LARGE DEFORMATION STUDIES WITH THIN WALLED STRUCTURES

by

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1. ... Expression
2. ... walled structure.

Certificate

This is to certify that the thesis titled **"Large Deformation Studies with Thin Walled Structures"** being submitted by **Lt Cdr Nagesh** to the Indian Institute of Technology, Delhi for the award of Degree of Doctor of Philosophy is a record of bonafide research work carried out by him. Lt Cdr Nagesh has worked under our supervision and guidance and has fulfilled the requisites for the submission of this thesis which has reached the requisite standard for the Doctor of Philosophy Degree.

The results contained in this thesis have not been submitted in part or full, to any other University or Institute for the award of any Degree or Diploma.

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ABSTRACT

Crashworthy design requires that in the case of a collision, the structural system and structural components are able to absorb designed amount of kinetic energy so that eventually costly equipment and human beings remain safe. The energy absorbing characteristics or the collapse behaviour of involved structural elements or energy absorbing devices therefore should be clearly understood for their proper design.

Tubes Under Quasi Static Axial Compressive Loading

Quasi-static experiments have been conducted on an Zwick / Roelle Universal testing machine of 25 T capacity and the corresponding load versus cross head movement graphs and energy absorption characteristics are obtained using the interface software on the computer. Experiments have been conducted on the cylindrical shells of D/t values ranging between 22 and 35. Finite element simulations have been performed to study their collapse mechanism as well as the load compression and the energy absorption response. Experimental data from various modes of collapse of the specimen were used to validate the numerical models. The deformation process is modeled and simulated in the FE code ANSYS using a quasistatic analysis incorporating both material and geometric nonlinearities. The FE model uses quadratic solid finite elements that permit large displacements, rotations, curvatures and distortions to be simulated accurately, economically and free from numerical instabilities. The model includes surface to surface contact and target elements for modeling support, self and rigid body contacts. Efficient and flexible solution strategies have been employed that permit economic stable and accurate incremental loading using Newton Raphson scheme within an implicit (Newmark - β) scheme of inumerical integration. The nonlinear material model adopted is bilinear isotropic using a Mises yiled criteria and associated flow rule.

Diameter to thickness ratio of the tubes were varied in different simulations to study the load deformation, collapse mechanism and energy absorption response. Convergence studies with respect to FE model parameters like load step size, mesh density and boundary conditions have also been carried out. For the axisymmetric concertina mode of collapse a thin sector model involving only one element with coupling conditions in circumferential direction has been proposed which can be effectively used to represent the large deformation response of the entire structure with drastic savings in CPU resources. Validation and comparison of numerical solution with experimental results for "as received" and "annealed" tube specimens have been carried out. Dependence of deformation characteristics and energy absorption response on geometrical parameter, D/t ratio and material parameters, yield strength and tangent modulus have also been studied. Comparison and validation of the full 360 degree tube numerical model results have been undertaken with experimental results of axial compression tests performed on aluminum round tubes with thickness eccentricity.

Transition of deformation mode shapes of round aluminum tubes from axisymmetric concertina to non-axisymmetric diamond mode have been studied with varying tube wall thickness, boundary conditions and tube shape eccentricities. Quasi static axial compression experiments were carried out on as received aluminum tubes and tubes with wall thickness eccentricity, incorporated by off center machining. The numerical results are validated by comparison with the experimental load compression and energy absorption responses both for axisymmetric concertina and non-axisymmetric diamond collapse modes. Having validated the numerical model with experimental results, it has been used to undertake a systematic study of the load - deformation characteristics, energy absorption response and collapse mode transition of the tubes in varying configurations of wall thickness, shape and inplane boundary condition eccentricities.

Large Deformation Response Of Plates and Tubes Under Shock Loading

Parametric numerical modeling has been undertaken for circular plates with varying boundary support configurations under uniform single square wave impulsive load using nonlinear transient dynamic FEA in ANSYS. An implicit time integration scheme has been used over multiple load steps at small time increments for the prediction of deflections, stresses, plastic zones and progression of failure. Large strain theory in conjunction with Newton-Raphson iterative solution scheme has been used in the nonlinear FE formulation of the adopted package for analysis. The constitutive model incorporated for the discussed FE analysis is bilinear isotropic with a Mises yield criteria and associated flow rule in conjunction with the Cowper-Symond's model of strain rate sensitivity. The implementation in the FE computational scheme is through an Euler backward scheme to enforce the consistency condition (updated stress, strains and internal variables on the yield surface). The simulation of the tearing phenomenon is through a stiffness reduction scheme under a single frame restart analysis in ANSYS (progressive degradation). The FE modeling is axisymmetric, taking advantage of the plate geometry and uniform transverse impulsive load on the top face, employing 3D plane quadratic axisymmetric elements to model the plate geometry with thickness along the y axis and the plate radius along the x axis. A fine mesh with element aspect ratio of the order 2.5 has been adopted for the discretisation of the plate domain.

Experimental results by Teeling-Smith etal. and Nurick et al. for the prediction of onset of thinning and tearing at the boundary of clamped circular plates subjected to uniformly loaded air blasts have been used to compare and validate the numerical simulation and procedure. The Mode II failure in respect of clamped circular plates has been simulated using a rupture strain criteria. Mode III failure of plastic shear sliding has been considered using a shear strain failure criteria as proposed by Yu and Chen for beams. A stiffness reduction scheme as discussed above has been proposed to decide on the initiation and progression of tearing in conjunction with suitable failure model under mode II and mode III. The deflections, plastic zones, rupture zones and failure modes under the blast loading conditions are found to be in very good correlation with the experimental results. The validated numerical model has further been used to study the effect of plate thickness on the deformation and tearing response of the circular plates subjected to impulsive loads.

The deformation, tearing and shock absorption response of clamped circular plates under uniform impulsive loads with ring support of varying edge configurations at the boundary have been numerically studied. The response of circular plate tube combinations under increasing square impulsive loads have also been carried out with clamped tube ends far away from the plate. The effect of ring support of varying edge configurations at the tube-plate junction on the axisymmetric deformation and tearing response of such structural combinations have further been studied using nonlinear transient dynamic FEA.

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