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Numerical Investigation of Repeated Impact Ballistic Performance of High-Hardness ARMOX 600T Steel Against 0.3-Caliber FSP

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Abstract In this study, the ballistic response of high-hardness ARMOX 600T armor steel under repeated impacts of 0.3 caliber Fragment Simulating Projectiles (FSP) was numerically investigated. ARMOX 600T, with a Brinell hardness of approximately 600 HB, is widely used in heavy armor applications due to its excellent combination of hardness and impact resistance. It is particularly preferred in armored vehicle structures and fixed protection systems where high levels of ballistic protection are required. Numerical simulations were conducted using the ABAQUS/Explicit finite element software, and the material behavior was defined using the Johnson–Cook strength and damage model. Three successive impacts were applied to the same location of 5 mm thick ARMOX 600T plates at velocities of 500 m/s, 750 m/s, and 1000 m/s. The study comprehensively examined the deformation geometries and stress distributions of both the projectile and the armor plate. The results revealed that projectile velocity and the number of impacts play a critical role in maintaining the structural integrity of high-hardness steel armors subjected to repeated ballistic loads. In this context, the findings provide valuable insights for armor designers and researchers evaluating ballistic performance under multiple-hit scenarios.

0.3 Kalibre FSP Karşısında Yüksek Sertlikli ARMOX 600T Çeliğinin Tekrarlı Atışlardaki Balistik Performansının Sayısal Olarak İncelenmesi

Anahtar Kelimeler
ARMOX 600T,
Yüksek sertlikli zırh çeliği,
Tekrarlı darbe,
Balistik performans,
Sonlu elemanlar analizi

Öz: Bu çalışmada, yüksek sertlikli ARMOX 600T zırh çeliğinin 0.3 kalibre FSP (fragment simulating projectile) mermilere karşı tekrarlı balistik darbeler altındaki davranışı sayısal olarak incelenmiştir. ARMOX 600T, yaklaşık 600 HB (Brinell sertliği) değerine sahip olup, yüksek sertliği ve darbe dayanımı ile ağır zırh uygulamalarında yaygın olarak kullanılan bir zırh çeliğidir. Özellikle zırhlı araçlar ve sabit koruma sistemlerinde, yüksek seviyede balistik koruma sağlamak amacıyla tercih edilmektedir. Sayısal analizlerde sonlu elemanlar yöntemi tabanlı ABAQUS/Explicit yazılımı kullanılmış ve malzeme davranışı Johnson–Cook akma ve hasar modeli ile tanımlanmıştır. Her biri 5 mm kalınlığında olan ARMOX 600T zırh plakalarına, sırasıyla 500 m/s, 750 m/s ve 1000 m/s hızlarda üç tekrarlı atış uygulanmıştır. Atışlar aynı noktaya gelecek şekilde modellenerek, plakanın kümülatif hasar davranışı analiz edilmiştir. Elde edilen sonuçlar, tekrarlı darbelere maruz kalan yüksek sertlikli çelik zırhların yapısal bütünlüğünün korunmasında hızın ve darbe sayısının kritik rol oynadığını ortaya koymaktadır. Bu bağlamda, çalışma sonuçları hem zırh tasarımcılarına hem de balistik performans değerlendirmesi yapan araştırmacılara önemli bilgiler sunmaktadır.

1. Introduction

The changing perception of threats today and the nature of military conflicts have brought new requirements for the performance of ballistic protection systems [1], [2]. Especially urban conflicts, asymmetric warfare conditions, and the increased use of fragmenting munitions have necessitated making armor systems resistant not only to single munitions impacts but also to consecutive (repeated) strikes at the same point [3], [4]. In this context, the ability of ballistic armor to maintain its structural integrity not only against the first impact but also when exposed to multiple high-velocity munitions has become a critical engineering objective for modern defense systems . With this increasing need for protection, high hardness steel armor materials have gained importance. Due to both their cost and high mechanical performance, these materials are used in many areas from armored vehicles to fixed defense systems [5], [6]. However, the ballistic behavior of such materials has mostly been evaluated with single-shot scenarios, and the effect of consecutive impact loading has not been sufficiently investigated. However, in real field conditions, multiple ammunition impacts at short intervals on the same area of an armor plate can lead to a much different damage distribution and fragility development compared to the first impact. In this context, systematic analysis of repeated impact scenarios is of great importance for both theoretical and applied ballistic research. High hardness steels are advanced engineering materials that are widely used in ballistic systems. Materials in this class increase their deformation resistance, especially due to their high hardness values, and create an effective energy absorption mechanism against ammunition [7], [8]. While the high hardness level makes penetration on the first surface it encounters more difficult, it also helps the core structure spread the impact loads to a wider volume. ARMOX 600T steel, which stands out among high hardness steels, has a hardness of approximately 600 HB Brinell and draws attention with its impact resistance.

ARMOX 600T is currently used in applications requiring high-level ballistic protection such as armored carriers, land vehicles, security walls and fixed defense systems [9], [10]. The success of the material in these areas is related not only to its hardness value but also to its ability to maintain high ductility. However, one of the most important engineering dilemmas in such high hardness materials is that the tendency to crack increases with increasing hardness. Therefore, the behavior of steels such as ARMOX 600T against repeated ballistic impacts is of strategic importance in terms of material integrity, beyond superficial damage. Although experimental ballistic tests allow direct determination of the behavior of the material, the high cost, time-consuming and dangerous nature of these tests have led researchers to numerical modeling approaches. For this reason, the finite element method (FEM) is widely used in ballistic analyses due to its capacity to model complex impact and deformation behaviors with high accuracy [11], [12]. In particular, advanced simulation platforms such as ABAQUS/Explicit have become an important tool in the simulation of ballistic tests. One of the most critical elements in numerical modeling studies is the accurate definition of material behavior [13], [14]. The Johnson–Cook yield and damage model used for this purpose is a successful approach in representing complex behaviors of metal materials such as high-speed plastic deformation, temperature effects and strain rate changes [13], [14], [15]. The use of this model is important in terms of realistically reflecting the deformation process of both the armor plate and the FSP ammunition.

There are studies in the literature on the behavior of high-hardness steels under single ballistic impacts. These studies generally focus on results such as the penetration resistance of the material, crater depth, ballistic limit velocity and front-back face deformations. However, most of these studies have been carried out on a single shot. In real conflict environments, ammunition impact often leads to random or consecutive repeated impacts in the same area. Therefore, the local damage caused by the first impact causes the armor to weaken against subsequent impacts. For this reason, when evaluating the ballistic performance of the armor plate, it is necessary to focus not only on the first impact but also on how it resists repeated impacts. However, this subject has been studied very limitedly in the literature. Some studies conducted on the subject are summarized below.

Göde et al. (2023) [16] conducted repeated shots with 7.62×51mm M61 AP bullets on 12mm thick targets in their studies with ARMOX600T armor steel. According to the results obtained, it was stated that the steel plate prevented penetration in the first three shots; however, it was pierced in the plugging mode in the fourth shot. In addition, the authors examined and reported the damage in detail with microstructural analysis and optical scanning. Another study was conducted by Siriphala et al. (2012) [17]. Plugging is a common ballistic failure mode observed in high-strength metallic plates, characterized by the formation and ejection of a plug-shaped fragment from the rear surface of the target. This failure typically occurs when the projectile pushes through the material by shearing it along its boundary, rather than causing extensive ductile deformation. In the relevant study, firing tests were performed on the ARMOX600T plate with the M193 bullet and numerical model verification was performed with Euler solvers such as ABAQUS/Explicit. According to the results, the 7 mm thick plate stopped the bullet in the first three shots, while plug penetration was observed in the fourth shot. Qiang et al. (2022) [18] conducted numerical simulations of multiple FSP impacts on thin metal plates. Simulations using the Johnson–Cook model reported that the experimental data were in good agreement with less than 5% deviation. It was stated that there was hole growth, cracking, and load distribution on the plate, especially after double shots. A study on ARMOX 500T was also conducted by Mao et al. (2023) [19]. In the related study, high-velocity impacts were modeled with LS-DYNA/Explicit. Implicit fracture and penetration behaviors were investigated by updating the Johnson–Cook parameters. The model provided realistic damage predictions by comparing with experimental results. In a study conducted by Van der Wal et al. (2018) [20] , V_{50} tests were performed against FSP impacts by applying various pre-layer materials on ARMOX 600T and RAMOR 450 plates. It was stated that the V_{50} value of ARMOX 600T increased by approximately 100m/s with 6mm HPL coating. How the layered structure affects the impact is presented in detail. In the study of Göçmen et al. (2023) [21], ARMOX 500T steel was numerically considered with both Johnson–Cook and Modified Mohr–Coulomb (MMC) models. The MMC model with lode dependence predicted cracking better than JC.

The aim of this study is to numerically investigate the mechanical behavior of high hardness ARMOX 600T armor steel under three consecutive impacts with 0.3 caliber FSP ammunition. Three consecutive impacts at 500 m/s, 750 m/s and 1000 m/s velocities were applied to armor plates, each 5 mm thick, and the cumulative damage relationship with the number and speed of impacts was investigated. In numerical analyses, dynamic, high-speed impact events were modeled using ABAQUS/Explicit software and the deformation processes of both the ammunition and the armor plate were investigated in detail. The material behavior was defined with the Johnson–Cook yield and damage model; thus, both plastic deformation and crack formation were captured realistically. The simulation results comprehensively evaluated the effects of different impact velocities and consecutive loading on ballistic performance by revealing the stress distribution, penetration depth, back face deformations and structural integrity loss of the armor after each impact.

2. Numerical Methods

The numerical model developed in this study includes a 0.3 caliber Fragment Simulating Projectile (FSP), a high-hardness ARMOX 600T armor steel plate, and the clamping fixtures used to constrain the plate. Ballistic impact analyses were performed using the commercial finite element software ABAQUS/Explicit® [22], which is well-suited for solving highly dynamic, nonlinear problems such as high-velocity impacts. As illustrated in Figure 1, a detailed three-dimensional model was constructed to simulate the ballistic response of ARMOX 600T under repeated high-speed impacts. The chemical composition of ARMOX 600T is presented in Table 1, and it reflects the typical alloying elements used in ultra-high-hardness armor steels.

One of the most critical aspects of numerical analysis is the accurate definition of material models and their corresponding parameters to ensure realistic results. In this context, the Johnson–Cook constitutive and damage model was employed for both the ARMOX 600T armor plate and the FSP to capture strain rate-dependent plastic deformation and failure behavior under high-speed loading conditions. Both the armor and the projectile were modeled using reduced-integration 8-node 3D solid elements (C3D8R). The support and clamping fixtures were assumed to behave as rigid bodies and were represented using 4-node 3D rigid surface elements (R3D4).

For the boundary conditions, all degrees of freedom of the clamping fixtures were fixed to replicate the physical test constraints and prevent movement of the armor plate. The projectile was allowed to move only along the firing direction. Contact interactions between the projectile and the armor, as well as between the armor and the clamping fixtures, were defined using ABAQUS's General Contact algorithm. This algorithm provides a robust and efficient framework for capturing the complex contact behavior and surface interactions that occur during high-speed impacts.

This comprehensive modeling approach enabled detailed investigation of the plastic deformation, contact forces, stress accumulation, and progressive failure mechanisms occurring throughout the repeated impact process.

Table 1. Chemical Composition of Armox 600T [23]

Material	C max (%)	Si (%)	Mn max (%)	P max (%)	S max (%)	Cr max (%)	Ni max (%)	Mo max (%)	B max (%)
Armox 600T	0,47	0,1-0,7	1,0	0,010	0,005	1,5	3,0	0,7	0,005

The damage modeling of the materials used in this study is detailed in this section. The focus is primarily on the Johnson–Cook (J–C) constitutive and failure model, which is widely used to represent the plastic deformation, penetration, and perforation behavior of metallic armor plates under high strain-rate loading conditions. The model is also employed to characterize the failure behavior of the projectile material.

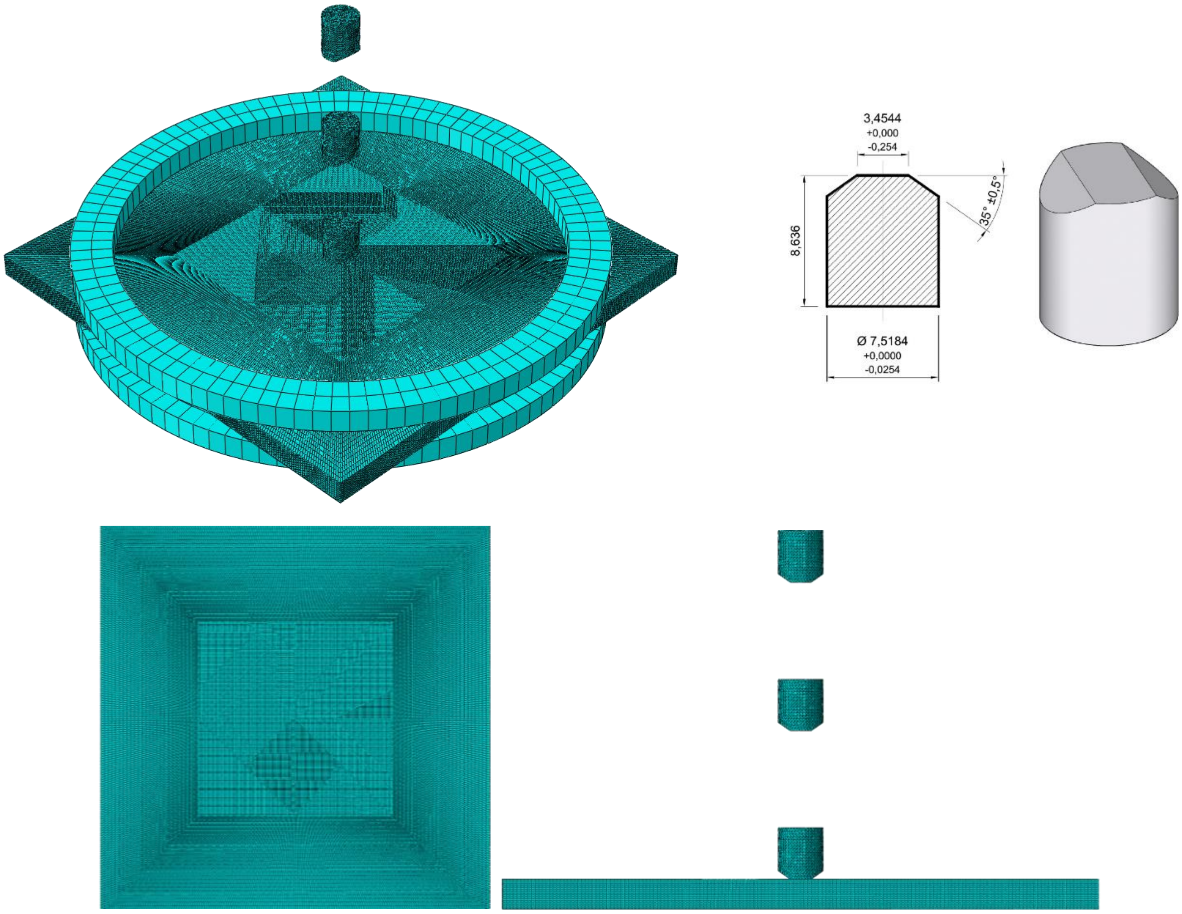

Figure 1. Numerical Model and 0.3 Caliber Simulated Projectile

The Johnson–Cook dynamic failure model is particularly suitable for simulating ductile damage in metals and is fully supported within ABAQUS/Explicit [22]. It defines the onset and evolution of damage based on an accumulative plastic strain criterion that considers the effects of stress triaxiality, strain rate, and temperature. The material parameters required for the J–C model are typically obtained from experimental studies involving quasi-static and dynamic mechanical testing.

The constitutive behavior of the ARMOX 600T armor steel, including its strength and failure parameters, is defined using the Johnson–Cook material model, as summarized in Table 2. The corresponding parameter values were taken from the literature [24], based on material tests conducted on high-hardness steels with similar compositions and mechanical characteristics.

The equivalent flow stress σ in the Johnson–Cook model is empirically described by Equation (1) [25]:

$$\sigma = [A + B(\varepsilon_p)^n]\left[1 + Cln\left(\frac{\dot{\varepsilon}_p}{\dot{\varepsilon}_0}\right)\right]\left[1 - \left(\frac{T - T_a}{T_f - T_a}\right)^m\right] \quad (1)$$

where:

- ε is the equivalent plastic strain,
- $\dot{\varepsilon}$ is the plastic strain rate,
- $\dot{\varepsilon}_0$ is the reference strain rate,
- T is the current temperature,
- $T_{room} and\ T_{melt}$ are the room and melting temperatures of the material, respectively,
- and A, B, C, n, m are material-specific constants.

This model effectively captures the material's strain rate sensitivity and thermal softening, both of which are critical in high-velocity impact scenarios.

The damage initiation and evolution criteria for the projectile material were also defined using a Johnson–Cook damage formulation, with specific parameter values derived from literature data on standard FSP materials. These parameters govern the onset of ductile fracture and are crucial for accurately predicting projectile break-up and penetration behavior.

Table 2. Johnson-Cook Material Model Parameters for Armox 600T [24]

Parameter	Armox 600T
Elastic Modulus, E/GPa	207
Specific Heat Capacity, cp, / J/kgK	450
Density, ρ/kg/m^3	7850
Melting Temperature, Tm/K	1800
Elastic Limit, A/GPa	1.58
Characteristic Constant for Plastic Behavior, B/GPa	0.958
Characteristic Constant for Plastic Behavior, n	0.175
Sensitivity to Strain Rate, C	0.00877
Material Constant Including Temperature Dependency, m	0.712

The Johnson–Cook dynamic damage model is based on the equivalent plastic strain accumulated at the integration points of finite elements. Failure is assumed to occur when the cumulative damage parameter exceeds a critical value of 1. The damage parameter, denoted as DDD, is defined as follows:

$$D = \sum\left(\frac{\Delta\varepsilon_{pl}}{\Delta\varepsilon_f}\right) \quad (2)$$

where:

- $\Delta\varepsilon_{pl}$ is the increment of equivalent plastic strain during each loading step,
- ε_f is the strain to fracture under the current state of stress, strain rate, and temperature.

The strain to fracture ε_f is further expressed as a function of stress triaxiality σ^*, strain rate $\dot{\varepsilon}$, and normalized temperature T^*, given by:

$$\varepsilon_f = [D_1 + D_2 \exp(D_3 \cdot \sigma^*)]\left[1 + D_4 \ln\left(\frac{\dot{\varepsilon}}{\dot{\varepsilon_0}}\right)\right][1 + D_5 T^*] \quad (3)$$

where:

- $\sigma^* = \frac{p}{\sigma_{eq}}$ is the stress triaxiality (ratio of hydrostatic pressure to equivalent von Mises stress),
- $T^* = \frac{T - T_{room}}{T_{melt} - T_{room}}$ is the homologous temperature,
- D_1 through D_5 are material constants determined experimentally.

This formulation enables the model to accurately predict failure under complex loading conditions, such as those encountered during high-velocity impact and penetration events.

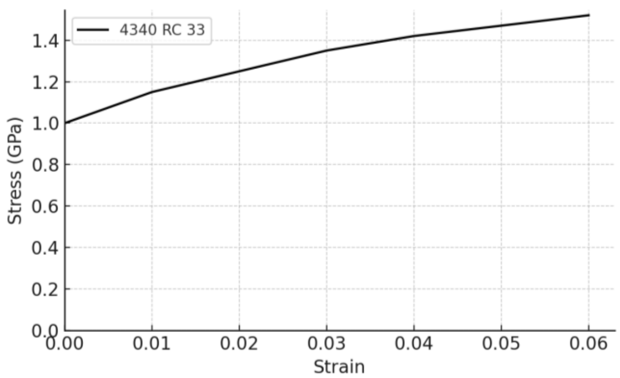

Figure 2. Stress-Strain Diagram of 4340 Steel (RC 33), Strain Rate: 500 /s [26]

Figure 2 shows the true stress–strain curve of the 0.3 caliber Fragment Simulating Projectile (FSP) made of AISI 4340 steel, obtained at a strain rate of 500/s and room temperature.

The ARMOX 600T armor plates used in this study have dimensions of 100 mm × 100 mm × 5 mm. In each simulation scenario, three successive impacts were applied to the same location on the plate. The impact velocities were defined as 500 m/s, 750 m/s, and 1000 m/s, respectively. To simulate repeated impact scenarios, three 0.3 caliber Fragment Simulating Projectiles (FSPs) were included in the numerical model. Through careful contact definitions in ABAQUS, interactions between the projectiles were suppressed, allowing each projectile to impact the previously deformed geometry without interference. This setup enables a more realistic representation of damage accumulation and degradation of structural integrity under multiple-hit conditions.

The projectiles used in the analysis are standard 0.3 caliber Fragment Simulating Projectiles (FSPs) made of AISI 4340 steel. These projectiles conform to the STANAG 4569 standard and are widely used for evaluating the penetration and perforation resistance of armor materials. In the numerical model, the geometry and material properties of the FSP were implemented based on data available in the literature [26].

In the numerical model, the target plate was represented by approximately 812,754 nodes and 761,914 elements, while the 0.3 caliber FSP projectile was modeled using 3,365 nodes and 16,635 elements. To enhance solution accuracy in the impact region, cubic elements with an edge length of approximately 0.1 mm were used on the contact surfaces between the plate and the projectile. Along the plate thickness, at least 18 layers of elements were assigned to accurately capture plastic deformation and stress accumulation during the high-speed impact event.

All degrees of freedom of the clamping fixtures were fully constrained to prevent any rigid body motion of the armor plate. The edges of the plate were tightly fixed, and only the projectiles were allowed to move, specifically along the Z-direction (impact axis). Initial velocities were assigned to the projectiles to initiate the ballistic impact. The simulation time and time increment were governed by ABAQUS/Explicit's automatic time stepping algorithm to ensure accurate resolution of high-speed deformation events. The *element deletion* technique was employed to allow for progressive material failure without numerical instability due to excessive element distortion.

3. Results and Discussion

Figure 3 shows the three dimensional finite element mesh created to represent both the plate and the bullet. In the modeling, smaller meshes were assigned to increase the local solution sensitivity in the impact region by adaptively tightening them. In this way, stress intensities and deformation types were estimated more accurately. By assigning the optimum number of layers throughout the thickness of the plate, local plasticity and delamination like effects that occur at the moment of impact could be observed in detail.

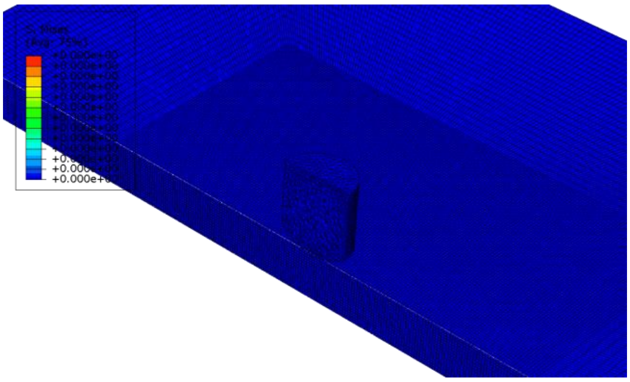

Figure 3. Element mesh structure along the cross-section and thickness

The behavior of three consecutive ballistic impacts of high hardness ARMOX 600T steel at a speed of 500 m/s was investigated by numerical simulation and the results are presented in Figure 4. During the first impact, a limited stress field was observed in the impact area of the target plate. This impact caused only local plastic deformation in the material and no holes or fractures were formed on the rear surface of the armor. This shows that ARMOX 600T can absorb the kinetic energy of the first impact to a large extent and has a high energy dissipation capacity. The bullet was severely deformed; its tip was crushed and spread. The second impact was applied to the same area that had previously been locally weakened. According to the results, the stress distribution spread over a wider area and the deformation depth increased with this impact. The residual stresses from the previous impact

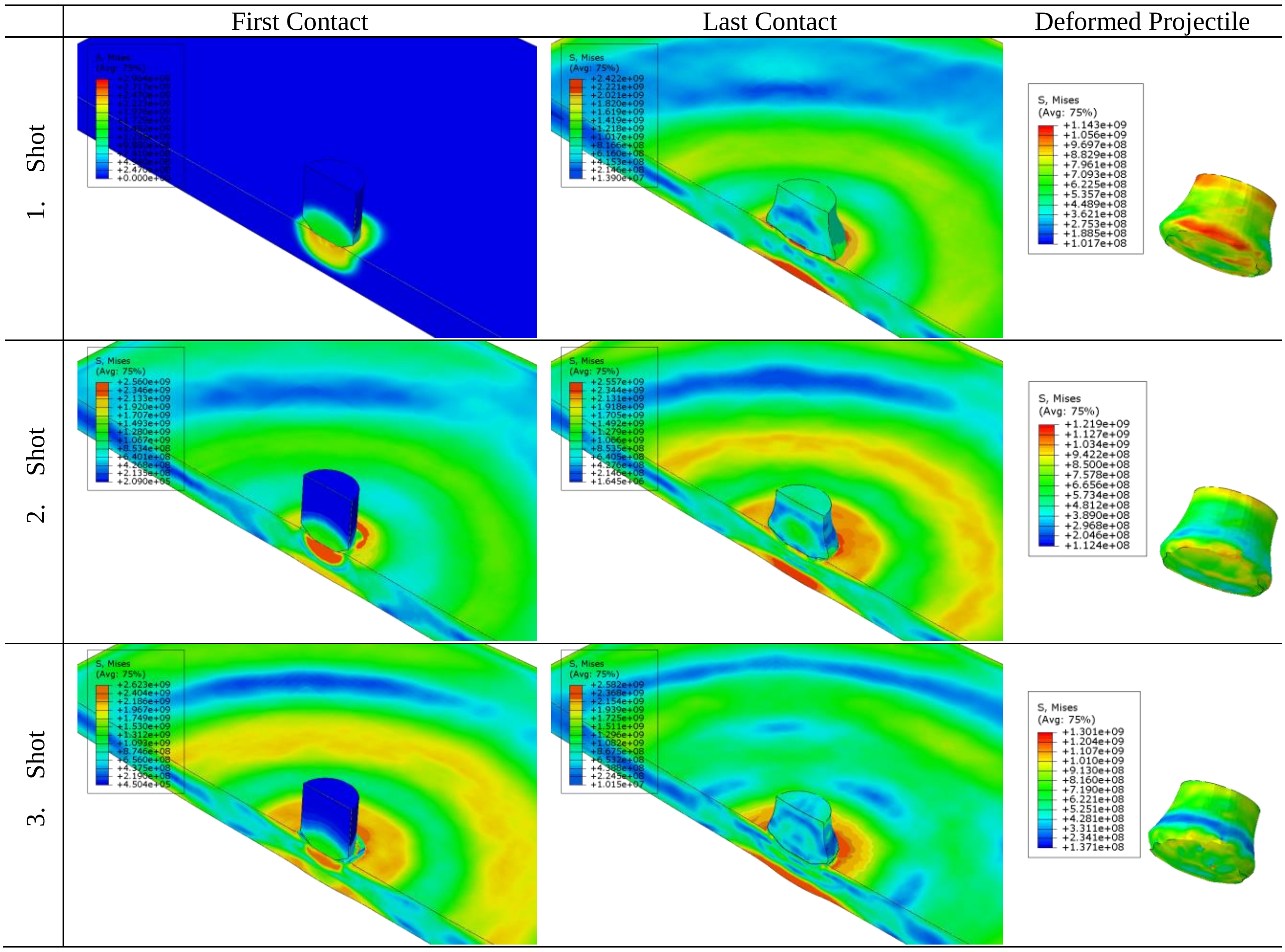

Figure 4. Stress distributions, deformation geometries and deformed projectile at the first and last contact moments of the plates with the projectile for a projectile velocity of 500 m/s. Stress is expressed in Pa.

increased the effect of the second impact, and a wider plastic deformation layer was formed on the plate. Although the second impact did not completely penetrate the plate, this cumulative damage accumulation indicates that the structure was approaching the limit of resistance to repeated impacts. The material was pushed outward in the direction of projection, and the shape of the plate was more obviously distorted. When the third hit was made to the weakened area caused by the previous two shots, both the width and density of the stress rings reached a higher level. The stress distribution has now reached a level that affects not only local but also peripheral areas. The deformation zone on the front surface of the plate has grown and the stress accumulation has increased even more. This situation indicates that the material has started to reach its limiting stress levels and poses a potential risk of penetration. Despite this, the simulation results show that the armor maintains its structural integrity after the third hit and no penetration occurs. The bullet, on the other hand, has been crushed more extensively and has suffered serious deformation compared to the first two shots. These findings show that high hardness steel armors exhibit quite effective performance especially after the first impact, but with successive impact effects, there is a gradual decrease in the energy absorption capacity of the structure. It has been determined that repeated shots, especially to the same point, significantly reduce the local mechanical strength of the layer and make it more susceptible to breakage or puncture.

The results of the repeated shots performed at a speed of 750 m/s are presented in Figure 5. When compared to the 500 m/s shooting scenario, it was observed that the effect of three consecutive shots at a speed of 750 m/s on the plate increased significantly. During the first impact, it was determined that a much more dense and wide-spread stress distribution occurred in the impact region. The diameter of the deformation region also increased significantly. These results show that the increasing impact speed stressed both the local and the surrounding material structure more due to the kinetic energy. The bullet underwent a significant change in shape as a result of this shot, and its tip flattened and expanded. The second impact was applied to the local damage area created by the first impact, and the stress accumulation in this area increased considerably. The stress area spread over a

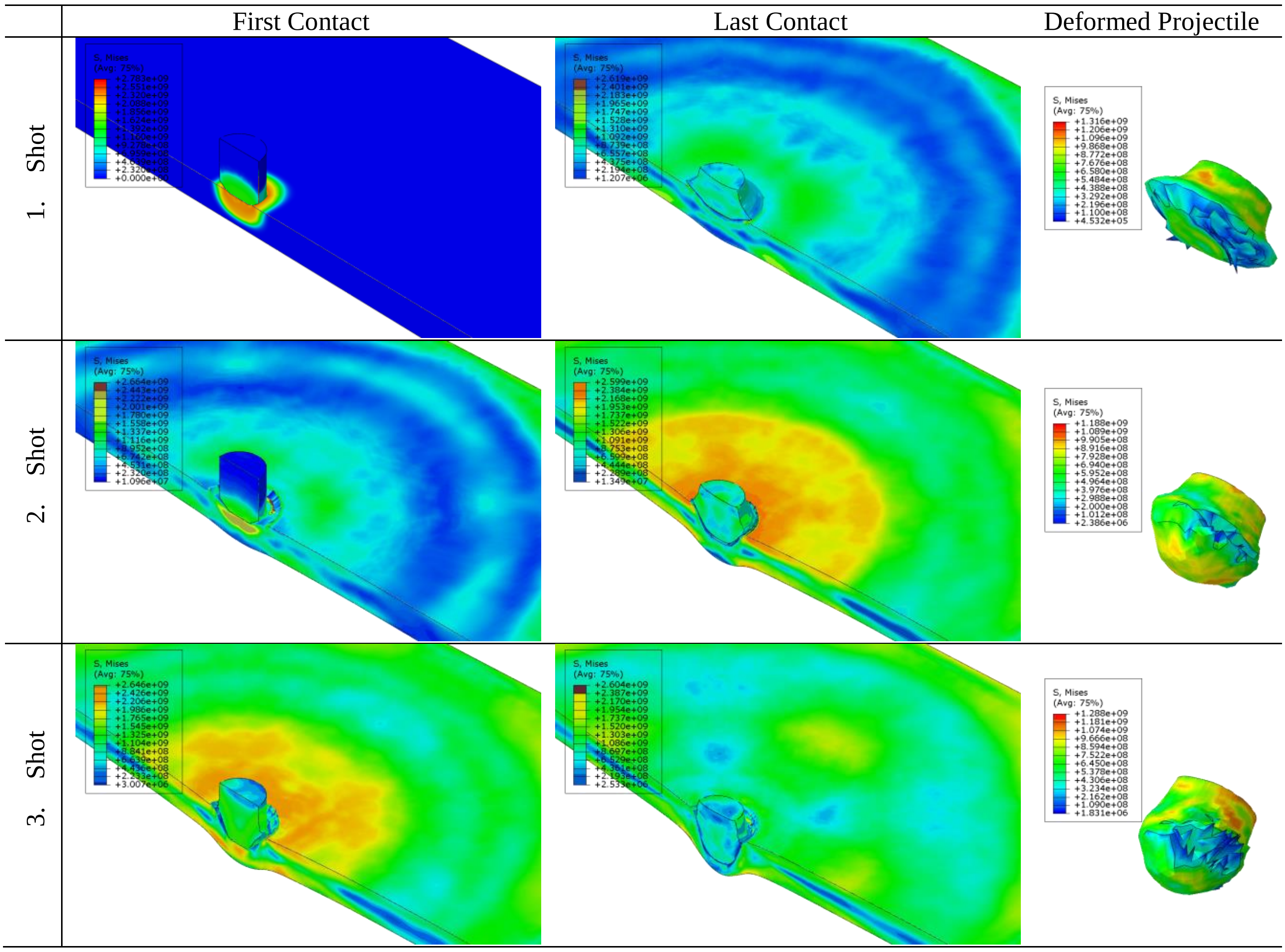

Figure 5. Stress distributions, deformation geometries, and deformed projectile at the first and last contact moments of the plates with the projectile for a projectile velocity of 750 m/s. Stress is expressed in Pa.

wider diameter, which revealed that the structure was strained not only at the contact point but also in the peripheral areas. The deformation geometry shows progressive plastic deformations on both the front surface of the plate and the regions close to its back surface. Although the plate was still not penetrated, the deformation became permanent after the second shot and the structural integrity of the target approached the limit. Serious structural deteriorations were detected in the bullet. The results obtained after the third impact show that the material is approaching its limit performance. It was observed that a widespread plastic deformation zone was formed in the armor plate. The diameter of the stress rings almost covered the width of the plate, which shows that the structure is at the limit of its energy dissipation capacity. The depression and deformation volume formed on the plate surface increased significantly. The third bullet underwent much higher deformation. This deformation shows that the armor has absorbed the impact energy to a large extent and that this absorption has now permanently weakened the armor structure. Repeated impacts at higher speeds, such as 750 m/s, push the performance limits of ARMOX 600T steel and reveal that the energy absorption capacity of the target decreases, especially after the second and third impacts. These findings once again emphasize that repeated ballistic impact scenarios are critical for a realistic armor design. While the ability of the material to maintain similar performance after the first impact is limited, impacts at increasing speeds cause the system to enter a fatigue-like deterioration process.

The stress distributions, target deformations and bullet shape changes of the repeated shots at 1000 m/s speed given in Figure 6 show that the armor system has reached its critical limits. In the first shot, a high stress accumulation localized in the contact area was observed, similar to other speeds. However, this time, plasticity signs spread over a wider area around the impact area and the target material started to show collapse behavior earlier. In the second shot, the bullet hitting the previously weakened area of the plate caused a significant puncture and a large volume of material loss in the target. The stress distributions reveal that the shock effect created by the high speed spreads over a wider circumferential area and that energy absorption is no longer limited to elastic deformation. At this stage, the bullet shape change has occurred at a more advanced level, and large-scale deformations are detected, especially at the ends. After the third shot, the plate has lost its structural integrity to a large extent. The stress fields are more irregular and spread out compared to the previous shots. This

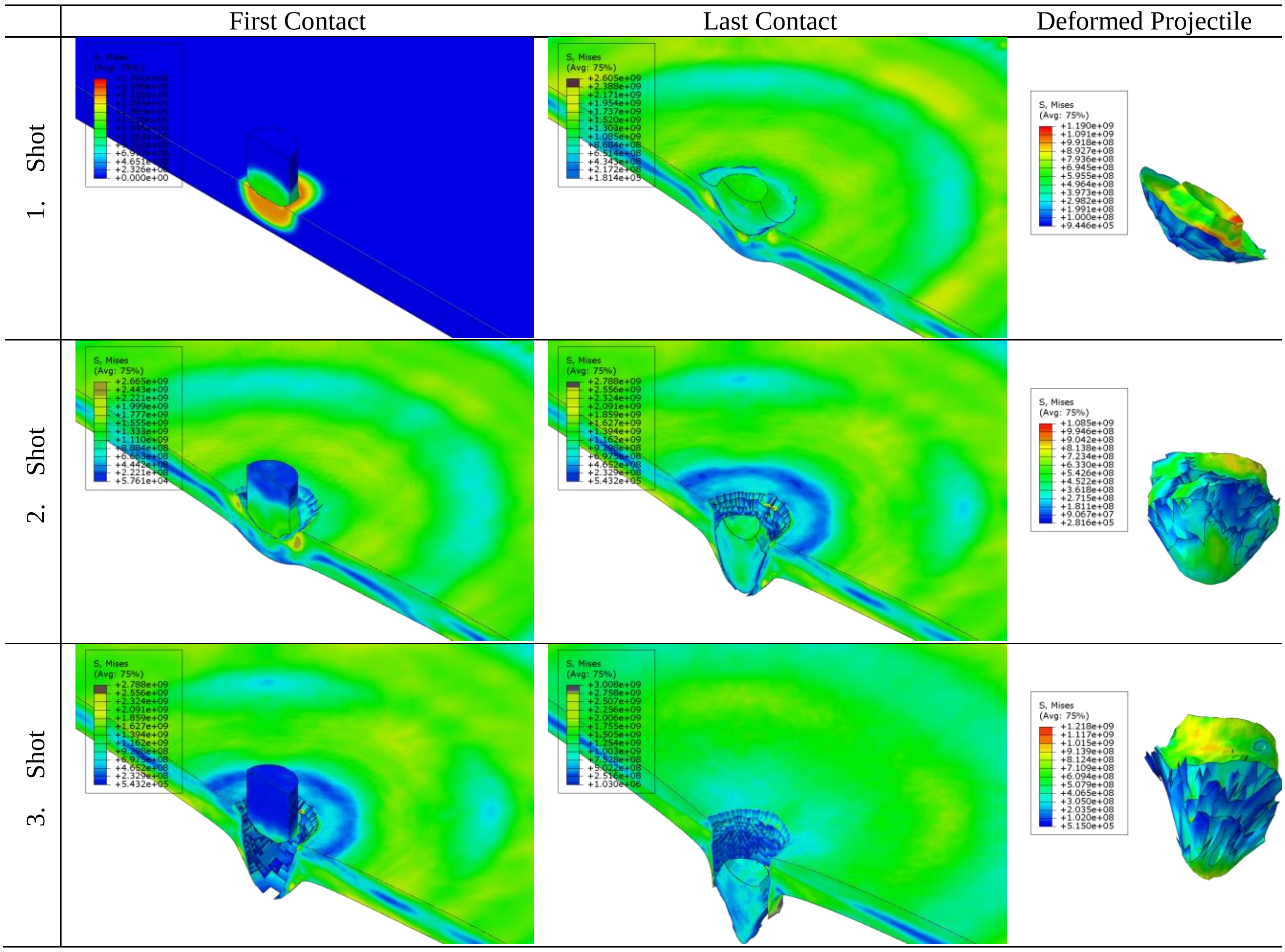

Figure 6. Stress distributions, deformation geometries and deformed projectile at the first and last contact moments of the plates with the projectile for a projectile velocity of 1000 m/s. Stress is expressed in Pa.

shows that the target material can no longer spread the energy homogeneously and that local accumulations and fractures have increased. The bullet has deformed to the extent that it has almost lost its geometric integrity.

Comparative deformations are given in Figure 7. Accordingly, it clearly shows that as the bullet speed increases, the shape change in the armor plate increases dramatically in terms of both size and spread area. While the deformations that occur especially at 500 m/s remain limited, the damage area and permanent collapse areas that occur at 750 m/s and 1000 m/s have expanded significantly. In the 500 m/s shots, an impact crater formed on the target at the first impact, but this collapse did not progress with the second and third shots. This shows that the ARMOX 600T material has sufficient plasticity and strength reserves to absorb low-velocity impacts. Although the bullet changed shape significantly at this speed, it was determined that the target material had a good energy absorption capacity. In the 750 m/s speed, the deformation area and permanent damage dimensions increased with each successive shot. The collapse that started with the first impact expanded with the second shot and a local perforation limit was reached at the center in the third impact.

When the deformation color scales in Figure 7 are considered, it is seen that the target's ability to dissipate energy is limited at this speed and local accumulations begin to form. In the 1000 m/s case, the energy of the bullet can no longer be sufficiently absorbed by the target. In all three repeated shots, it is observed that the collapse area expands circularly and the armor plate comes very close to being penetrated. In this case, the deformation is not limited to the center but spreads to a wider peripheral area. At the same time, it is determined that the shape change of the bullet becomes more irregular and chaotic compared to the previous speeds.

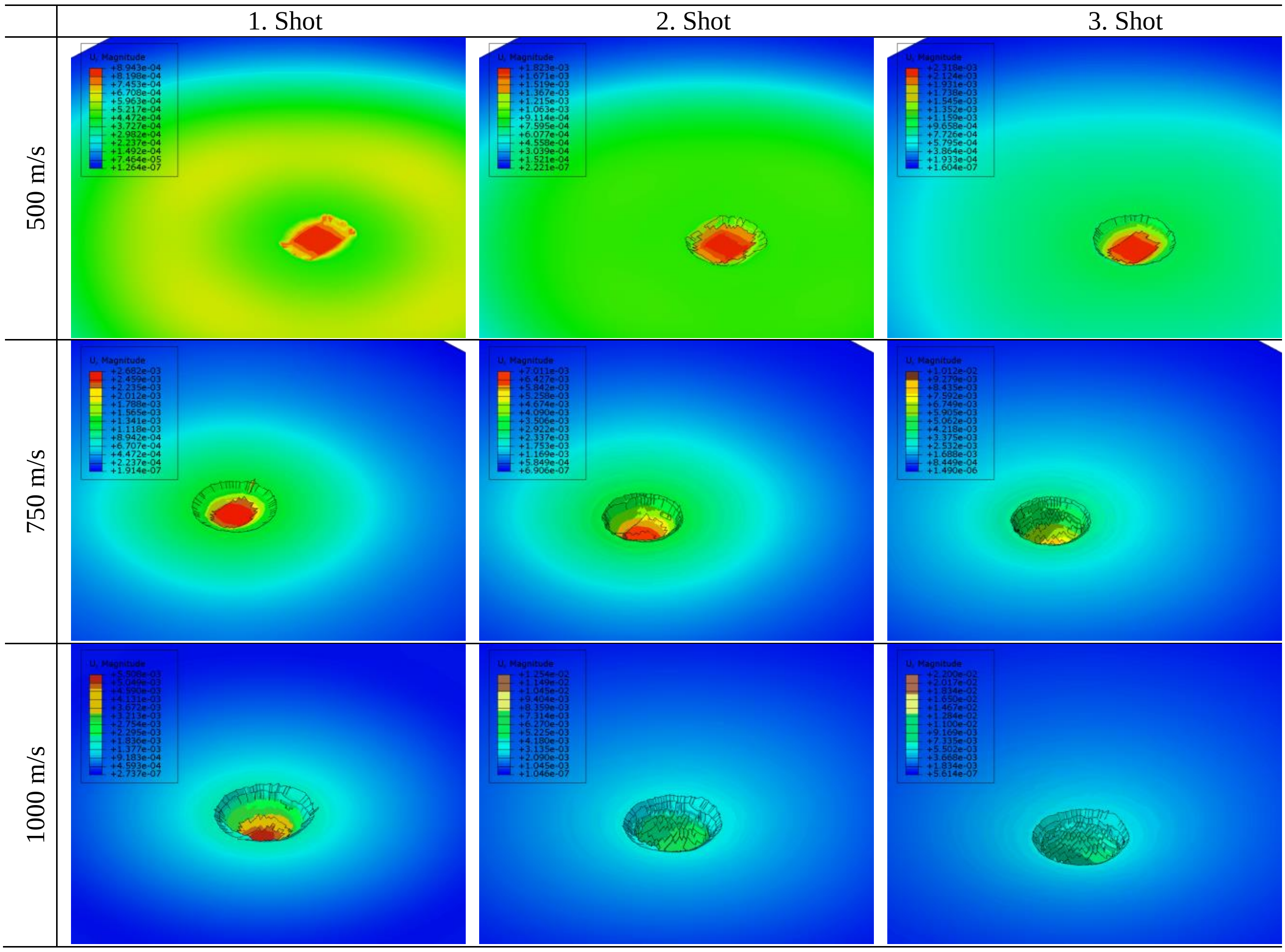

Figure 7. Plate deformations for projectile velocities of 500, 750, 1000 m/s Deformation is expressed in mm.

4. Conclusion

In this study, the ballistic behavior of ARMOX 600T armor steel plates against repeated high-speed impacts was numerically investigated at speeds of 500, 750 and 1000 m/s. The results obtained revealed that as the bullet speed increased, there were significant changes in the stress distribution, deformation character and energy absorption capacity of the target material. In shots fired at a speed of 500 m/s, the plate largely absorbed the impact energy and exhibited effective resistance with limited plastic deformation, while the bullet was significantly crushed. In the speed of 750 m/s, the stress distribution expanded, moderate deformation was observed in the target and significant deterioration in the bullet structure. In shots fired at a speed of 1000 m/s, it was observed that the penetrating effect increased, the plate was locally punctured and seriously deformed, and the bullet shape changed dramatically. In addition, the increase in the accumulated damage in the structure in repeated shots caused the structural integrity to weaken and the energy absorption capacity to decrease. These findings reveal that not only the projectile velocity but also the repeated impact effect must be taken into account in armor design.

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