3] G.S. Sekhon, N.K. Gupta, P.K. Gupta, "An analysis of external inversion of round tubes", *Journal of Materials Processing Technology* 133 (2003) 243.
- [4] T.Y. Reddy, "Guist and marble revisited—on the natural knuckle radius in tube inversion", *International Journal of Mechanical Sciences* 34 (1992) 761.
- [5] S.R. Reid, "Plastic deformation mechanisms in axially compressed metal tubes used as impact energy absorbers", *International Journal of Mechanical Sciences* 35 (1993) 1035.
- [6] T.Y. Reddy and A. Colakaglu, "Free External Tube Inversion – An Experimental Study", *Tr. J. of Eng. And Envi Sci.* 20, 1996, 143-149.
- [7] Development and validation of sled FE model for frontal crash Mahindra & Mahindra Ltd, Auto Sector, IDAM centre.
- [8] A.A.A. Alghamdi, "Collapsible impact energy absorbers: an overview", *Thin-Walled Structures* 39 (2001) 189–213.
- [9] ECE Regulations [R-16, R-17, R-44].
- [10] Automotive Industry Standard [AIS 005 & AIS 016], Printed by: the Automotive Research Association Of India, Pune.

