Impact Analysis of Plate

A Report Submitted by

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Impact Analysis of Steel Plate

1 Introduction

Impact loading is one of the most critical conditions that engineering structures may encounter during their service life. Structures such as towers, plates, and aerospace components are often subjected to high-velocity impacts caused by accidental collisions, debris, or moving objects. Understanding the structural behavior of such systems under dynamic impact conditions is essential for designing safe and reliable structures.

This project focuses on two distinct impact scenarios involving structures. The first case studies the impact of a bullet on a plate, representing a localized, high-velocity impact problem. The second case investigates the collision between an aircraft wing (impactor) and a mass tower, representing a large-scale structural impact scenario. These two cases allow the analysis of different modes of deformation, stress distribution, and energy transformation under varying magnitudes of dynamic loads.

The simulations have been performed using **ANSYS Workbench**, the **inbuilt LS-DYNA solver**, and **LS-PrePost** for post-processing. These software tools enable the modeling of transient impact events with high accuracy, accounting for nonlinear material behavior, contact interactions, and energy dissipation mechanisms. The study primarily evaluates parameters such as kinetic energy, internal energy, total energy, and rigid body displacement to understand the response and performance of structures under impact loading.

1.0.1 Impact of Bullet on Plate

This case represents a localized high-velocity impact similar to situations where a bullet or small projectile strikes a metallic surface or wall. The aim is to study local deformation behaviour and the transfer of kinetic energy into the plate. The geometric model used for the bullet–plate configuration is shown in Figure **??**.

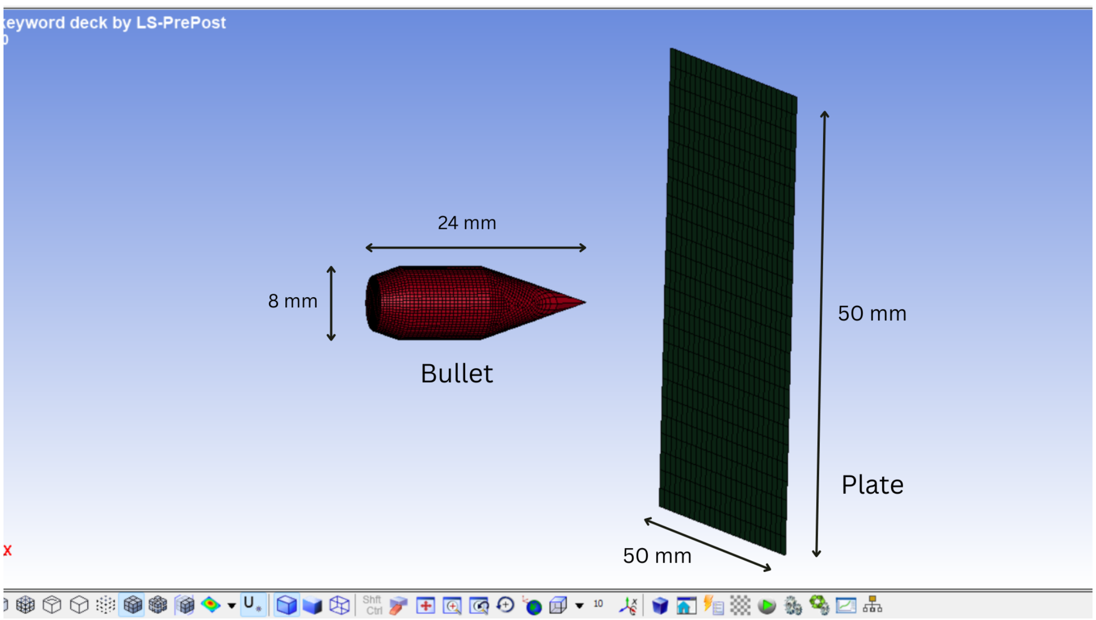

Figure 1.1: Geometric model of the bullet–steel plate impact configuration.

2 Problem Statement

2.1 Impact of Bullet on Plate

2.1.1 Problem definition

This case represents a localized, high-velocity impact in which a rigid bullet strikes a steel plate. The objectives are (1) to characterise the transient stress and deformation response of the plate under the specified impact and (2) to quantify the energy transfer by extracting and analysing kinetic, internal and total energy histories.

2.1.2 Geometry and parameters

1. Plate geometry: square plate of dimensions 50 $mm \times 50$ mm and thickness 5 mm.
2. Bullet geometry: rigid projectile composed of a cylindrical and conical section with total length 24 mm (cylindrical portion 9 mm, conical nose 12 mm, base 3 mm). Cross-section diameter is defined in the model.
3. Initial condition: bullet initial velocity = 200 m/s directed normal to the plate.
4. Material models: plate modelled using MAT_024 (piecewise linear plasticity with strain-rate sensitivity); bullet modelled as rigid (MAT_020 or equivalent rigid-body definition).
5. Boundary condition: plate edges/clamped support to prevent rigid-body motion.
6. Contact: automatic surface-to-surface contact between bullet and plate.
7. Finite elements detail: For the bullet model, the mesh consists of 11,364 elements and 13,091 nodes, with a computed surface area of 481.535 mm^2 and a total volume of 767.213 mm^3. The plate model contains 625 elements and 676 nodes, with a total surface area of 2,500 mm^2.

2.1.3 Simulation outputs and assessment

1. Extract global energy histories (kinetic energy, internal energy, total energy) from the LS-DYNA `d3plot` file and export as CSV for plotting.
2. Record the Resultant rigid body displacement of the plate to capture deformation.

2.1.4 Simulation outputs and assessment

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3 Results

3.1 Impact of Bullet on Plate

This section presents the results obtained from the high–velocity impact of the bullet on the plate.

3.1.1 Visualisation of impact of bullet on the plate

The deformation progression of the plate during bullet impact at different time frames is shown below . The sequence clearly highlights the initiation of contact, plastic deformation, peak penetration, and the final state after the bullet comes to rest.

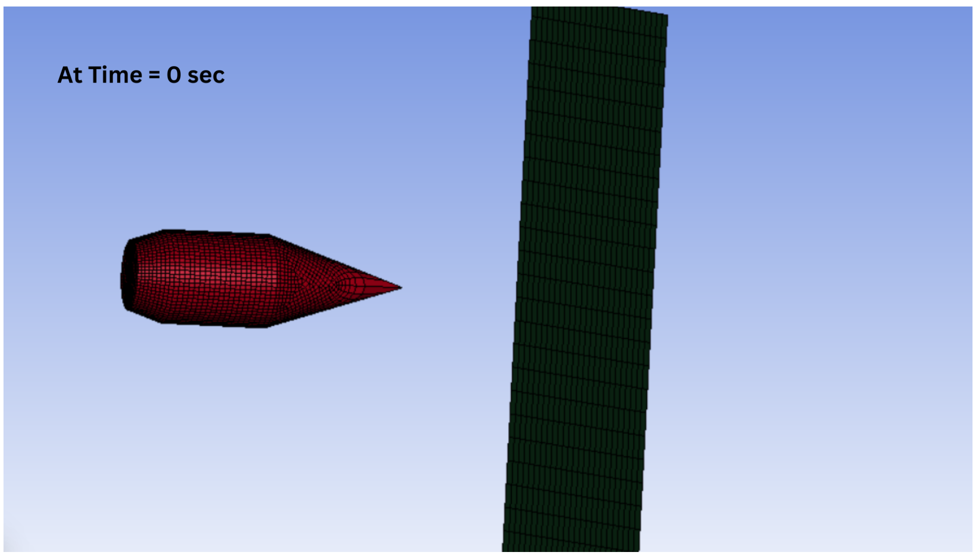

Figure 3.1: Impact of bullet at $t = 0.0$ sec

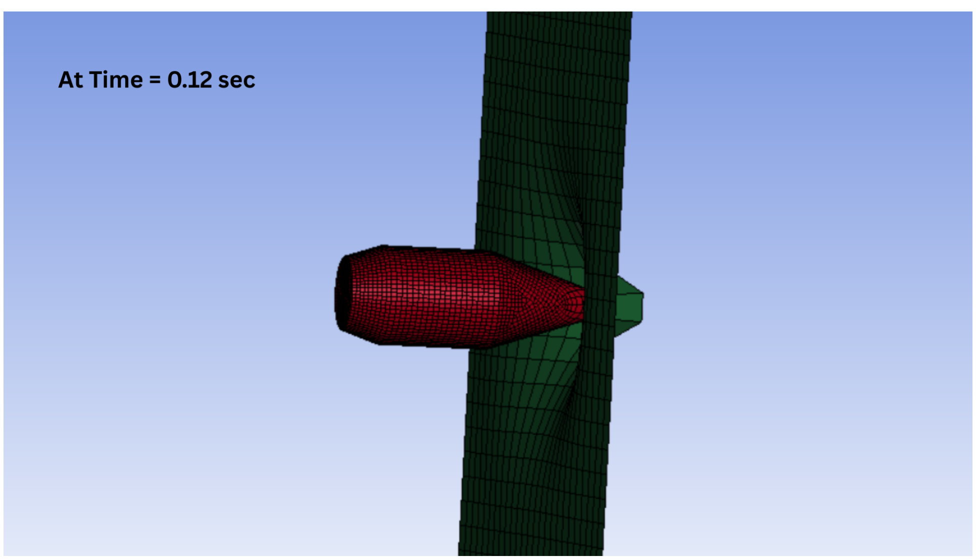

Figure 3.2: Impact of bullet at $= 0.12$ sec

Figure 3.3: Bullet impact deformation at different time frames captured from LS-PrePost (Part 1).

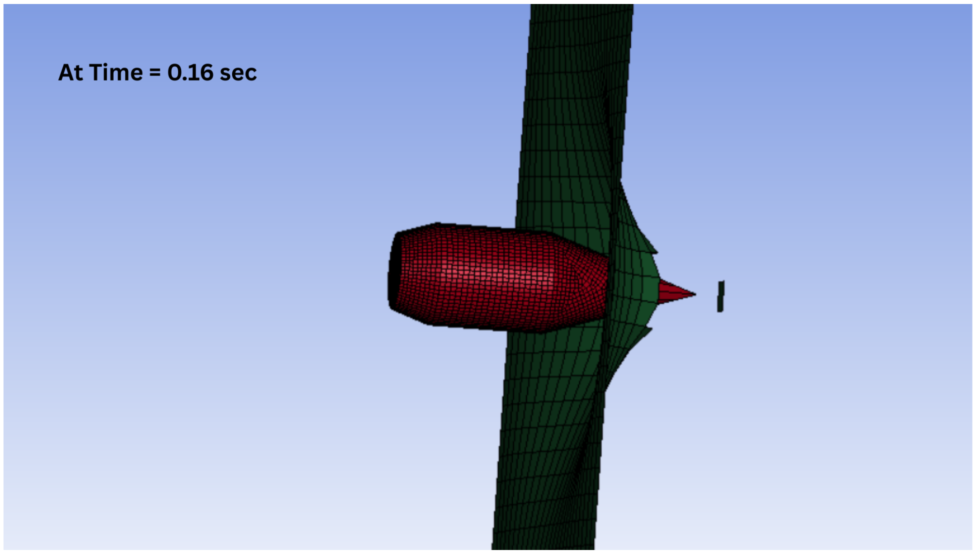

Figure 3.4: Impact of bullet at $t = 0.16$ sec

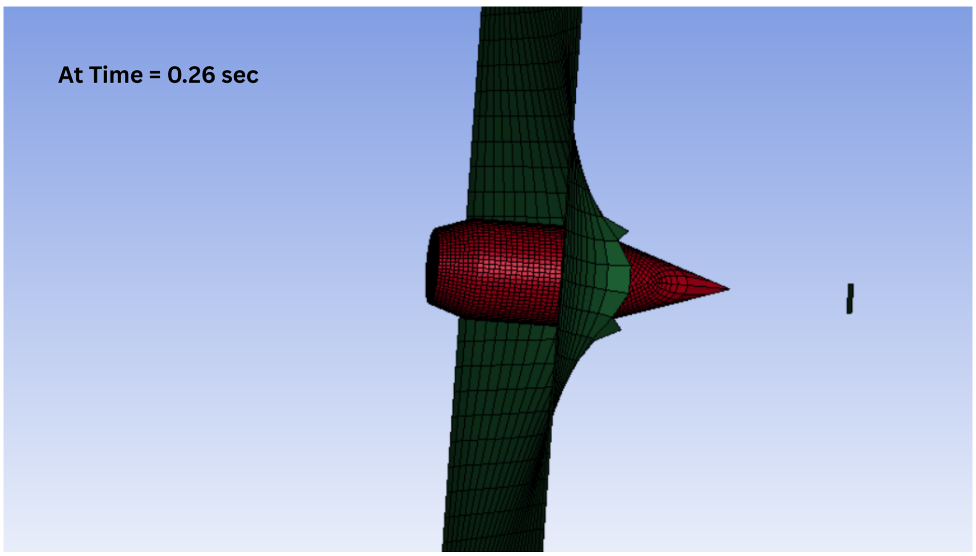

Figure 3.5: Impact of bullet at $t = 0.26$ sec

Figure 3.6: Bullet impact deformation at different time frames captured from LS-PrePost (Part 2).

3.1.2 Internal Energy

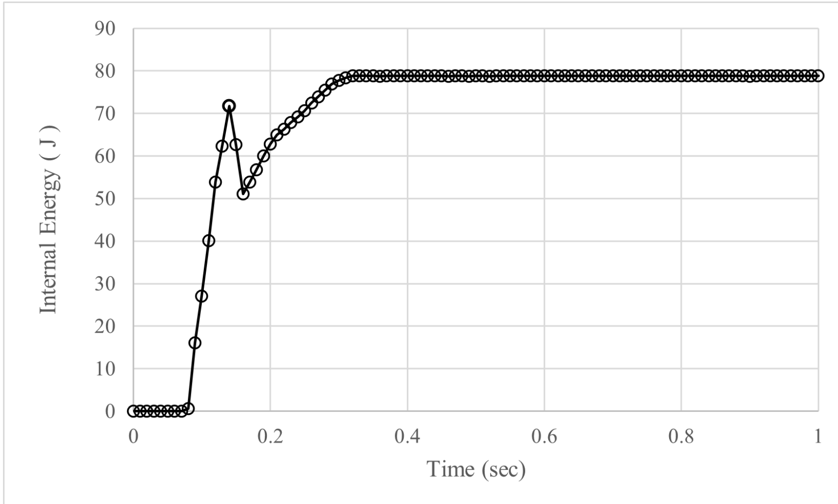

Figure 3.7: Internal energy variation during bullet impact.

The internal energy rises sharply after impact and reaches a maximum value of approximately **78 units**. This indicates rapid plastic deformation in the steel plate. After about **0.35–0.40 s**, the internal energy curve becomes nearly constant, confirming that the major deformation phase has completed. The smooth plateau verifies that the system has reached a stable post–impact state.

3.1.3 Kinetic Energy

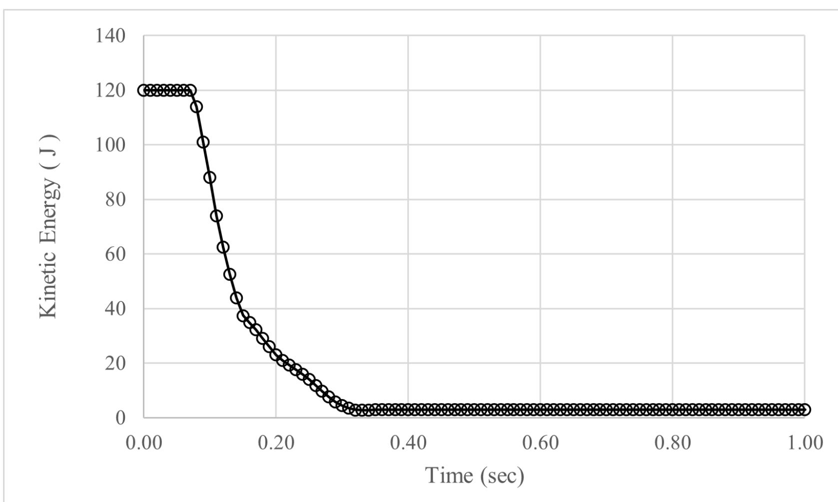

Figure 3.8: Kinetic energy decay of the bullet during impact.

The bullet begins with a kinetic energy of approximately **120 units**. As the bullet impacts the plate, the kinetic energy drops steeply and approaches nearly **zero by 0.30–0.35 s**. This indicates that almost all the bullet's kinetic energy is absorbed by the plate through deformation. The rapid reduction in kinetic energy confirms a strong, non–recoverable impact.

3.1.4 Resultant Displacement

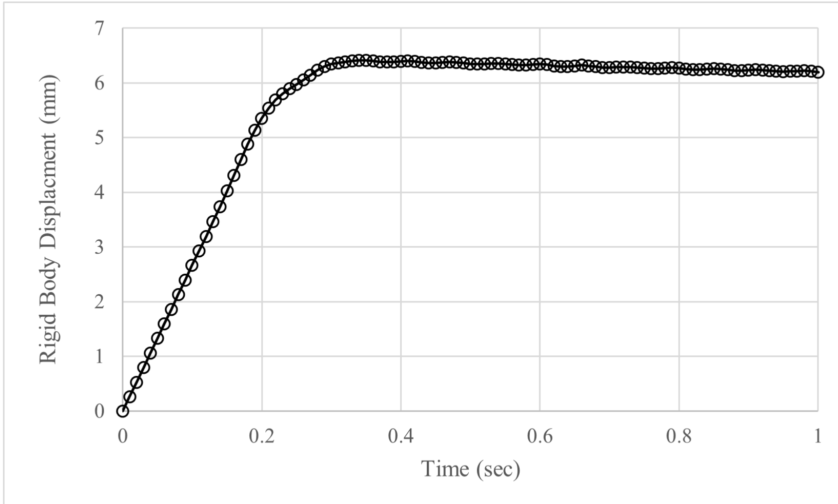

Figure 3.9: Resultant displacement of the bullet during impact.

The displacement increases continuously and reaches a maximum value of approximately **6.4 units**. After reaching this peak, the displacement becomes constant, indicating that the bullet comes to rest inside the deformed plate. This permanent displacement confirms significant plastic deformation and a fully inelastic impact.

3.1.5 Total Energy

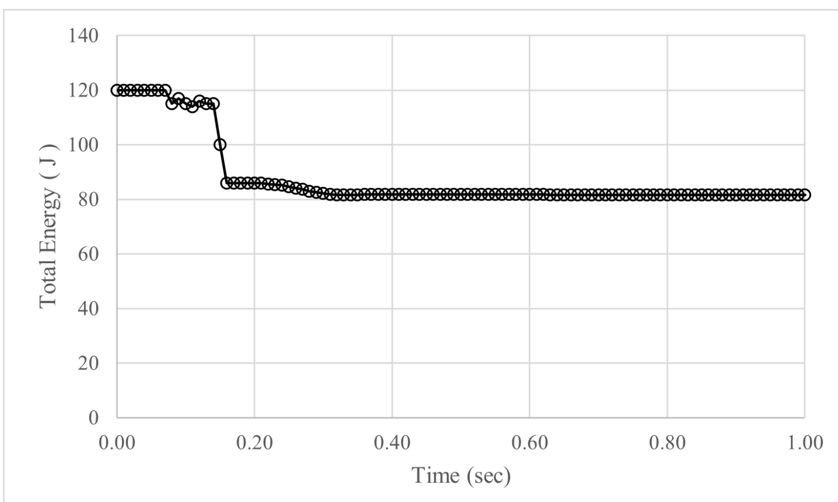

Figure 3.10: Total energy response of the system during bullet impact.

The total energy curve shows an initial drop from approximately **120 units to 85 units**, followed by a nearly constant response. The early reduction is due to conversion of kinetic energy into internal (plastic) energy. Once stabilised, the total energy remains conserved, indicating numerical stability of the simulation.