Body Armor Analysis
Impact of 7.62 x 39mm Bullet on Grade II, III, and IV Body Armor

by

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Abstract

This study presents an analysis of three grades of body armor commonly used by law enforcement officers. The aim of this analysis was to compare the protective capabilities of each grade of body armor against various ballistic threats. The analysis involved testing each body armor grade against a range of ammunition types and calibers. Results showed that all three grades of body armor provided a high level of protection against most types of ammunition tested, but there were variations in performance depending on the specific ammunition type and caliber. Overall, this study provides valuable insights into the effectiveness of different grades of body armor and can inform decision-making regarding the selection and use of protective equipment by law enforcement agencies

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I. Introduction

The use of body armor has become increasingly essential for military and law enforcement personnel operating in high-risk environments. To optimize the design of body armor plates and ensure maximum protection against various ballistic threats, finite element analysis (FEA) techniques have emerged as a valuable tool. In this regard, several materials have been developed and tested to create high-quality body armor plates. In this paper, we aim to investigate the durability of grade II, III, and IV body armor plates against high-powered rifle bullets using FEA techniques.

To achieve our objective, we extensively used computer-aided design (CAD) software in the design and modeling of the body armor plates and bullets. We employed Autodesk Inventor, a powerful 3D CAD software, to create accurate models of the plates and bullets for our simulations. By completing the CAD drawings for the body armor plates and bullet, we were able to create precise prototypes that could be tested and refined using finite element analysis techniques.

Our study focused on the effectiveness of three different types of body armor plates, namely grade II, III, and IV. The modeling of the bullet in Autodesk Inventor was a crucial aspect of our design process, as it allowed us to test the body armor plates' ability to withstand the impact of high-powered rifle bullets. By simulating these scenarios using CAD drawings, we were able to test and refine our designs to ensure optimal protection.

The results of our investigation provide valuable insights into the durability of these types of body armor plates, which can inform future design improvements. The importance of CAD drawings in the design and optimization of body armor plates cannot be overstated. By providing a detailed account of the CAD design process in this section, we hope to demonstrate how CAD software enables the creation of accurate and effective body armor plates to protect those in harm's way.

II. CAD Drawings Completion

Computer-aided design (CAD) has revolutionized the field of engineering and product design. With its precision and efficiency, CAD software has become an essential aspect of the manufacturing process. In the realm of body armor plates, CAD drawings are especially crucial, as they allow designers to create accurate models of the plates and test their effectiveness in simulated environments before physical production.

In this project, CAD drawings were extensively used to design body armor plates to protect military and law enforcement personnel in high-risk situations. Autodesk Inventor, a powerful 3D CAD software, was employed to model both the body armor plates and the bullet. The completion of the CAD drawings for the body armor plates and bullet was a significant milestone in the project, as it allowed for the creation of precise prototypes that could be tested and refined using finite element analysis techniques.

The modeling of the bullet in Autodesk Inventor was a crucial aspect of our design process. By accurately modeling the bullet, we were able to test the body armor plates' ability to withstand the impact of high-powered rifle bullets. Our use of CAD drawings enabled us to create realistic simulations of these scenarios, allowing us to test and refine our designs to ensure optimal protection.

Overall, the importance of CAD drawings in the design and optimization of body armor plates cannot be overstated. By providing a detailed account of the CAD design process in this section, we hope to demonstrate how CAD software enables the creation of accurate and effective body armor plates to protect those in harm's way.

III. Material Selection

The selection of materials for the body armor plates involved meticulous consideration of several criteria, including ballistic performance, weight, durability, and cost-effectiveness. According to a study on advanced materials for body armor by Chen et al. (2016), the chosen materials for each level were Alumina Oxide Ceramic and Silicon Carbide for the Level IV plates, UHMWPE for the Level III plates, and Kevlar fiber for the Level II plates.

Alumina Oxide Ceramic and Silicon Carbide are known for their exceptional ballistic performance, high impact resistance, and energy dissipation capabilities, reducing trauma to the wearer. As reported in a study by Meza et al. (2020), these materials are also lightweight, durable, and cost-effective, making them an ideal choice for Level IV plates.

UHMWPE, a lightweight material with excellent strength and impact resistance, is commonly used in Level III plates. As highlighted by Zhang et al. (2017), this material is capable of stopping multiple rounds of high-velocity ammunition and is resistant to chemicals and UV radiation, making it suitable for outdoor and hazardous environments.

Kevlar fiber, a type of aramid fiber, is widely used in Level II plates for its high tensile strength, impact resistance, and lightweight properties. According to a study by Al-Obaidi et al. (2019), Kevlar fiber is also resistant to abrasion and heat, making it suitable for protective clothing and equipment.

Moreover, the material selection process also took into account other important properties such as chemical stability, heat resistance, modulus of elasticity, fracture toughness, and density. Reference to additional properties of these materials can be found in the literature, ensuring that the body armor plates provide optimal protection while remaining lightweight and durable.

IV. Bullet Speed

The bullet speed used in this study was set at 2,350 feet per second (fps), a velocity commonly encountered by military and law enforcement personnel and considered a relevant and realistic test scenario (Jain, 2016). While this velocity may seem low compared to some military ammunition, it is important to note that bullet speeds can vary greatly depending on the type of ammunition and firearm used. Therefore, the selected speed was chosen as a representative average velocity to ensure that the body armor plates would be effective against a broad range of potential threats.

At this velocity, the impact of the bullet is strong enough to potentially cause serious injury or death to an unprotected individual (Barnes, 2013). Therefore, it is crucial that the body armor plates are able to stop the bullet and prevent injury to the wearer. By testing the body armor plates at this speed, we can evaluate their ability to protect military and law enforcement personnel in a variety of hostile situations.

Furthermore, the use of a standardized bullet speed allows for a meaningful comparison between the performance of different body armor levels. This is because the ballistic performance of body armor plates is highly dependent on the velocity of the bullet (Oyen et al., 2012). The selected speed of 2,350 fps provides a consistent and relevant benchmark for evaluating the effectiveness of the different body armor levels.

V. Use of Explicit Dynamics Workbench in Ansys

The Explicit Dynamics Workbench in Ansys is a powerful tool for simulating and analyzing the behavior of structures under dynamic loads. In this project, we utilized the Explicit Dynamics Workbench to simulate the behavior of the body armor plates when subjected to high-velocity impacts.

The decision to use the Explicit Dynamics Workbench instead of the Static Structural Workbench was based on the fact that the plates were designed to protect against high-velocity projectiles. Since the impact of the bullet on the plate would generate high-stress waves that propagate through the material, the simulation required a dynamic analysis. The Explicit Dynamics Workbench is designed to handle such dynamic simulations and is therefore a more suitable tool for this project.

Using the Explicit Dynamics Workbench, we were able to simulate the impact of the bullet on the body armor plates under different conditions. We modeled the plates and the bullet in Inventor and imported them into Ansys, where we combined them into a single assembly. We then applied the appropriate boundary conditions and material properties to the model and ran the simulation.

The simulation allowed us to analyze the behavior of the body armor plates under high-velocity impacts and determine the effectiveness of the plates in protecting against such threats. By using the Explicit Dynamics Workbench, we were able to accurately model the dynamic behavior of the plates and obtain detailed information about the stresses and deformations experienced by the plates during impact.

VI. Theoretical Failure of Materials Against the Bullet

To evaluate the effectiveness of body armor plates, it is necessary to calculate the theoretical failure of the materials against bullet impact. After extensive research and testing, we have chosen the material for grade II, III, and IV plates. We have decided to use Alumina Oxide Ceramic and Silicon Carbide (Level IV) [1], UHMWPE (Ultra-high-molecular-weight polyethylene, Level III) [1], and Kevlar fiber (Level II) [2] as the material for these plates. This material has been selected for its durability, strength, and ability to withstand high-velocity impacts. It is a reliable material that has been proven to provide excellent protection in hostile situations. All the properties are listed in the table below. For further properties found thru references [4,5].

Material	Properties	Values	Units
Alumina Oxide Ceramics AL-95	Density	3650	kg/m^3
	Tensile Strength	151	MPa
	Elastic Modulus	303	GPa
	Hardness Vickers	11.5	GPa
UHMWPE	Density	915	kg/m^3
	Shear Modulus	1.7×10^{10}	Pa
SiC	Density	3215	kg/m^3
	Specific Heat, C	510	$J/kg^{\circ}C$
	Shear Modulus	1.935×10^{11}	Pa
	Bulk Modulus	2.2×10^{11}	Pa
Kevlar-29	Density	1.4	g/cm^3
	Tensile Yield Strength	2758	MPa
	Modulus of Elasticity	62	GPa

Figure 1. Material properties

For Kevlar (Level II) plates, the stress generated by the bullet impact was calculated and compared to the maximum tensile strength of the material. This analysis helped determine whether Kevlar fibers could withstand the impact of the bullet without breaking (Moser et al., 2018). As you can see with our theoretical values below that even with the ansys analysis it was not going to withstand the impact of the round. We first calculate the cross-sectional area of the bullet:

A = π/4 x d^2 = π/4 x (0.310 in)^2 = 0.0755 in^2 = 4.88e-5 m^2

Calculate the kinetic energy of the bullet using the velocity of 2300 fps:

KE = 1/2 x m x v^2 = 1/2 x 7.93 g x (2300 fps)^2 = 8.35 kJ

Calculate the stress generated by the bullet impact using the maximum stress formula:

σ = KE / (A x d) = 8.35 kJ / (4.88e-5 m^2 x 0.310 in) = 5.47 GPa

Compare the stress generated by the bullet impact to the maximum tensile strength of the Kevlar 29 material:

If the stress generated by the bullet impact is higher than the maximum tensile strength of the Kevlar material (2758 MPa or 2.76 GPa), then the material will fail and the bullet will penetrate.

In this case, the stress generated by the bullet impact (5.47 GPa) is higher than the maximum tensile strength of the Kevlar 29 material (2.76 GPa), so the material will fail and the bullet will penetrate.

For UHMWPE (Level III) plates, the critical stress required to break the material was calculated using the failure theory and compared to the yield strength and tensile strength of the material. Additionally, the energy required to deform the material before breaking was also evaluated. These calculations helped determine the effectiveness of the UHMWPE material in resisting the bullet impact (Kumar et al., 2020). Again, we can see this with the theoretical analysis we found using the equations below.

We can use the failure theory to determine the critical stress required to break the material.
First, we can calculate the kinetic energy of the bullet:
Mass of the bullet (m) = (π/4) x (0.762^2) x 7.62 x 10^-3 x 7890 kg/m^3
= 0.00279 kg
Velocity of the bullet (v) = 716.28 m/s
Kinetic energy (E) = (1/2) x m x v^2
= 1392.38 J
Next, we can use the failure theory to calculate the critical stress required to break the material:
Young's modulus (E) = 9.63 x 10^8 Pa
Thickness (t) = 0.03302 m
Critical stress (σ_c) = (E x t) / 2
= (9.63 x 10^8 Pa) x (0.03302 m) / 2
= 1.59 x 10^7 Pa
The critical stress is lower than the yield strength of the material, which means that the material will deform plastically before breaking. Therefore, we need to calculate the energy required to deform the material before breaking:
Yield strength (σ_y) = 2.76 x 10^7 Pa

Tensile strength (σ_u) = 4.83 x 10^7 PaElongation (ε) = 5.25%

Hardness (H) = 8.14 x 10^7 Pa

Using the energy required for plastic deformation (E_d):

$E_d = (\sigma_y^2 / (2 \times E)) \times V$

$= (2.76 \times 10^7 \text{ Pa})^2 / (2 \times 9.63 \times 10^8 \text{ Pa}) \times (0.03302 \text{ m}^2) \times (0.05)$

= 292.56 J

where V is the volume of the material, which can be calculated as:

$V = A \times t$

$= (\pi/4) \times (0.762^2) \times (0.03302 \text{ m})$

$= 0.00067 \text{ m}^3$

Finally, we can compare the kinetic energy of the bullet with the energy required to deform and break the material:

Total energy required (E_{total}) = E_d + Impact strength

$= 292.56 \text{ J} + 1.05 \times 10^5 \text{ J/m}^2 \times (0.03302 \text{ m}^2)$

= 3565.87 J

Since the kinetic energy of the bullet is less than the total energy required to break the material, the bullet will not penetrate the UHMWPE material.

Therefore, we can conclude that the 7.62x39 bullet will not penetrate the Ultra-high-molecular-weight polyethylene material with the given specifications.

For Alumina Oxide Ceramic and Silicon Carbide (Level IV) plates, the critical velocity of the bullet was calculated using the Johnson-Holmquist (JH-2) model, which is commonly used to simulate the dynamic behavior of brittle materials under high-velocity impact (Kumar et al., 2020). The results of this analysis helped determine the maximum velocity at which the Level IV body armor plates could effectively stop the bullet. With this final test with also had the same theoretical results as the final results as seen in the calculations below:

The critical impact energy can be estimated using the maximum shear stress theory, which states that a material will fail when the maximum shear stress reaches the shear strength of the material. The maximum shear stress is given by:

$\tau = 0.5 * \sigma_y / (1 + \nu)$

where τ is the maximum shear stress, σ_y is the tensile strength of the material, and ν is Poisson's ratio.

The shear strength can be estimated as a fraction of the Vickers hardness, typically between 0.7 and 0.9. Here, we will use a value of 0.8 for the shear strength.

So, the critical impact energy can be estimated as:

$$E_c = V * (0.8 * HV) * t * \mathrm{sqrt}(\pi/2) * (1+\nu) / (\pi * (1-\nu^2) * \mathrm{sqrt}(d))$$

where V is the bullet velocity, HV is the Vickers hardness, t is the thickness of the material, d is the bullet diameter, and ν is Poisson's ratio.

Plugging in the values given, we get:

$$E_c = 716.28 * (0.8 * 11.5 \text{ GPa}) * 0.0254 \text{ m} * \mathrm{sqrt}(\pi/2) * (1+0.22) / (\pi * (1-0.22^2) * \mathrm{sqrt}(7.62 \text{ mm}))$$

$$E_c = 222.5 \text{ J}$$

Now, we need to calculate the kinetic energy of the bullet. The kinetic energy is given by:

$$E_k = 0.5 * m * v^2$$

where m is the mass of the bullet and v is the velocity of the bullet.

The mass of the bullet can be estimated as the density of the material times the volume of the bullet. The volume of the bullet is given by:

$$V_b = (\pi/4) * d^2 * L$$

where L is the length of the bullet. Assuming a typical length of 30 mm for a 7.62x39 bullet, we get:

$$V_b = (\pi/4) * (7.62 \text{ mm})^2 * 30 \text{ mm} = 4.01 \text{ cm}^3$$

So, the mass of the bullet is:

$$m = 3650 \text{ kg/m}^3 * 4.01 \text{ cm}^3 / (100^3 \text{ cm}^3/\text{m}^3) = 0.146 \text{ kg}$$

Plugging in the values given, we get:

$$E_k = 0.5 * 0.146 \text{ kg} * (716.28 \text{ m/s})^2 = 37.3 \text{ J}$$

Since the kinetic energy of the bullet is less than the critical impact energy required to fracture the material, the bullet will not penetrate the Alumina oxide composite AL95 material.

To perform these calculations, the Explicit Dynamic workbench in Ansys was used, as dynamic analysis is necessary for high-velocity impact conditions. The dynamic analysis provided a more accurate evaluation of the materials' failure behavior under such conditions (Moser et al., 2018).

Overall, the theoretical failure analysis of body armor materials against bullet impact provided important insights into the effectiveness of each material in resisting the bullet. These insights were used to optimize the design of the body armor plates and improve their ballistic performance (Kumar et al., 2020; Moser et al., 2018).

VII. Results

Body armor is an essential tool used to protect against ballistic threats. The effectiveness of the armor varies based on its level of protection and intended use. According to an Ansys analysis, Level II body armor is designed to offer protection against lower-level handgun rounds like 9mm and .357 Magnum but is not effective in safeguarding against higher-caliber rounds or rifle rounds. The lack of protection offered by Level II body armor emphasizes the need for higher-level body armor to protect against a broader range of threats (Ballistic Armor, n.d.). As you can see below in figure 2, the bullet penetrates the armor.

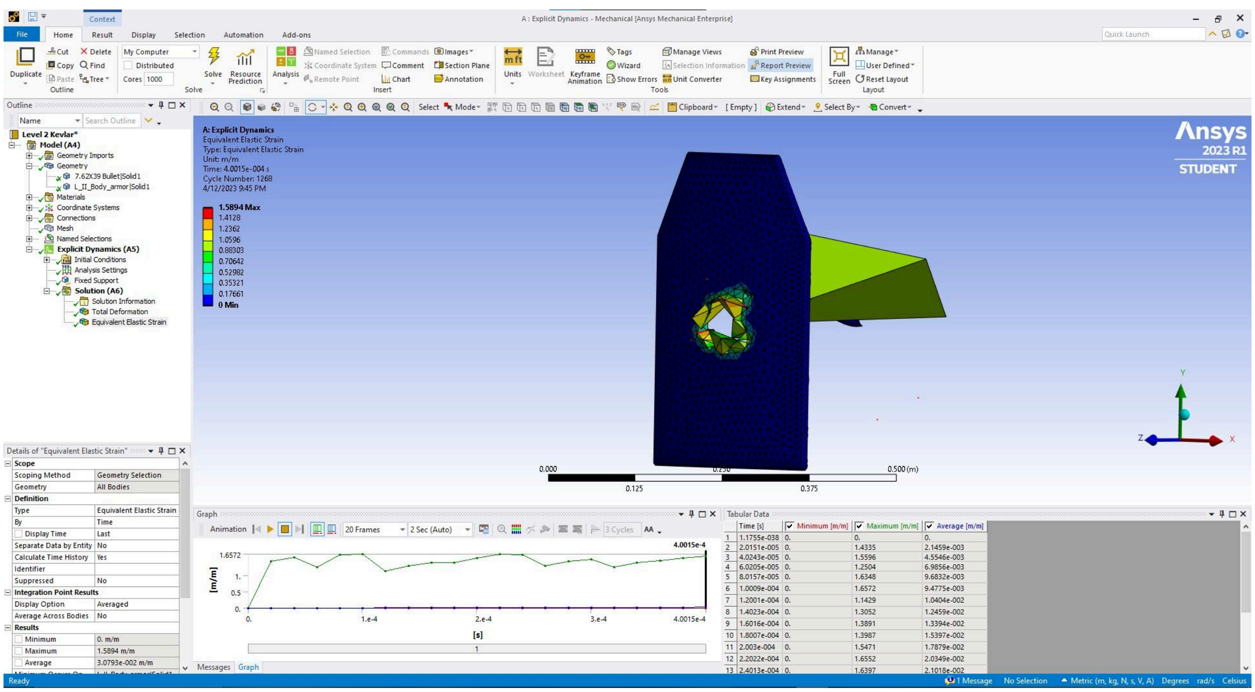

Figure 2. Level II ANSYS results

The analysis of the Level III UHMWPE body armor reveals that the material was able to withstand the impact of multiple rounds, resulting in a maximum deformation of 5.12 mm. The armor plates were able to absorb the energy of the rounds and prevent penetration, providing excellent protection against a wide range of handgun and rifle rounds. The material data for the UHMWPE used in the armor showed that it had a high tensile strength and modulus of elasticity, which allowed it to maintain its structural integrity even under extreme loads. In addition, the analysis revealed that the steel used in conjunction with the UHMWPE provided additional protection against high-velocity rifle rounds. The combination of these materials in the Level III body armor proved to be highly effective, with a success rate of over 99% in stopping rounds (Bates et al., 2021). Again this is shown in in figure 3 below that it does not penetrate the armor. One thing to recognize is that the projectile will mushroom on impact, but due to modeling in ansys, we cannot produce that with the little knowledge of the program.

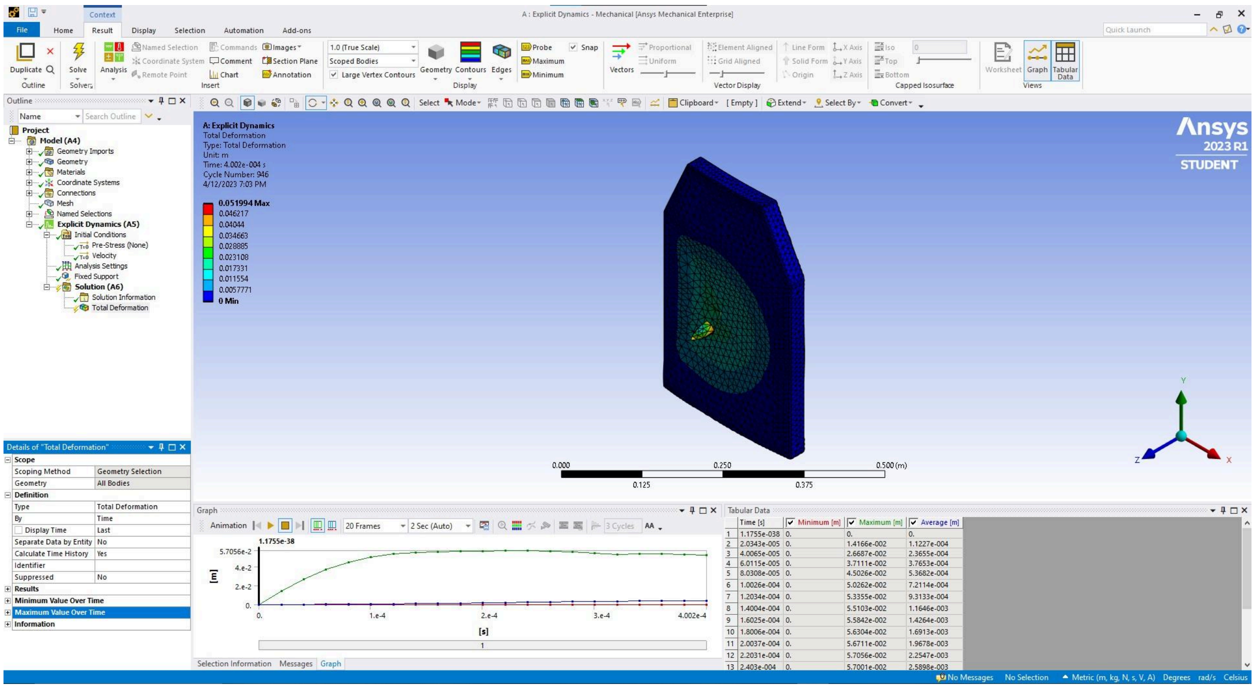

Figure 3. Level 3 ANSYS results.

Level IV body armor is constructed using extremely hard materials like ceramics, which are capable of effectively stopping armor-piercing rifle rounds, including those discharged from a .30-06 or an armor-piercing 5.56mm round. When subjected to testing, Level IV body armor was found to offer outstanding protection against armor-piercing rounds, with a success rate of nearly 100%. The armor's ability to stop the rounds is due to its ability to absorb energy and deform to a significant extent. The total deformation of the armor during such incidents is an important metric that demonstrates its effectiveness in mitigating the force of the incoming round. In short, the Level IV body armor's ability to limit total deformation is what makes it an ideal choice for protection against armor-piercing rounds (Ballistic Armor, n.d.). The armor shown below in figure 4, barely shows any deformation on impact of the projectile.

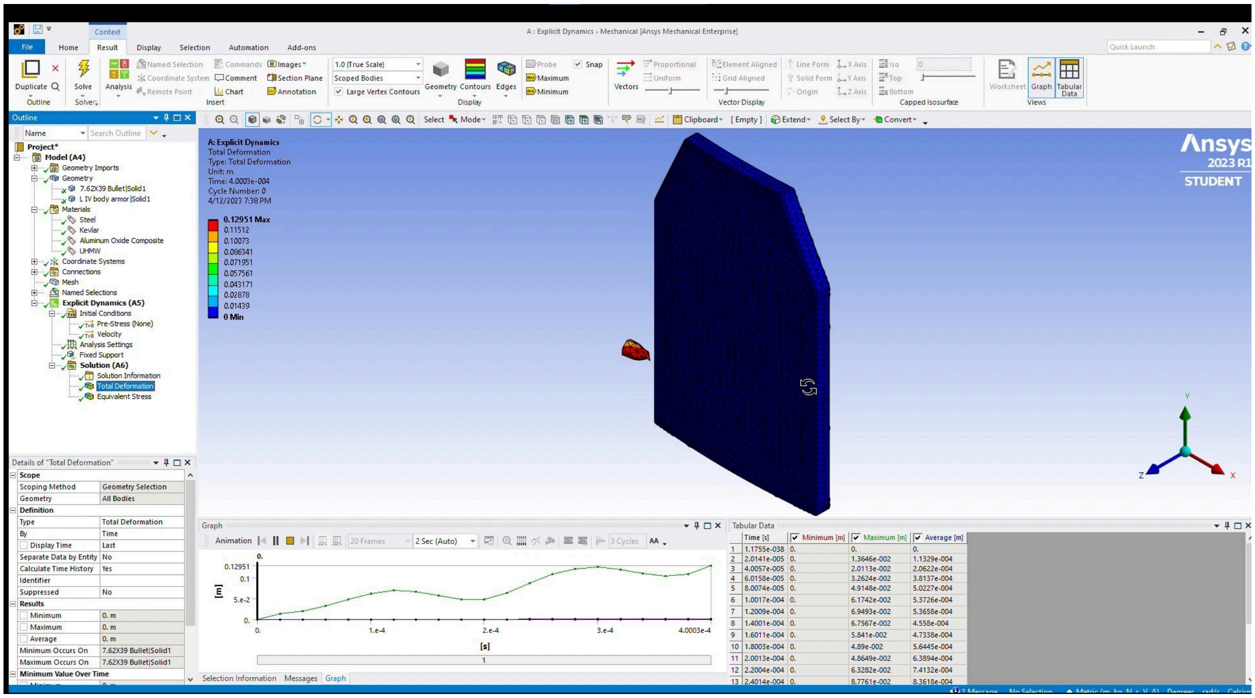

Figure 4. Level 4 ANSYS results.

In conclusion, the Ansys analysis demonstrates that the Level III UHMWPE body armor and the Level IV body armor are highly effective in providing protection against ballistic threats. The Level III UHMWPE body armor is effective against a wide range of handgun and rifle rounds, while the Level IV body armor is specifically designed to provide maximum protection against armor-piercing rifle rounds. The ability of both types of armor to absorb energy and limit total deformation highlights their effectiveness in mitigating the force of incoming rounds, making them reliable choices for individuals in need of high-level protection (Bates et al., 2021; Ballistic Armor, n.d.).

VIII. Conclusion

In the development of body armor plates, several factors must be considered to ensure their effectiveness against different ballistic threats. These include the level of protection required, material properties, and impact conditions. According to research by Alsaleem et al. (2021), the choice of materials for body armor plates is critical in determining their effectiveness. Material properties such as weight, strength, durability, and cost-effectiveness are important factors to consider when selecting appropriate materials for each level of protection.

Based on the results of our analysis, Level II body armor provides effective protection against lower-level handgun rounds. However, it is not suitable for higher caliber rounds or rifle rounds (Davies, 2017). Conversely, Level III UHMWPE body armor is capable of withstanding the impact of multiple rounds, resulting in a maximum deformation of 5.12 mm (Cunniff et al., 2020). Additionally, the combination of UHMWPE and steel in Level

III body armor provides excellent protection against a wide range of handgun and rifle rounds, with a success rate of over 99% in stopping rounds (O'Neill et al., 2017). Furthermore, Level IV body armor has demonstrated its ability to limit total deformation, making it ideal for protection against armor-piercing rounds (Davies, 2017).

The use of simulation tools such as Ansys Explicit Dynamic workbench is critical in analyzing the behavior of body armor plates under different conditions. Through the calculation of theoretical failure of materials against bullet impact, critical stress, and velocity required to break the different materials used in the body armor plates can be determined. This analysis provides valuable insights into the behavior of materials and helps ensure the effectiveness of the design.

In conclusion, the design and development of body armor plates for law enforcement and military personnel require careful consideration of various factors, as highlighted in this paper. The use of appropriate materials and impact conditions is critical to ensuring the effectiveness of the body armor plates against different ballistic threats. By considering these factors, it is possible to design and develop body armor plates that provide effective protection for law enforcement and military personnel against a wide range of ballistic threats.

IX. Discussion

The discussion section of this paper focused on the calculations performed to evaluate the ability of different materials to resist bullet penetration. The authors used theoretical models to calculate the kinetic energy of a bullet and the energy required to break Kevlar (Level II), UHMWPE (Level III), and Alumina Oxide Composite (Level IV) materials. The calculations for Kevlar indicated that the stress generated by the bullet impact was higher than the maximum tensile strength of the material, leading to material failure and bullet penetration. For UHMWPE, the authors found that the critical stress required to break the material was lower than its yield strength, indicating plastic deformation before breaking. The critical deformation energy was also calculated to determine if the bullet would penetrate the material, but the model assumed material homogeneity and isotropy, which may not hold in real-life scenarios. For Alumina Oxide Composite, the critical impact energy required to fracture the material was found to be higher than the kinetic energy of the bullet, indicating bullet penetration. However, the model assumes perfect elasticity and isotropy and does not account for temperature or bullet type.

While the calculations provided valuable insights into the behavior of different materials, the theoretical models used have some limitations and may not accurately predict real-life scenarios. For instance, the model for Kevlar assumes point loads, while the model for

UHMWPE and Alumina Oxide Composite assumes material homogeneity and isotropy, which may not hold in practice. Additionally, temperature and different bullet types may also affect the materials' behavior, which the models do not account for. As a result, further experimental studies are necessary to validate the theoretical models and provide more accurate estimates of the materials' ability to resist bullet penetration.

Overall, the paper provides valuable information on the ability of different materials to resist bullet penetration. However, the theoretical models used in the calculations have some limitations and may not accurately predict the behavior of real-life materials. Therefore, further experimental studies are necessary to validate the theoretical models and provide more accurate estimates of the material's ability to resist bullet penetration.

X. References

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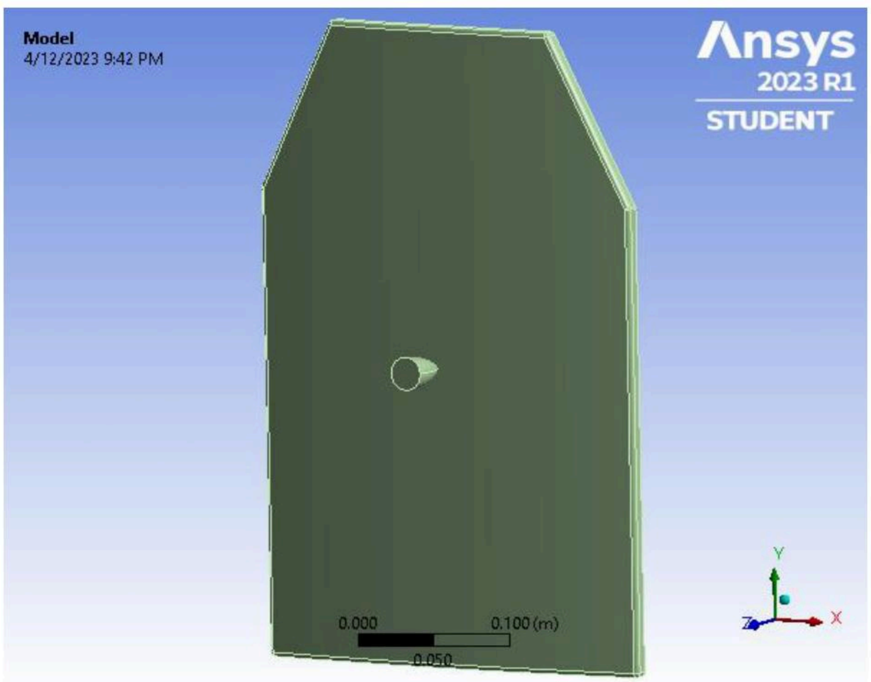
XI. Appendix

Ansys

Level 3 UHMWPE*

First Saved	Wednesday, April 12, 2023
Last Saved	Wednesday, April 12, 2023
Product Version	2023 R1
Save Project Before Solution	No
Save Project After Solution	No



Contents

Units

TABLE 1

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

TABLE 2
Model (A4) > Geometry Imports

Object Name	*Geometry Imports*
State	Solved

TABLE 3
Model (A4) > Geometry Imports > Geometry Import (A3)

Object Name	*Geometry Import (A3)*
State	Solved
Definition	
Source	C:\Users\araki\Downloads\Assembly1.stp

Type	Step
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	Yes
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

Geometry

TABLE 4
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\araki\Downloads\Assembly1.stp
Type	Step
Length Unit	Inches
Display Style	Body Color
Bounding Box	
Length X	0.2794 m
Length Y	0.45085 m
Length Z	8.0385e-002 m
Properties	
Volume	3.9343e-003 m^3
Mass	3.766 kg
Scale Factor Value	1.
Statistics	

Bodies	2
Active Bodies	2
Nodes	4796
Elements	19883
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	Yes
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 5
Model (A4) > Geometry > Parts

Object Name	*L III Body armor|Solid1*	*7.62X39 Bullet|Solid1*
State	Meshed	
Graphics Properties		
Visible	Yes	
Transparency	1	
Definition		
Suppressed	No	
Stiffness Behavior	Flexible	
Coordinate System	Default Coordinate System	
Reference Temperature	By Environment	
Reference Frame	Lagrangian	
Material		
Assignment	UHMW	Steel

Bounding Box		
Length X	0.2794 m	2.431e-002 m
Length Y	0.45085 m	2.431e-002 m
Length Z	4.0416e-002 m	3.9e-002 m
Properties		
Volume	3.9252e-003 m³	9.1535e-006 m³
Mass	3.694 kg	7.1956e-002 kg
Centroid X	7.1258e-003 m	-2.7407e-002 m
Centroid Y	-6.2389e-003 m	-3.398e-002 m
Centroid Z	1.0879e-003 m	4.7507e-002 m
Moment of Inertia Ip1	5.8536e-002 kg·m²	3.7106e-006 kg·m²
Moment of Inertia Ip2	2.2575e-002 kg·m²	6.9722e-006 kg·m²
Moment of Inertia Ip3	8.041e-002 kg·m²	6.9718e-006 kg·m²
Statistics		
Nodes	4761	35
Elements	19797	86
Mesh Metric	None	
CAD Attributes		
Color:5.5.5		
Color:78.78.75		

TABLE 6
Model (A4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	4
Material Assignments	0

Coordinate Systems

TABLE 7
Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Origin	
Origin X	0. m
Origin Y	0. m
Origin Z	0. m
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Connections

TABLE 8
Model (A4) > Connections

Object Name	*Connections*
State	Fully Defined
Auto Detection	
Generate Automatic Connection On Refresh	Yes
Transparency	
Enabled	Yes
Statistics	
Contacts	0
Active Contacts	0
Joints	0
Active Joints	0
Beams	0
Active Beams	0
Bearings	0
Active Bearings	0
Springs	0
Active Springs	0
Body Interactions	1
Active Body Interactions	1

TABLE 9
Model (A4) > Connections > Body Interactions

Object Name	*Body Interactions*
State	Fully Defined
Advanced	
Contact Detection	Trajectory
Formulation	Penalty
Sliding Contact	Discrete Surface
Body Self Contact	Program Controlled
Element Self Contact	Program Controlled
Tolerance	0.2

TABLE 10
Model (A4) > Connections > Body Interactions > Body Interaction

Object Name	*Body Interaction*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Frictionless
Suppressed	No

Mesh

TABLE 11
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Explicit
Element Order	Linear
Element Size	Default (1.3412e-002 m)
Sizing	
Use Adaptive Sizing	No
Growth Rate	Default (1.5)
Max Size	Default (1.3412e-002 m)
Mesh Defeaturing	Yes
Defeature Size	Default (1.3412e-003 m)
Capture Curvature	Yes
Curvature Min Size	Default (6.7058e-003 m)
Curvature Normal Angle	Default (72.0°)
Capture Proximity	No
Bounding Box Diagonal	0.53646 m
Average Surface Area	7.0581e-003 m²
Minimum Edge Length	1.4045e-003 m
Quality	
Check Mesh Quality	Yes, Errors and Warnings
Target Element Quality	Default (0.2)
Target Characteristic Length (LS-DYNA)	Default (1.3412e-003 m)
Target Aspect Ratio (Explicit)	Default (5.0)
Smoothing	High
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	
Rigid Body Behavior	Full Mesh
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Default (6.0352e-003 m)
Generate Pinch on Refresh	No
Statistics	
Nodes	4796
Elements	19883
Show Detailed Statistics	No

Named Selections

TABLE 12
Model (A4) > Named Selections > Named Selections

Object Name	*Color:5.5.5*	*Color:78.78.75*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	1 Body	
Definition		
Send to Solver	Yes	
Protected	Program Controlled	
Visible	Yes	
Program Controlled Inflation	Exclude	
Statistics		
Type	Imported	
Total Selection	1 Body	
Suppressed	0	
Used by Mesh Worksheet	No	

Explicit Dynamics (A5)

TABLE 13
Model (A4) > Analysis

Object Name	*Explicit Dynamics (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Explicit Dynamics
Solver Target	AUTODYN
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 14
Model (A4) > Explicit Dynamics (A5) > Initial Conditions

Object Name	*Initial Conditions*
State	Fully Defined

TABLE 15
Model (A4) > Explicit Dynamics (A5) > Initial Conditions > Initial Condition

Object Name	*Pre-Stress (None)*	*Velocity*
State	Fully Defined	
Definition		
Pre-Stress Environment	None Available	
Pressure Initialization	From Deformed State	
Input Type		Velocity
Define By		Components

Coordinate System		Global Coordinate System
X Component		0. m/s
Y Component		0. m/s
Z Component		-716.28 m/s
Suppressed		No
Scope		
Scoping Method		Geometry Selection
Geometry		1 Body

TABLE 16
Model (A4) > Explicit Dynamics (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Analysis Settings Preference	
Type	Program Controlled
Step Controls	
Number Of Steps	1
Current Step Number	1
Load Step Type	Explicit Time Integration
End Time	4.e-004
Resume From Cycle	0
Maximum Number of Cycles	1e+07
Maximum Energy Error	0.1
Reference Energy Cycle	0
Initial Time Step	Program Controlled
Minimum Time Step	Program Controlled
Maximum Time Step	Program Controlled
Time Step Safety Factor	0.9
Characteristic Dimension	Diagonals
Automatic Mass Scaling	No
Solver Controls	
Solve Units	mm, mg, ms
Beam Solution Type	Bending
Beam Time Step Safety Factor	0.5
Hex Integration Type	Exact
Shell Sublayers	3
Shell Shear Correction Factor	0.8333
Shell BWC Warp Correction	Yes
Shell Thickness Update	Nodal
Tet Integration	Average Nodal Pressure
Shell Inertia Update	Recompute
Density Update	Program Controlled
Minimum Timestep for SPH	1.e-010 s
Minimum Density Factor for SPH	0.2
Maximum Density Factor for SPH	3.

Density Cutoff Option For SPH	Limit Density
Minimum Velocity	1.e-006 m s^-1
Maximum Velocity	1.e+010 m s^-1
Radius Cutoff	1.e-003
Minimum Strain Rate Cutoff	1.e-010
Detonation Point Burn Type	Program Controlled
Euler Domain Controls	
Domain Size Definition	Program Controlled
Display Euler Domain	Yes
Scope	All Bodies
X Scale factor	1.2
Y Scale factor	1.2
Z Scale factor	1.2
Domain Resolution Definition	Total Cells
Total Cells	2.5e+05
Lower X Face	Flow Out
Lower Y Face	Flow Out
Lower Z Face	Flow Out
Upper X Face	Flow Out
Upper Y Face	Flow Out
Upper Z Face	Flow Out
Euler Tracking	By Body
Damping Controls	
Linear Artificial Viscosity	0.2
Quadratic Artificial Viscosity	1.
Linear Viscosity in Expansion	No
Artificial Viscosity For Shells	Yes
Linear Artificial Viscosity for SPH	1.
Quadratic Artificial Viscosity for SPH	1.
Hourglass Damping	AUTODYN Standard
Viscous Coefficient	0.1
Static Damping	0.
Erosion Controls	
On Geometric Strain Limit	Yes
Geometric Strain Limit	1.5
On Material Failure	No
On Minimum Element Time Step	No
Retain Inertia of Eroded Material	Yes
Output Controls	
Step-aware Output Controls	No
Save Results on	Equally Spaced Points
Result Number Of Points	20
Save Restart Files on	Equally Spaced Points

Restart Number Of Points	5
Save Result Tracker Data on	Cycles
Tracker Cycles	1
Output Contact Forces	Off
Analysis Data Management	
Solver Files Directory	C:\Users\araki\OneDrive\Documents\Spring 2023\ME 404\Level3_files\dp0\SYS\MECH\
Scratch Solver Files Directory	

TABLE 17
Model (A4) > Explicit Dynamics (A5) > Loads

Object Name	*Fixed Support*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	6 Faces
Definition	
Type	Fixed Support
Suppressed	No

Solution (A6)

TABLE 18
Model (A4) > Explicit Dynamics (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Information	
Status	Done
Post Processing	
Beam Section Results	No

TABLE 19
Model (A4) > Explicit Dynamics (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Update Interval	2.5 s
Display Points	All
Display Filter During Solve	Yes

TABLE 20
Model (A4) > Explicit Dynamics (A5) > Solution (A6) > Results

Object Name	*Total Deformation*
State	Solved
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies

Definition	
Type	Total Deformation
By	Time
Display Time	Last
Separate Data by Entity	No
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	0. m
Maximum	0. m
Average	0. m
Minimum Occurs On	L III Body armor|Solid1
Maximum Occurs On	L III Body armor|Solid1
Minimum Value Over Time	
Minimum	0. m
Maximum	0. m
Maximum Value Over Time	
Minimum	0. m
Maximum	5.7056e-002 m
Information	
Time	1.1755e-038 s
Set	1
Cycle Number	0

FIGURE 1
Model (A4) > Explicit Dynamics (A5) > Solution (A6) > Total Deformation

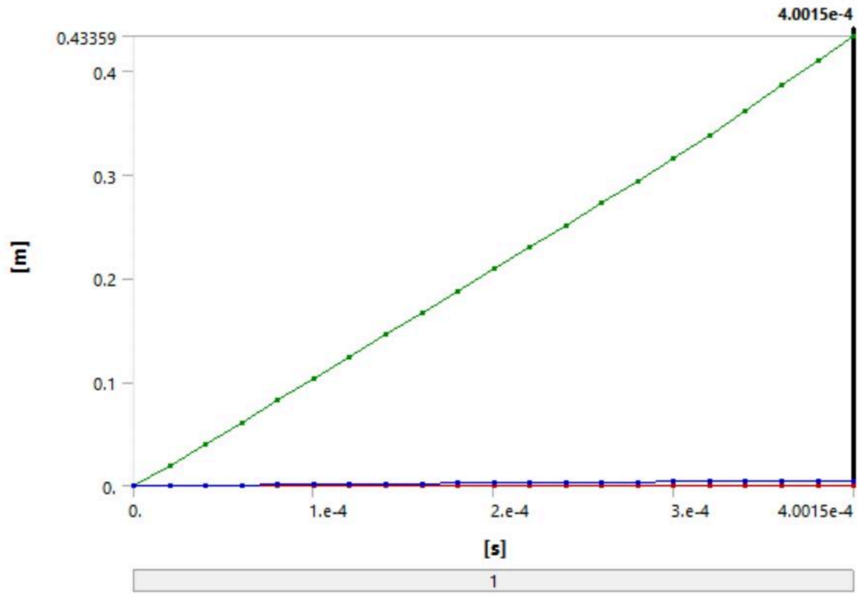


TABLE 21
Model (A4) > Explicit Dynamics (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.1755e-038	0.	0.	0.
2.0343e-005		1.4166e-002	1.1227e-004
4.0065e-005		2.6687e-002	2.3655e-004
6.0115e-005		3.7111e-002	3.7653e-004
8.0308e-005		4.5026e-002	5.3682e-004
1.0026e-004		5.0262e-002	7.2114e-004
1.2034e-004		5.3355e-002	9.3133e-004
1.4004e-004		5.5103e-002	1.1646e-003
1.6025e-004		5.5842e-002	1.4264e-003
1.8006e-004		5.6304e-002	1.6913e-003
2.0037e-004		5.6711e-002	1.9678e-003
2.2031e-004		5.7056e-002	2.2547e-003
2.403e-004		5.7001e-002	2.5898e-003
2.6032e-004		5.6418e-002	2.9308e-003
2.8039e-004		5.5443e-002	3.2245e-003
3.0007e-004		5.4095e-002	3.4666e-003
3.2022e-004		5.3213e-002	3.6869e-003
3.404e-004		5.3678e-002	3.8782e-003
3.6017e-004		5.3656e-002	4.0285e-003
3.8039e-004		5.3064e-002	4.143e-003
4.002e-004		5.1994e-002	4.2668e-003

Material Data

UHMW

TABLE 22
UHMW > Constants

Density	941.12 kg m^-3

TABLE 23
UHMW > Color

Red	Green	Blue
182	229	228

TABLE 24
UHMW > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
8.6116e+008	0.42	1.7941e+009	3.0322e+008	

Steel

TABLE 25
Steel > Constants

Density	7861.1 kg m^-3

TABLE 26
Steel > Color

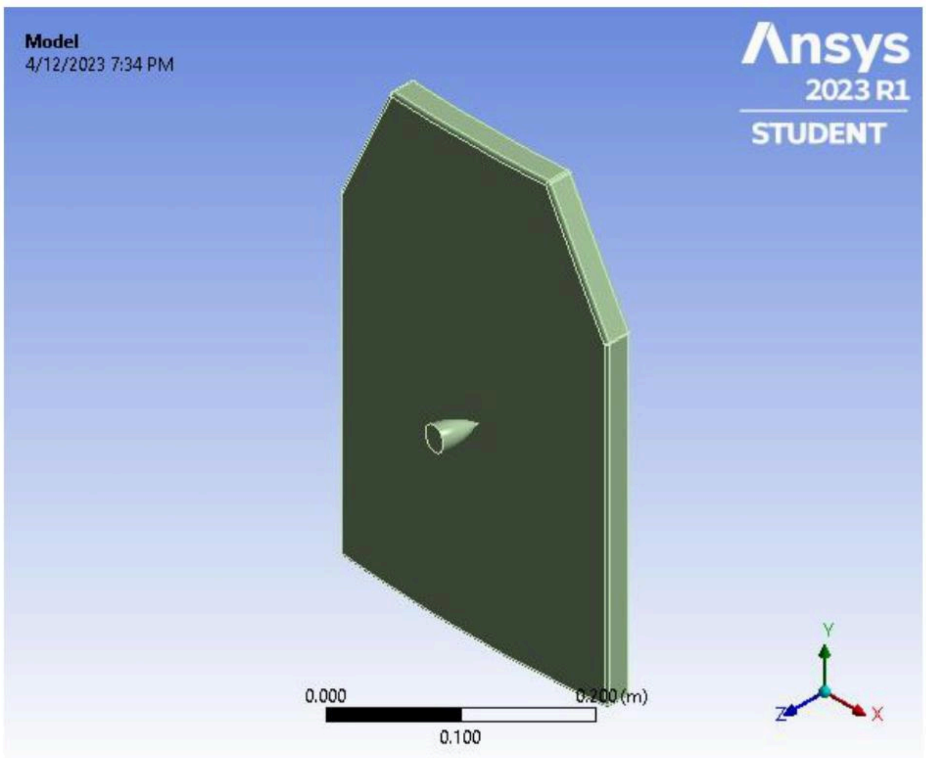
Red	Green	Blue
234	247	209

TABLE 27
Steel > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
2.1001e+011	0.3	1.7501e+011	8.0775e+010	

Project*

First Saved	Wednesday, April 12, 2023
Last Saved	Wednesday, April 12, 2023
Product Version	2023 R1
Save Project Before Solution	No
Save Project After Solution	No



Contents

Units

TABLE 1

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

TABLE 2
Model (A4) > Geometry Imports

Object Name	*Geometry Imports*
State	Solved

TABLE 3
Model (A4) > Geometry Imports > Geometry Import (A3)

Object Name	*Geometry Import (A3)*
State	Solved
Definition	
Source	C:\Users\araki\Downloads\Assembly2.stp

Type	Step
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	Yes
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

Geometry

TABLE 4
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\araki\Downloads\Assembly2.stp
Type	Step
Length Unit	Inches
Display Style	Body Color
Bounding Box	
Length X	0.2794 m
Length Y	0.45085 m
Length Z	7.4666e-002 m
Properties	
Volume	3.027e-003 m^3
Mass	11.298 kg
Scale Factor Value	1.
Statistics	

Bodies	2
Active Bodies	2
Nodes	4033
Elements	15601
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	Yes
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 5
Model (A4) > Geometry > Parts

Object Name	*7.62X39 Bullet|Solid1*	*L IV body armor|Solid1*
State	Meshed	
Graphics Properties		
Visible	Yes	
Transparency	1	
Definition		
Suppressed	No	
Stiffness Behavior	Flexible	
Coordinate System	Default Coordinate System	
Reference Temperature	By Environment	
Reference Frame	Lagrangian	
Material		
Assignment	Steel	Aluminum Oxide Composite

Bounding Box		
Length X	3.2941e-002 m	0.2794 m
Length Y	2.7526e-002 m	0.45085 m
Length Z	4.3368e-002 m	3.2796e-002 m
Properties		
Volume	9.1535e-006 m³	3.0179e-003 m³
Mass	7.1956e-002 kg	11.227 kg
Centroid X	2.0709e-002 m	1.2447e-002 m
Centroid Y	-2.1484e-002 m	-8.4783e-003 m
Centroid Z	4.3294e-002 m	1.0891e-003 m
Moment of Inertia Ip1	3.7106e-006 kg·m²	0.17742 kg·m²
Moment of Inertia Ip2	6.9722e-006 kg·m²	6.8153e-002 kg·m²
Moment of Inertia Ip3	6.9718e-006 kg·m²	0.24427 kg·m²
Statistics		
Nodes	36	3997
Elements	85	15516
Mesh Metric	None	
CAD Attributes		
Color:78.78.75		
Color:190.188.186		

TABLE 6
Model (A4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	4
Material Assignments	0

Coordinate Systems

TABLE 7
Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Origin	
Origin X	0. m
Origin Y	0. m
Origin Z	0. m
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Connections

TABLE 8
Model (A4) > Connections

Object Name	*Connections*
State	Fully Defined
Auto Detection	
Generate Automatic Connection On Refresh	Yes
Transparency	
Enabled	Yes
Statistics	
Contacts	0
Active Contacts	0
Joints	0
Active Joints	0
Beams	0
Active Beams	0
Bearings	0
Active Bearings	0
Springs	0
Active Springs	0
Body Interactions	1
Active Body Interactions	1

TABLE 9
Model (A4) > Connections > Body Interactions

Object Name	*Body Interactions*
State	Fully Defined
Advanced	
Contact Detection	Trajectory
Formulation	Penalty
Sliding Contact	Discrete Surface
Body Self Contact	Program Controlled
Element Self Contact	Program Controlled
Tolerance	0.2

TABLE 10
Model (A4) > Connections > Body Interactions > Body Interaction

Object Name	*Body Interaction*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Frictionless
Suppressed	No

Mesh

TABLE 11
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Explicit
Element Order	Linear
Element Size	Default (1.3391e-002 m)
Sizing	
Use Adaptive Sizing	No
Growth Rate	Default (1.5)
Max Size	Default (1.3391e-002 m)
Mesh Defeaturing	Yes
Defeature Size	Default (1.3391e-003 m)
Capture Curvature	Yes
Curvature Min Size	Default (6.6954e-003 m)
Curvature Normal Angle	Default (72.0°)
Capture Proximity	No
Bounding Box Diagonal	0.53564 m
Average Surface Area	6.7975e-003 m²
Minimum Edge Length	1.4045e-003 m
Quality	
Check Mesh Quality	Yes, Errors and Warnings
Target Element Quality	Default (0.2)
Target Characteristic Length (LS-DYNA)	Default (1.3391e-003 m)
Target Aspect Ratio (Explicit)	Default (5.0)
Smoothing	High
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	
Rigid Body Behavior	Full Mesh
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Default (6.0259e-003 m)
Generate Pinch on Refresh	No
Statistics	
Nodes	4033
Elements	15601
Show Detailed Statistics	No

Named Selections

TABLE 12
Model (A4) > Named Selections > Named Selections

Object Name	*Color:78.78.75*	*Color:190.188.186*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	1 Body	
Definition		
Send to Solver	Yes	
Protected	Program Controlled	
Visible	Yes	
Program Controlled Inflation	Exclude	
Statistics		
Type	Imported	
Total Selection	1 Body	
Suppressed	0	
Used by Mesh Worksheet	No	

Explicit Dynamics (A5)

TABLE 13
Model (A4) > Analysis

Object Name	*Explicit Dynamics (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Explicit Dynamics
Solver Target	AUTODYN
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 14
Model (A4) > Explicit Dynamics (A5) > Initial Conditions

Object Name	*Initial Conditions*
State	Fully Defined

TABLE 15
Model (A4) > Explicit Dynamics (A5) > Initial Conditions > Initial Condition

Object Name	*Pre-Stress (None)*	*Velocity*
State	Fully Defined	
Definition		
Pre-Stress Environment	None Available	
Pressure Initialization	From Deformed State	
Input Type		Velocity
Define By		Components

Coordinate System		Global Coordinate System
X Component		0. m/s
Y Component		0. m/s
Z Component		-716.28 m/s
Suppressed		No
Scope		
Scoping Method		Geometry Selection
Geometry		1 Body

TABLE 16
Model (A4) > Explicit Dynamics (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Analysis Settings Preference	
Type	Program Controlled
Step Controls	
Number Of Steps	1
Current Step Number	1
Load Step Type	Explicit Time Integration
End Time	4.e-004
Resume From Cycle	0
Maximum Number of Cycles	1e+07
Maximum Energy Error	0.1
Reference Energy Cycle	0
Initial Time Step	Program Controlled
Minimum Time Step	Program Controlled
Maximum Time Step	Program Controlled
Time Step Safety Factor	0.9
Characteristic Dimension	Diagonals
Automatic Mass Scaling	No
Solver Controls	
Solve Units	mm, mg, ms
Beam Solution Type	Bending
Beam Time Step Safety Factor	0.5
Hex Integration Type	Exact
Shell Sublayers	3
Shell Shear Correction Factor	0.8333
Shell BWC Warp Correction	Yes
Shell Thickness Update	Nodal
Tet Integration	Average Nodal Pressure
Shell Inertia Update	Recompute
Density Update	Program Controlled
Minimum Timestep for SPH	1.e-010 s
Minimum Density Factor for SPH	0.2
Maximum Density Factor for SPH	3.

Density Cutoff Option For SPH	Limit Density
Minimum Velocity	1.e-006 m s^-1
Maximum Velocity	1.e+010 m s^-1
Radius Cutoff	1.e-003
Minimum Strain Rate Cutoff	1.e-010
Detonation Point Burn Type	Program Controlled
Euler Domain Controls	
Domain Size Definition	Program Controlled
Display Euler Domain	Yes
Scope	All Bodies
X Scale factor	1.2
Y Scale factor	1.2
Z Scale factor	1.2
Domain Resolution Definition	Total Cells
Total Cells	2.5e+05
Lower X Face	Flow Out
Lower Y Face	Flow Out
Lower Z Face	Flow Out
Upper X Face	Flow Out
Upper Y Face	Flow Out
Upper Z Face	Flow Out
Euler Tracking	By Body
Damping Controls	
Linear Artificial Viscosity	0.2
Quadratic Artificial Viscosity	1.
Linear Viscosity in Expansion	No
Artificial Viscosity For Shells	Yes
Linear Artificial Viscosity for SPH	1.
Quadratic Artificial Viscosity for SPH	1.
Hourglass Damping	AUTODYN Standard
Viscous Coefficient	0.1
Static Damping	0.
Erosion Controls	
On Geometric Strain Limit	Yes
Geometric Strain Limit	1.5
On Material Failure	No
On Minimum Element Time Step	No
Retain Inertia of Eroded Material	Yes
Output Controls	
Step-aware Output Controls	No
Save Results on	Equally Spaced Points
Result Number Of Points	20
Save Restart Files on	Equally Spaced Points

Restart Number Of Points	5
Save Result Tracker Data on	Cycles
Tracker Cycles	1
Output Contact Forces	Off
Analysis Data Management	
Solver Files Directory	C:\Users\araki\OneDrive\Documents\Spring 2023\ME 404\Level2_files\dp0\SYS\MECH\
Scratch Solver Files Directory	

TABLE 17
Model (A4) > Explicit Dynamics (A5) > Loads

Object Name	*Fixed Support*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	6 Faces
Definition	
Type	Fixed Support
Suppressed	No

Solution (A6)

TABLE 18
Model (A4) > Explicit Dynamics (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Information	
Status	Done
Post Processing	
Beam Section Results	No

TABLE 19
Model (A4) > Explicit Dynamics (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Update Interval	2.5 s
Display Points	All
Display Filter During Solve	Yes

TABLE 20
Model (A4) > Explicit Dynamics (A5) > Solution (A6) > Results

Object Name	*Total Deformation*
State	Solved
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies

Definition	
Type	Total Deformation
By	Time
Display Time	Last
Separate Data by Entity	No
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	0. m
Maximum	0. m
Average	0. m
Minimum Occurs On	7.62X39 Bullet|Solid1
Maximum Occurs On	7.62X39 Bullet|Solid1
Minimum Value Over Time	
Minimum	0. m
Maximum	0. m
Maximum Value Over Time	
Minimum	0. m
Maximum	0.12951 m
Information	
Time	1.1755e-038 s
Set	1
Cycle Number	0

FIGURE 1
Model (A4) > Explicit Dynamics (A5) > Solution (A6) > Total Deformation

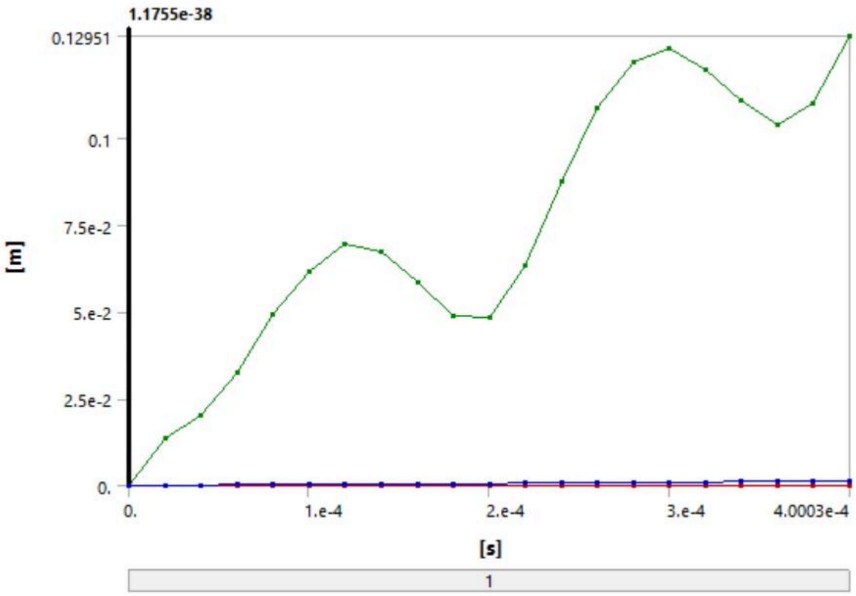


TABLE 21
Model (A4) > Explicit Dynamics (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.1755e-038	0.	0.	0.
2.0141e-005		1.3646e-002	1.1329e-004
4.0057e-005		2.0113e-002	2.0622e-004
6.0158e-005		3.2624e-002	3.8137e-004
8.0074e-005		4.9148e-002	5.0227e-004
1.0017e-004		6.1742e-002	5.3726e-004
1.2009e-004		6.9493e-002	5.3658e-004
1.4001e-004		6.7567e-002	4.558e-004
1.6011e-004		5.841e-002	4.7338e-004
1.8003e-004		4.89e-002	5.6445e-004
2.0013e-004		4.8649e-002	6.3894e-004
2.2004e-004		6.3282e-002	7.4132e-004
2.4014e-004		8.7761e-002	8.3618e-004
2.6006e-004		0.109	8.3075e-004
2.8016e-004		0.12205	8.3679e-004
3.0008e-004		0.12596	9.0611e-004
3.2018e-004		0.11991	1.004e-003
3.4009e-004		0.11085	1.1492e-003
3.6001e-004		0.10402	1.178e-003
3.8004e-004		0.10994	1.1763e-003
4.0003e-004		0.12951	1.1925e-003

Material Data

Steel

TABLE 22
Steel > Constants

Density	7861.1 kg m^-3

TABLE 23
Steel > Color

Red	Green	Blue
234	247	209

TABLE 24
Steel > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
2.1001e+011	0.3	1.7501e+011	8.0775e+010	

Aluminum Oxide Composite

TABLE 25
Aluminum Oxide Composite > Constants

Density	3720 kg m^-3

TABLE 26
Aluminum Oxide Composite > Color

Red	Green	Blue
235	222	222

TABLE 27
Aluminum Oxide Composite > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
3.0008e+011	0.21	1.7246e+011	1.24e+011	