Chapter 4
VERIFICATION OF THE FE MODEL BY EXPERIMENTAL RESULTS

Experimental studies were carried out at the Lab at Bangalore. The studies were performed to study the behaviour of 7.62x51mm SLR bullet with the target plates in different configurations of monolithic and layered combinations.

4.1 Experimental setup

The schematic diagram of the experimental setup is shown in Fig. 4.1. The universal gun as shown in Fig. 4.2 was used to trigger the SLR bullet for the experiment. Target used was Domex Protect 500 steel plates and bullet used for the ballistic test was 7.62x51mm SLR bullet.

Distance between gun and target was 10.0 m. The velocity measuring system was placed in between the gun and target for measuring the initial velocity of the bullet. Laser sight was attached for the accuracy in firing. The test specimens were tightly clamped between two steel frames. Bolts at the corners of the steel frame were tightened to ensure a rigid mount on all four edges of the test specimen.

Fig. 4.1: Schematic diagram of the experimental setup.
The SLR (7.62x51mm) bullet as shown in Fig. 4.2 is constructed with a lead inner core covered with the copper jacket was used for the experimental studies.

4.2 Experimental results

The experimental impact studies of impact between the SLR bullet and target plates were carried out at the ballistic lab. Experimental studies were performed on monolithic and double-layered configurations.

4.2.1 Monolithic target plate

Ballistic testing of SLR bullets on a 6.5mm thick monolithic plate made of Domex Protect 500 steel was done in a ballistic lab. No penetration of the bullet with a velocity of 850 m/s was observed through the monolithic target plate. From the experimental results, it can be seen that after impact of the bullet into the target, the bullet undergoes full erosion. From the experiment, the bulge height also called as trauma was found to be 3.24 mm. Fig. 4.4 shows the monolithic target plate impacted with the SLR bullet.

Fig. 4.4: Monolithic target plate after impact.
(a) Front face (b) Rear face
4.3 Numerical analysis

Fig. 4.5 and 4.6 show the FE model of the target and the bullet that were modelled using a standard linear solid mesh. In order to reduce the simulation time the number of elements in the target was reduced by maintaining 0.5 mm element size at the impact location and it was gradually increased to 5 mm away from the impact location. This kind of mesh biasing reduced the number of elements from 10,08,000 to 1,71,200 due to which the computation time reduced from hrs to minutes.

![Fig. 4.5: FEA model of target plate](image1)

The bullet consists of an inner core made of lead and a gliding copper outer jacket. Average mesh size of the bullet is 0.5 mm. CAD model and finite element model of the target and bullet are shown in Fig. 4.5.

![Fig. 4.6: 7.62mm SLR bullet](image2)
4.4 Numerical simulation results

Numerical studies were carried out using LS-DYNA to study the behaviour of monolithic and double-layered target plate impact by a bullet with the velocity of 850m/s. The results were compared with the experimental results and the study was further extended to optimize the mass of the target plates by adding circular perforation in target plates. Fig. 4.8 shows the sequence of various stages of impact of bullet on a 6.5mm thick monolithic target plate. Global bending is observed in the target plate. Fig. 4.8 shows von Mises stress distribution on the target plate at various intervals of time with an initial velocity of 850m/s. The stress ranges from a zero value and reaches 2.58GPa at the impact location. After impact, no penetration of the bullet was observed through the monolithic plate. The behaviour of bullet onto the target plate studied experimentally was captured correctly in the numerical simulations. From the numerical studies, the trauma height obtained was 3.46 mm. Result shows the trauma obtained after SLR bullet hits the monolithic target. From the plot it is observed that between 0.02 and 0.05 milliseconds the trauma increases linearly at a high rate and after that the trauma variation is marginal because the bullet undergoes complete erosion. Good correlation between experimental and analysis results was found with the difference of 6.79%. This may be due to the plugging caused due to the shearing action. According to the law of conservation of momentum, the exchange between the energies takes place between the bullet and the target. It is understood that kinetic energy lost by the bullet is not exactly equal to the internal energy because some part of energy is lost due to friction between the bullet and the target. This frictional energy is obtained as sliding energy in numerical analysis. The internal energy absorbed by the target plate was 396J.
4.4.1 **Comparison of 6.5mm thick monolithic and double-layered target plate**

The results obtained are tabulated in Table 4.1. From the results it was observed that, layering of target plate does not make any change in the total strength of the target plate. From the table it can be observed that the maximum stress values obtained by numerical studies in all the target plates are nearly equal. It was further seen from numerical studies that the deformation was less in 6.5mm thick monolithic target compared to double-layered target plates in contact. Both configurations in the double-layered targets showed similar kinds of deformation independent of the spacing. In all the cases after impact, no penetration of the bullet was observed through the rear face of the target plate. From the results obtained it can be concluded that with a 7.62 x 51mm SLR bullet with a velocity of 850 m/s the analyzed
configurations were capable of resisting the bullet from penetrating the target plate. The layering of the target does not make any difference in the strength of target plates. Similar conclusions were given by Borvik et al. [26].

Table 4.1: Comparison of 6.5mm thick monolithic and layered target plate

<table>
<thead>
<tr>
<th>Type of Target</th>
<th>Thickness of target</th>
<th>Gap between target plates</th>
<th>Type of Study</th>
<th>Initial velocity m/s</th>
<th>Penetration of the bullet</th>
<th>Trauma</th>
<th>Von Mises stress in the target plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monolithic</td>
<td>6.5mm</td>
<td>----</td>
<td>Experimental</td>
<td>850</td>
<td>No</td>
<td>3.24mm</td>
<td>----</td>
</tr>
<tr>
<td>Monolithic</td>
<td>6.5mm</td>
<td>----</td>
<td>Numerical</td>
<td>850</td>
<td>No</td>
<td>3.46mm</td>
<td>2580 Mpa</td>
</tr>
<tr>
<td>Layered</td>
<td>3.25+3.25 =6.5mm</td>
<td>0mm</td>
<td>Numerical</td>
<td>850</td>
<td>No</td>
<td>5.71mm</td>
<td>2630 Mpa</td>
</tr>
<tr>
<td>Layered</td>
<td>3.25+3.25 =6.5mm</td>
<td>10mm</td>
<td>Numerical</td>
<td>850</td>
<td>No</td>
<td>0.95mm</td>
<td>2590 Mpa</td>
</tr>
</tbody>
</table>