Charpy Impact Test Simulation of Pressure Plate Ear Using Altair Radioss 10

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Abbreviations: KE-Kinetic Energy, SQRT-Square root.

Keywords: Charpy test, Pressure plate, Impact test

Abstract
Charpy test is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of the given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition. The major objective of the analysis is to estimate the resilience of Pressure plate ear when subjected to the Charpy Impact Test. Altair HyperMesh 10.0 was used to prepare the FE Model. The Striker was modeled as a rigid body and a portion of the pressure plate with the ear was modeled with higher order tetrahedral elements. Radioss Type 7 contact with friction was modeled to define contact between the striker and the ear. Initial Velocity was calculated from kinetic energy and applied to the striker. Radioss Elasto-plastic material model MAT36 was used for the pressure plate material. Altair Radioss Block Explicit was used as solver and the energy at which plastic failure in the material is likely to occur was predicted by performing post processing in Altair HyperView and Altair HyperGraph 10.0.

Introduction
The pressure plate is an integral factor in the function of an automobile’s manual transmission. The pressure plate pushes the clutch disc, sometimes called the clutch plate, against the constantly spinning engine flywheel. Pressure plates are, as the name implies, round, metallic devices containing springs and fingers, or levers, and controlled by the release fork connected to the shifter. All of the clutch components are enclosed in the bell housing of the transmission, between the rear of the engine and the front of the gearbox. Charpy Test is a standard validation test as per the requirements of Standard Design Validation Plan and Report for the component.

The objective of the charpy test on Pressure plate is to evaluate the strength of the Pressure plate ears under shock. The energy absorbed before the ear experiences failure is compared with a minimum acceptable value.
Figure 1: Typical Set up for Charpy Impact test

Figure 2: Photograph of Modern Charpy Test Setup
Process Methodology (details with figures)

Set up of Geometry and Energy Calculations

The striker is placed very close to the pressure plate ear with the clearance of 0.1mm and the initial velocity is assigned to the striker. Geometry Cleanup is done using Altair HyperMesh.

- Mass of the striker is around 10 kg.
- The initial kinetic energy of striker is equal to the impact energy.
- The calculated velocity will be assigned to the striker.
- The velocity of the striker at the time of impact is calculated as follows.

\[
\text{Kinetic energy of the striker at the time of impact} = \text{Impact energy} \\
\text{KE} = \frac{1}{2} m v^2
\]

where,

- \( V \) – Velocity of the striker at the time of impact (mm/sec)
- \( \text{Velocity} (V) = \sqrt{(2*\text{KE})/m} \)

Velocity calculation is tabulated below.

FE Model preparation

Meshing

For evaluation of Design concepts of the Pressure plate ear is to select the best design, Tetra4 element is used. This is done to minimize the solution time at concept evaluation phase. For validation of the final design, Tetra10 element is used. Striker is modeled using Surface mesh and then designating it as rigid body. Minimum gap is maintained between the striker and the pressure plate ear to reduce the solution time. Whenever the Pressure Plate Ear geometry is simple and compatible with Hexahedral mesh, Hex mesh is used. Altair HyperMesh 10.0 used for Meshing.

Appropriate Node sets were created for Contact definition, Loads and Boundary conditions.

Contact Surfaces were created to define surface to surface contact between the striker and pressure plate ear surfaces using the HyperMesh Contact Surfaces and Interfaces options in HyperMesh. Type 7 Radioss Interface was used for the contact definition.
Care is taken to ensure that the element size and quality of elements are well within the acceptance criteria for explicit simulation and the stable time increment is also above limits to Guarantee relatively faster solution.

![Image](image-url)

**Figure 4: Pressure Plate ear with striker**

**Material Definition**

Different grades of Cast Iron material were considered for conformance to the validation requirements. Stress Strain data were input through the Altair Radioss MAT36 Tabular input. Care is taken to input appropriate values of density to ensure correct mass of the striker in order obtain the required kinetic energy.

**Boundary Conditions**

The ends of the pressure plate ear are fixed in all degrees of freedom. The striker is fixed in all degrees of freedom except the plane in which it is expected to move. Initial velocity as calculated is provided using the INIVEL card image in Radioss.

![Image](image-url)

**Figure 5: Boundary conditions**
Output Blocks

Appropriate output blocks were created to obtain results of all component forces, internal energy, Kinetic energy and Hourglass energy for the component striker. Control cards for appropriate unit systems were created. Animation requests were also provided in the engine file for stress and strain results.

Results & Discussions

The Initial Kinetic energy and time t=0 ms is checked to be equal to the impact energy. Altair HyperView 10.0 is used for post processing. Results at different time intervals were reviewed to verify whether establishment of contact and deformation pattern are physical. Plastic strain and Principal Stresses were reviewed at appropriate time intervals to check failure. The Ear was deemed to have failed when the Plastic strain exceeded the strain at break and the contours for the high strain were spread at least in to 3 layers of elements. The principal stresses at which this plastic strain occurs was also reviewed to verify simultaneous occurrence of high strain and stress. The minimum time step at which the failure was observed and the corresponding energy levels were noted.

This energy is compared with the minimum acceptable energy and the conclusions on failure were detailed.

Figure 6: Plastic strain plot- cut section at breakage plane
Benefits Summary

Physical Tests required One week for sample machining and 1 day for test for each concept generated. The Test facility, calibration and maintenance of supplier (when it was tested by 3rd party) were also bottlenecks.

Physical tests for different materials for the same concept also involved a significant lead time.

For each concept generated, the complete simulation cycle time was 16 hours with first order tetrahedral elements and 26 hours with second order tetrahedral elements for the ear.

These figures directly translate in to appropriate savings in product development costs.
Challenges
The choice of the appropriate element type for the ear for the final calculation, appropriate boundary conditions to avoid unwanted motion of the striker and the trade-off between element type between concept evaluation stage and the final design stage were the real challenges in the job.

Future Plans
This simulation project is executed without the material model with combined Damage and failure criterion. For better correlation between test and simulation results, the material test data need to be obtained with inputs for building combined damage and failure criterion from suppliers is envisaged in future.

Future plans are also on to reduce the total simulation cycle to 8 hours at concept evaluation stage and 16 hours for final design stage.

Conclusions
This paper illustrates the application of Altair Radioss in simulation of destructive tests like Charpy Impact tests which are very time consuming and high cost physical tests especially when different concepts of the design need to be validated in a shorter time. The provisions in Altair Radioss tool to build material models that include damage and failure criterion provides greater scope for obtaining closer simulation results.

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