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Ballistic Simulation Of Bullet Impact on a Windscreen Made of Floatglass and Plexiglass Sheets

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ABSTRACT
The paper reports on numerical simulation of impact problems on an assembly of Floatglass and Plexiglass sheets arranged alternatively. The ballistic impact caused by bullet of AK47 rifle is analyzed to obtain an estimate for the global damage. All estimates have been carried out using the finite difference numerical code AUTODYN-3D. Resulting simulations predicts the deformation and damage of the cumulative assembly and ballistic performance.

Keywords
Linear Transient Dynamics, Ballistic-Bullet Impact, Plexiglass, Floatglass .

1. INTRODUCTION
There are a large number of affecting factors like shape of colliding objects, relative velocity of objects, location of contact, masses, relative stiffnesses, boundary conditions, material characteristics, etc, which makes calculations of impact problems very complex and time taking. Further, these problems increase when different materials are involved, as because of different materials, different modes of failure occur, as resulting dynamic behavior is a function of material properties. Thus, designing and testing an assemblage, that too, for a bullet impact test would require a very large number of experimental tests, which may consume both time and resources.

With the recent advancement in various testing and modeling softwares (e.g Ansys Autodyn and Catia), the understanding of damage mechanisms and mechanics of different materials in different shapes assembled together – altogether in a dynamic environment, has become simpler, and thus use of such softwares offer the possibility of avoiding many of the experimental tests which otherwise needs to be done practically. Thus, keeping the same in mind, the modeling of objects, and the assembly of all the components was done in Catia V5. The impact simulation was done in Explicit Dynamics Workbench of Ansys Autodyn.

The objective of this paper is to report on experimental numerical simulation of impact problems on sheets Floatglass and Plexiglass (placed together alternatively) and to illustrate the performance of the simulation, laying ground for predictions solely based on numerical models.

All the simulations presented in the paper have been carried out by using the AUTODYN, specially designed for non-linear transient dynamic events such as ballistic impact, penetration and blast problems.

The software is based on explicit finite difference, finite volume and finite element techniques, which use both grid based and gridless numerical methods. A set of partial differential equations for conservation of mass, momentum and energy is solved together with the constitutive equations using an explicit time integration scheme. An additional relationship between pressure, volume and energy from an equation of state specific to the material provides a solvable set describing the purely hydrodynamic portions of stresses and strains. These, together with a material model and a set of initial and boundary conditions, define the complete solution of the problem.

2. FINITE ELEMENT ANALYSIS

2.1 CAD Modelling and Assembly of Parts
Total 7 CAD models are made in Catia V5, which are of, lead core and outer shell (see fig.1) and 3 similar sheets of Floatglass (each 7.62 mm thick), and 2 sheets of Plexiglass (each 7.62 mm thick). Floatglass and Plexiglass sheets have been arranged alternatively (see fig.2), with Floatglass sheet at both top and bottom.

The dimensions of bullet have been kept similar to the bullet of AK47, an assault rifle. The outer shell was assigned ‘cartridge brass’ as material. Lead core has been assigned ‘lead’ as material. Floatglass and plexiglass sheets were assigned materials of same name.

2.2 Simulation of Bullet Impact
Simulation of impact has been done in Ansys Autodyn. The finished product after modeling and assembly in Catia V5 was imported as geometry in Ansys Explicit Dynamics Workbench. After selection of materials from material library, it was opened in Autodyn for loading of impact conditions. Both the lead core and outer shell are connected and are given a velocity of 700 m/s. The bullet is initially touching the assemblage of sheets (see fig.2). As the high velocity impact phenomenon is of localized nature, the boundary conditions do not influence the results and therefore only a square region of all the sheets (200 x 200 mm) was modeled. After finalizing the loading conditions, and output as Total Deformation and Equivalent (von-Mises) Stress, solver was run.

2.3 Materials Used.
Float glass has a refractive index of 1.52, while Plexiglass has refractive index of 1.49. When two different transparent materials are placed together to form a single product, then to maintain transparency through it, it is very important that the refractive indexes of both materials should be almost equal.

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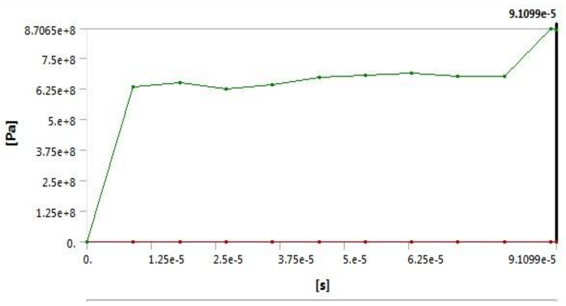
Table 1. General Properties of Materials Used.

Part	Material	Young's Modulus (GPa)	Density (Kg/m3)	Poisson's Ratio
Outer Shell	Cart Brass	16	8450	0.34
Lead Core	Lead	16	11340	0.44
Plexiglass Sheet	Plexiglass	2.4-3.3	1186	0.35-0.40
Floatglass Sheet	Floatglass	8.5±0.05	2530	0.20±0.01

3. SIMULATION RESULTS

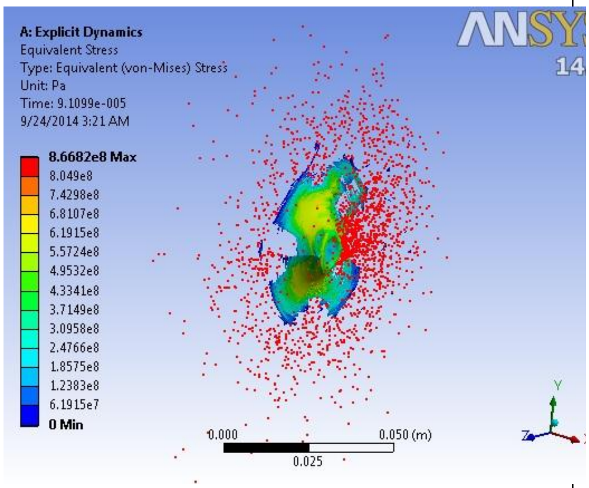
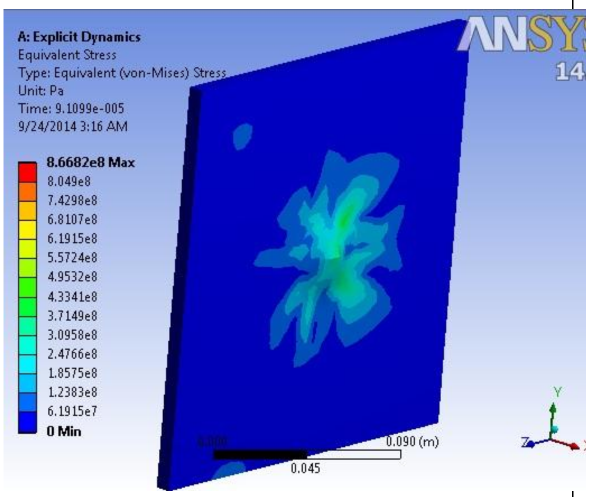
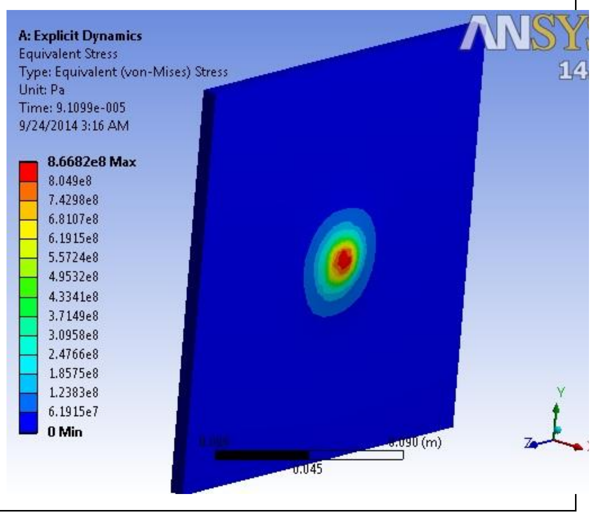
The bullet was unable to pierce the assemblage in the simulation test. Bullet was assigned a velocity of 700 m/s and an impact angle of 15° from normal to plate. A maximum deformation of 0.0834 m took place, and overall, the screen gave good bullet resistant characteristics. The analysis was run for 0.0018 seconds. Below are the test results :

3.1 Von Mises Stress Distribution



3.2 Von Mises Stress Distribution on Each Component

Von Mises Stress Distribution of each component has been shown using screenshots from the Autodyn Workbench. See table 2.

	Von Mises Stress on Each Component at time of impact.
1	Bullet after impact. 
2	1st plate – Floatglass. 
3	2nd Plate – Plexiglass. 

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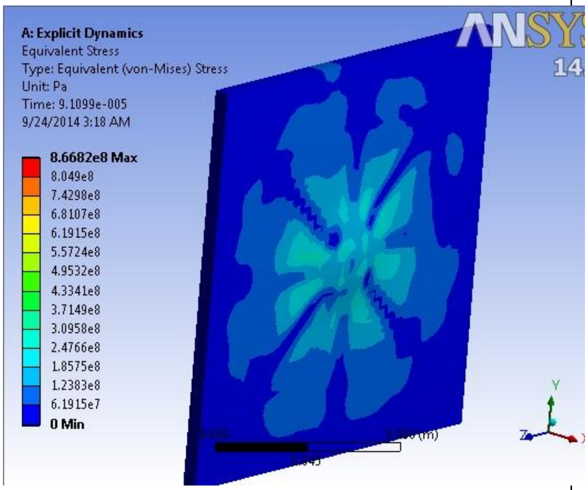
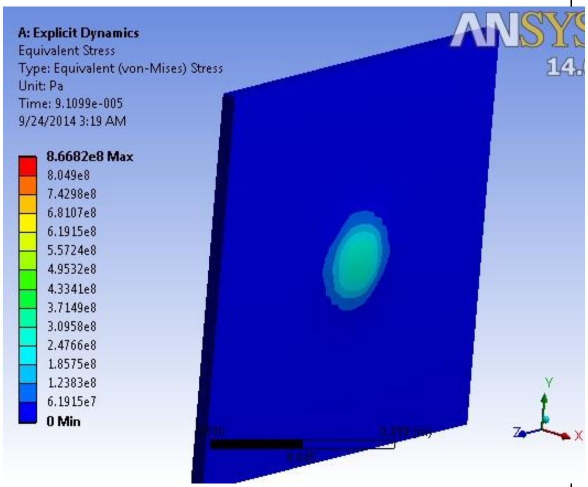
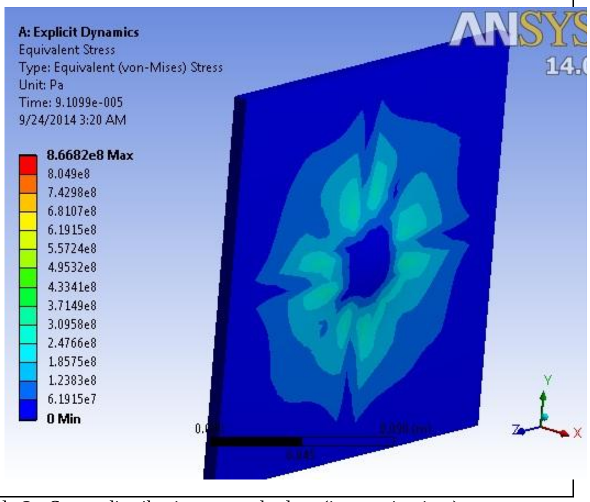
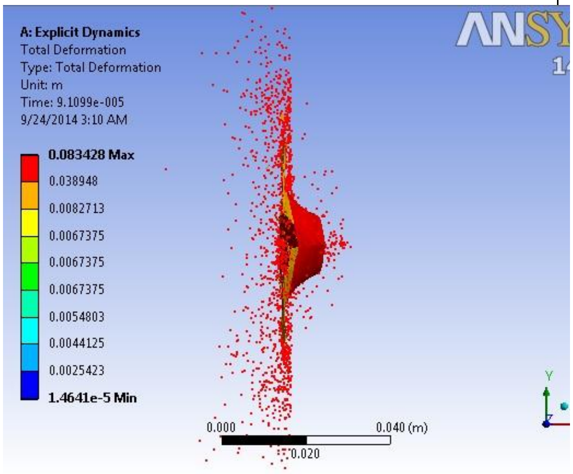
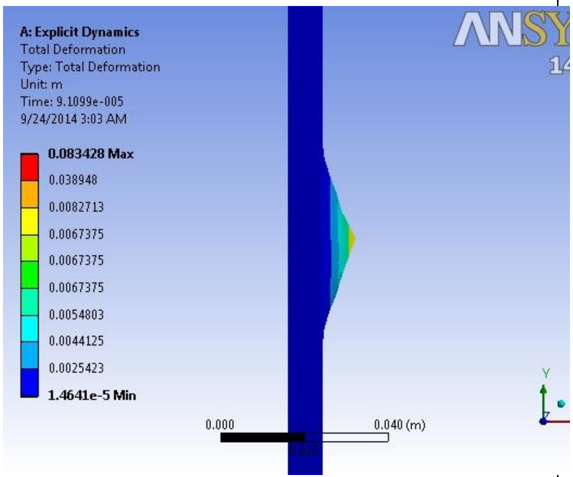
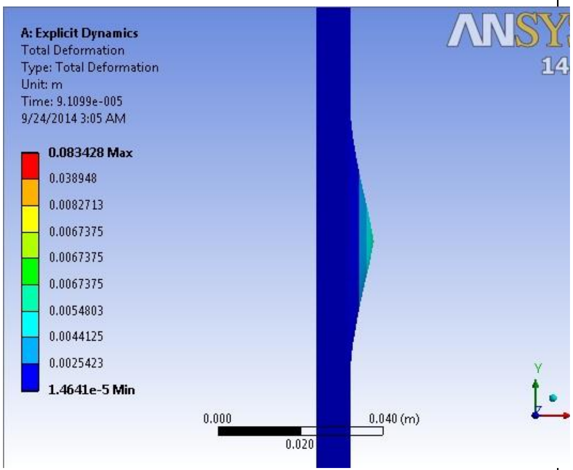
4	3rd Plate – Float Glass. 
5	4th Plate – Plexiglass. 
6	5th Plate – Floatglass 

Table 2 : Stress distribution on each plate (isometric view).

3.3 Deformation on each component.

Table 3 shows deformation undergone by each component in side view.

	Deformation of Each Part
1	Bullet 
2	1st Plate – Floatglass 
3	2nd Plate – Plexiglass 
4	3rd Plate – Floatglass

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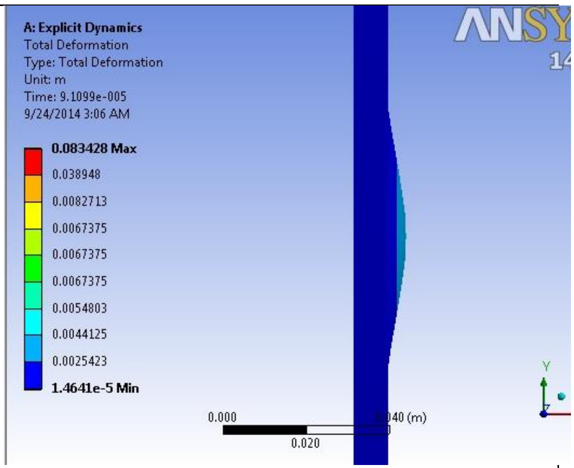
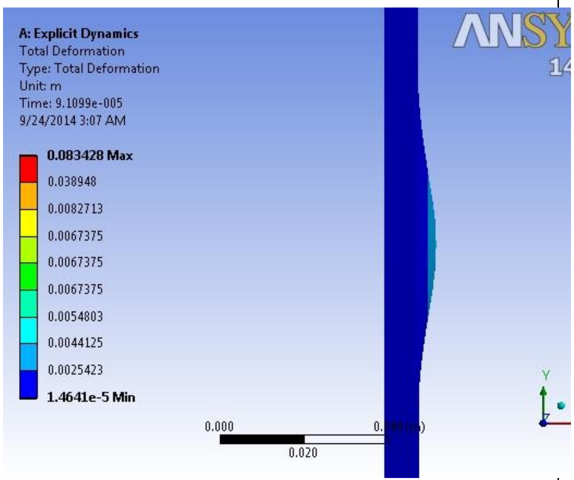
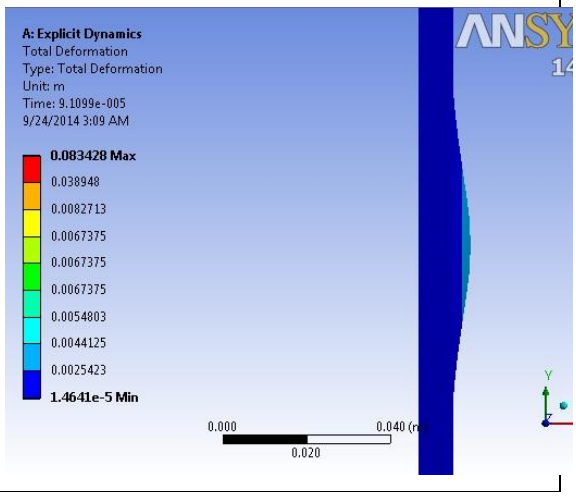
	
5	4th Plate – Plexiglass
	
6	5th Plate – Floatglass
	

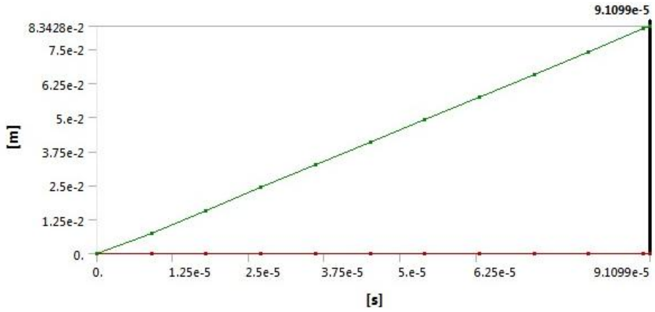


Table 4. Total deformation.

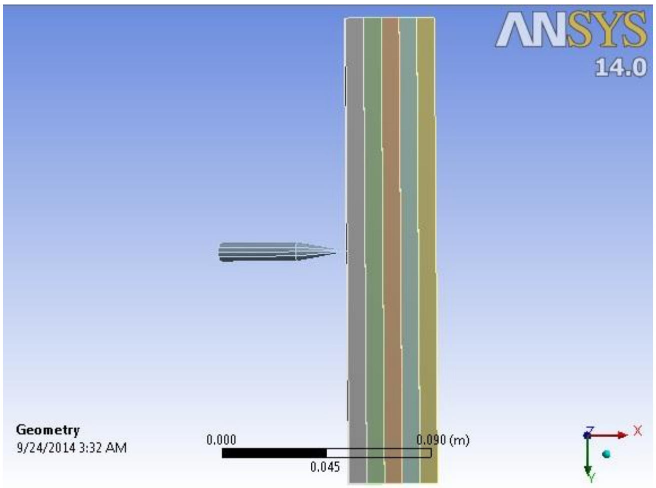


Fig. 4: Initial Setting

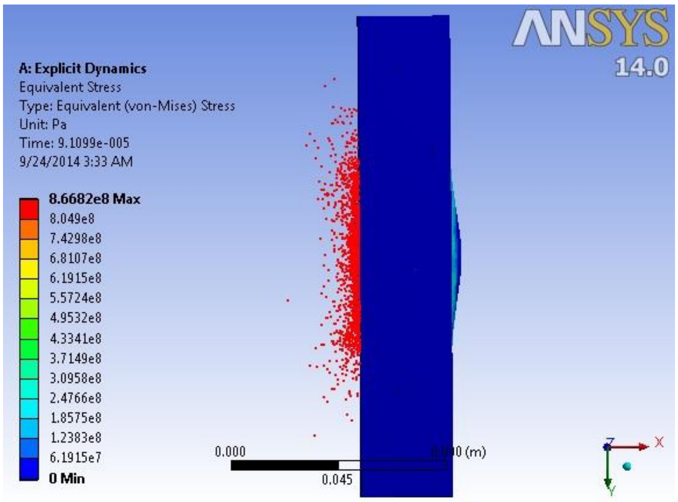


Fig. 5: Deformation after impact.

4. CONCLUSION

This assemblage made of floatglass and plexiglass sheets arranged in alternate order can take a bullet impact, without getting damaged significantly. It can thus be incorporated in car windows, windscreens, offices, etc, where bullet resistant charecterstics are desired. It has a total thickness of 1.5 inches (each plate is 7.62 mm thick), which is optimum keeping in mind that plexiglass is a cheaper substitute of polycarbonate – which is usually used with glass for bullet proofing solutions, when extereme strength is required and is expensive.

5. ACKNOWLEDGMENT
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