

Dynamic Stress-Strain investigation

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Section 1- Abstract

This report will be explaining the laboratory experiment completed as part of the OME Physics Module. This Module had a focus on building a high speed ballistic impact of a projectile onto a laminated plate on abaqus application. The projectile is made of one material of choice and values are given accordingly. The material used in this report is Mild Steel. The laminated plate is made of two materials; Aluminium and Plastic. Johnson-cook damage evolution is focused upon in this report especially. Results at different times throughout the experiment showing the different levels of stress and strain.

Section 2- Introduction

This Physics assignment will be focusing on material properties for the projectile and target plate layers. Stress is a force per unit area within materials that occurs from externally applied forces. Strain is the amount of deformation experienced by the body in the direction of force applied, divided by the original body dimensions. [1]

“The constitutive equations (CE) are the expressions describing the relationship between the measures of the stress state and the measures of deformation.” [2]
Momentum and energy which is also known as kinetic energy are important properties of a moving object and governed by Newton’s Laws of motion.

Section 3- Modelling set up

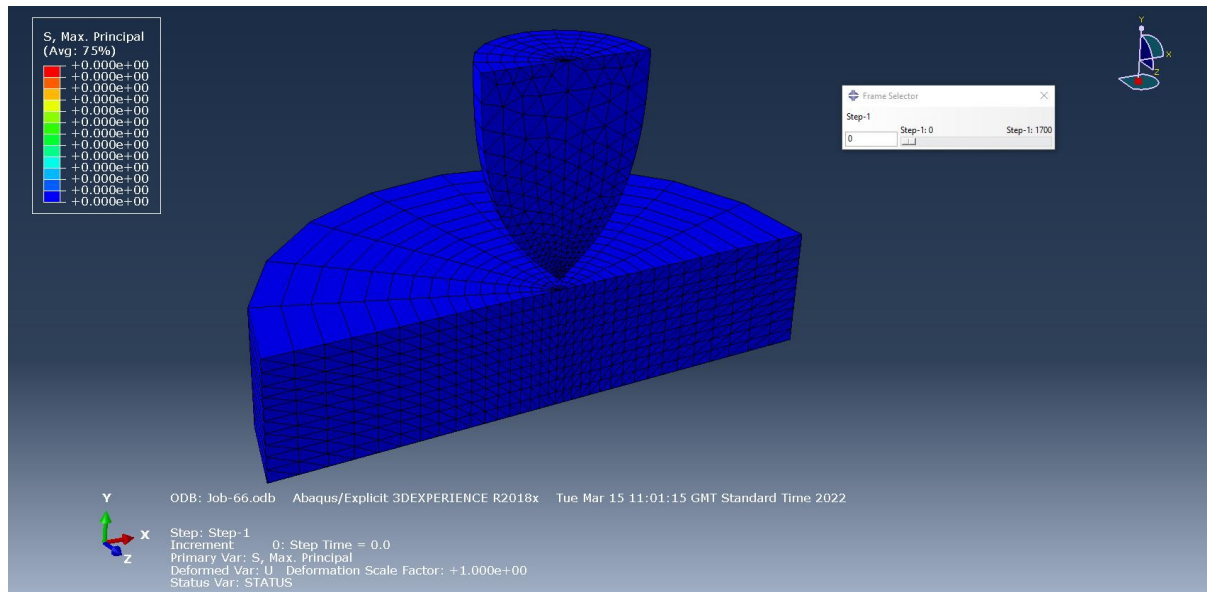


Figure 1

See figure 1 to understand the shape of this experiment. This is the model in 3D cut directly in half. This is before any stress or strain takes place as the impact has not been made. The Bullet here is made from Mild Steel as would most bullets be made from. The Laminated plate is made from two materials, Aluminium and Plastic which are stacked one after the other in 5 layers total; 3 with Aluminium materials and 2 with Plastic.

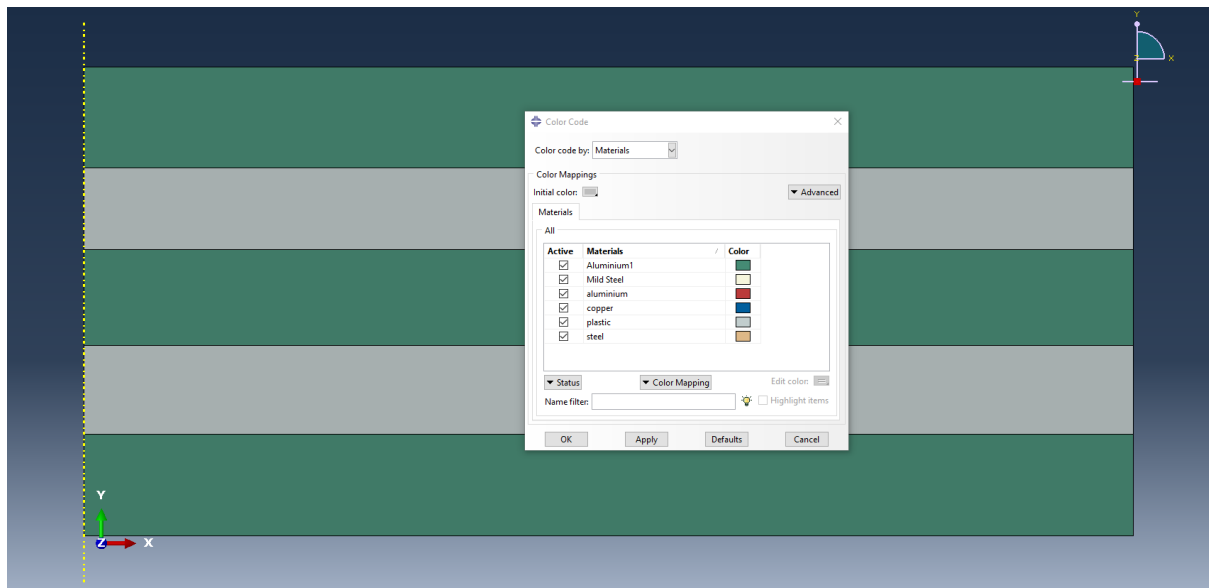
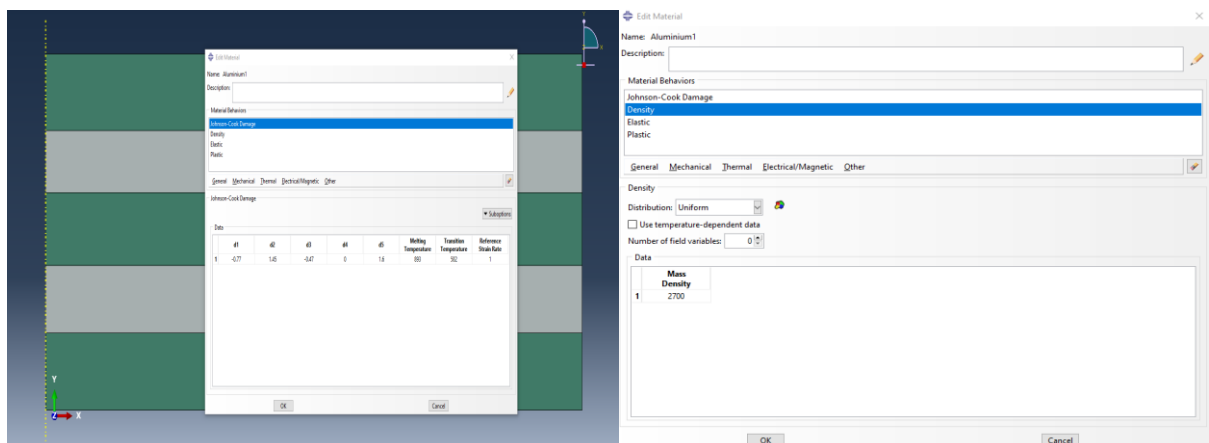


Figure 2

See figure two to see into colour coding of materials. As you can see Aluminium1 is the first material used, coded green. Plastic is then coloured a light grey and mild steel, the bullet, is a white shade. These coloured sections make it easy to determine which material is which and where the laminated plates different materials start and stop.

Section 4- Material properties



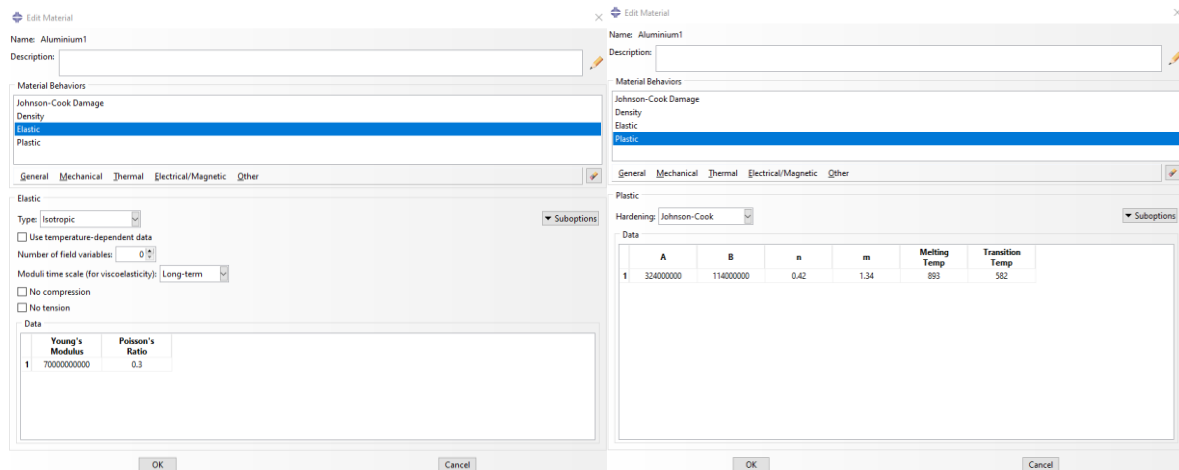
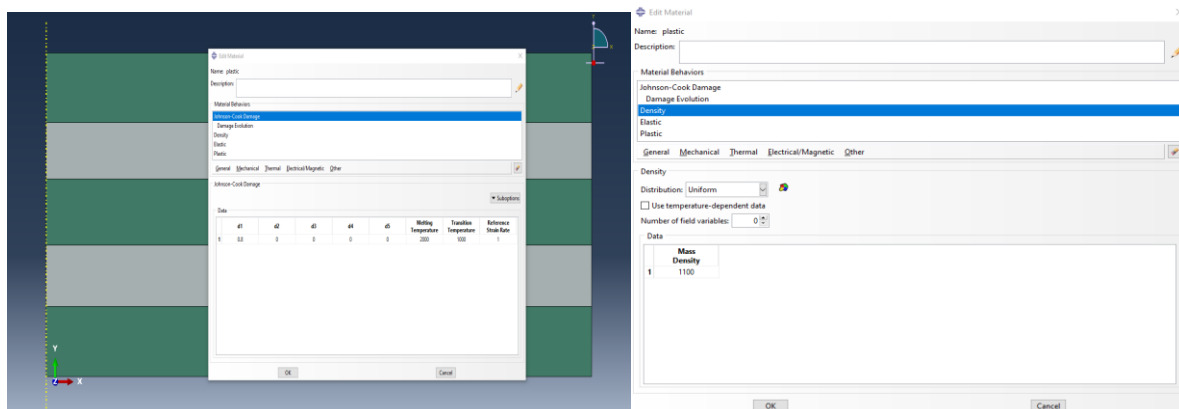


Figure 3

See figures 3 to see the material properties of the Aluminium used in the laminated plate. In class research was completed in order to find these figures and also resources were given on the university Moodle. Johnson cook damage was found, finding figures d1-5. The Melting temperature was set at 893 degrees and a transition temperature of 582 degrees. Reference strain rate was set to 1. Next mass density was put to 2700. The isotropic elastic used the Young's modulus which was set to 70000000000 and Poisson's ratio set to 0.3. Last plastic element in aluminium was given an A Value of 324000000 and a B value of 114000000. n was set to 0.42 and m to 1.34. This had a melting temperature of 893 and a transition temperature of 582, same as Johnson cook as this was figures for the hardening of Johnson cook.



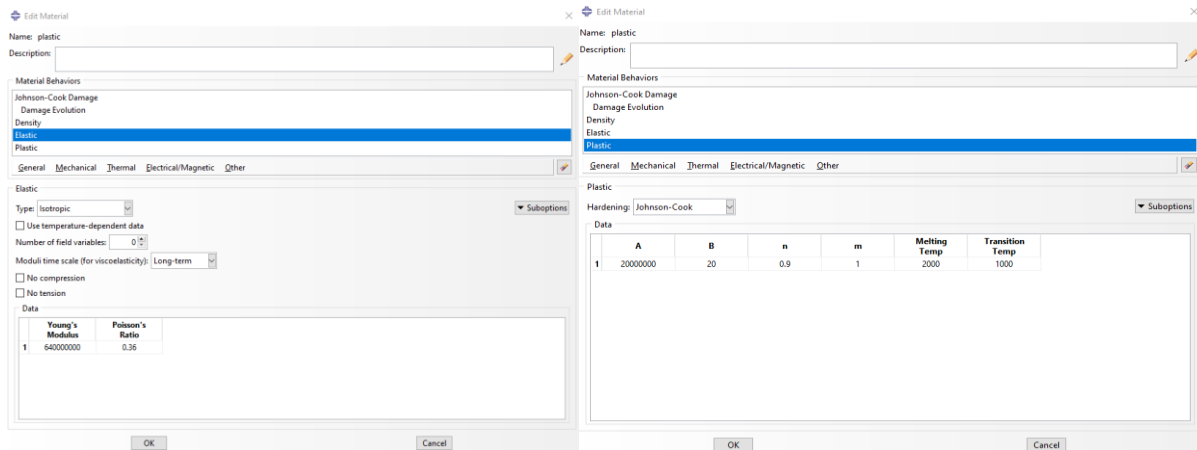
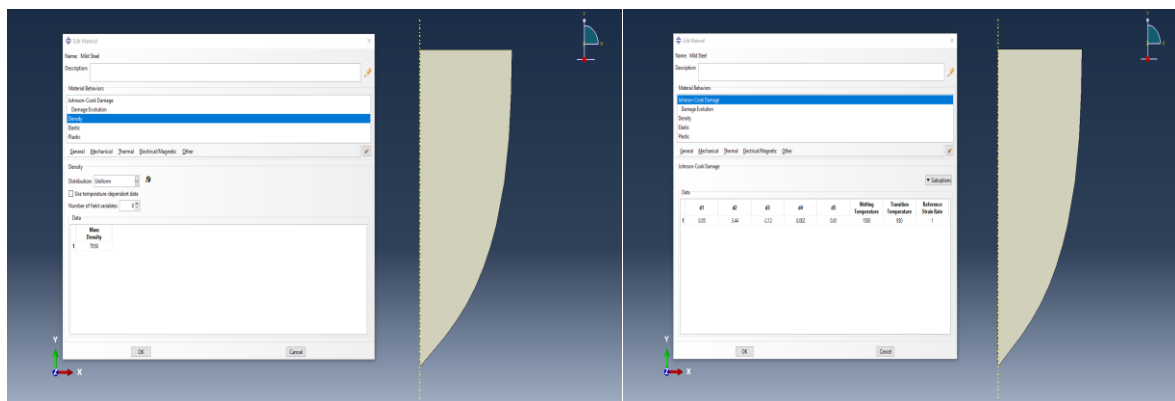


Figure 4

See figures 4 to see the material properties of the Plastic used in the laminated plate. Johnson cook damage was again started finding figures d1-5. The Melting temperature was set at 2000 degrees and a transition temperature of 1000 degrees. Reference strain rate was set to 1 once again. Next mass density was put to 1100. The elastic used the Young's modulus which was set to 640000000 and Poisson's ratio set to 0.36. Last plastic element was given an A Value of 20000000 and a B value of 20. n was set to 0.9 and m to 1. This had a melting temperature and transition temperature Johnson cook.



See figure 6 where a graph with the Y axis labelled Velocity and the X axis labelled time. The unevenness of this graph shows how high stress environments are handled quite abruptly with no real pattern. Simulation set up contained of researching and applying figures into chosen materials. This was all made on ABAQUS software, first in a 2D model and later could be set into a 3D to get a better idea of what realistically would happen. Maximum Principle was looked at first to calculate and display stress in the structure. These were shown as bright colours and there was labelling to describe measurements of stress. S,S12 was also then looked into gathering figures on stress in the model.

Section 6- Results

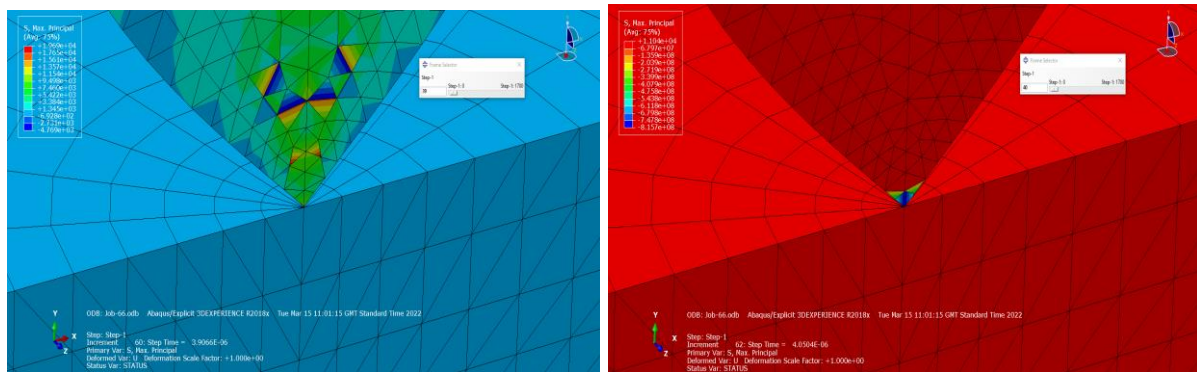


Figure 7

See figures 7 as the bullet first hits the laminated plate. This is done in maximum principle. Maximum principal is the maximum value of normal stress acting on one of the principal planes where the value of shear stress is zero. You can see in step 39 the laminated plates are at 6.928×10^2 and majority of the bullet is at 7.460×10^3 whereas the tip has turned to 5.422×10^3 . This shows the majority of the stress is at the tip of the bullet as it hits the laminate plates. The next screen, step 40, shows a drastic colour change and according to scale majority of bullet and laminated plates is at 1.104×10^4 with the stress in the tip decreasing to -8.157×10^8 .

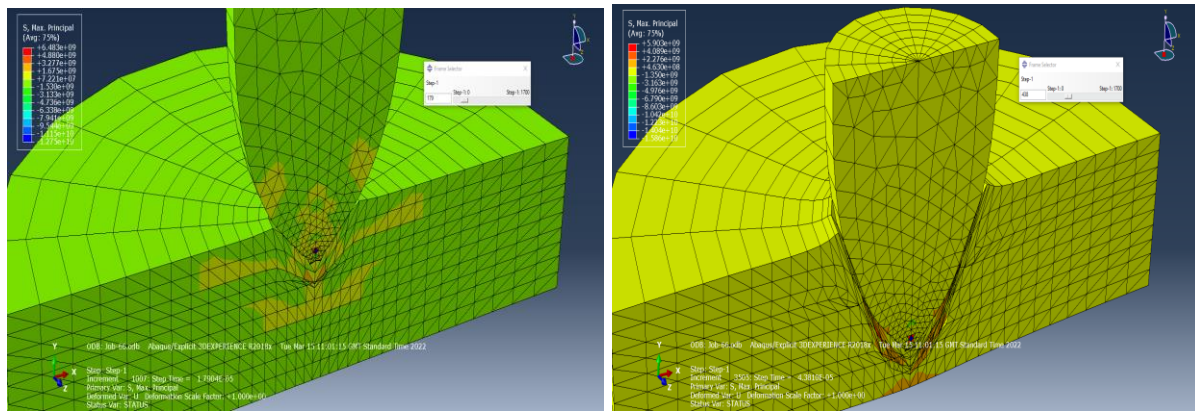


Figure 8

See figure 8 for further bullet penetration. In step 179 the overall body majority is set at -1.530×10^9 with a higher measurement of 7.221×10^9 closer to the impact. These higher levels of stress in maximum principle can be seen having more effect on the aluminium layers on the aluminium plate. Step 438 shows main stress overall is at -1.350×10^9 . In both figure 8's there is a decrease of stress level to as little as -1.586×10^{10} in line with the tip and not far from it.

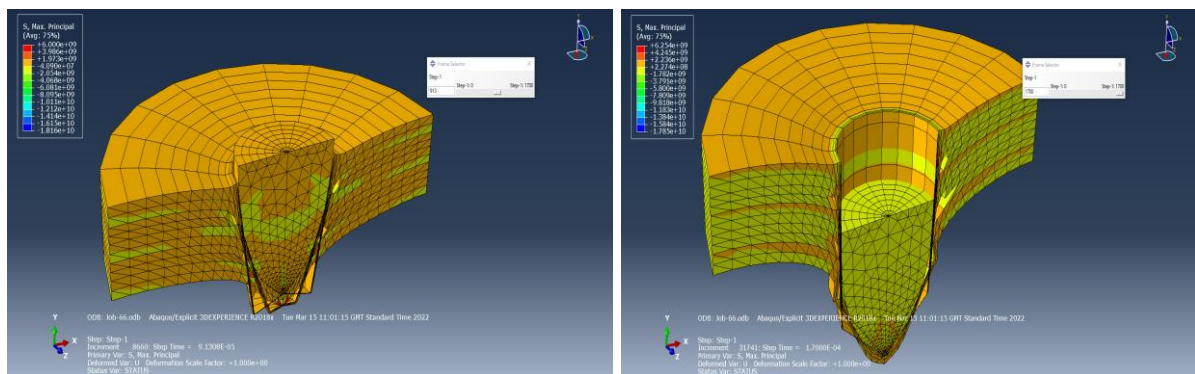


Figure 9

See figures 9 as the bullet goes through the middle of the laminated plate. You can see in step 913 the laminated plates and bullet are majority covered by the stress of 1.973×10^9 with some noticeable yellow, -4.090×10^7 going throughout. The start of the yellow is shown in the aluminium plates, showing more weakness. This shows the majority of the stress is in the middle of the bullet and laminated plates. The next screenshot on the right, step 1700, is the final step available. This shows a drastic colour change to majority of stress turning yellow in both the bullet and laminated plates. There is still less stress shown in the plastic plates, suggesting this material is

more resistant. Overall the final stress is on this experiment is between $1.973\text{e}+09$ and $-4.090\text{e}+07$.

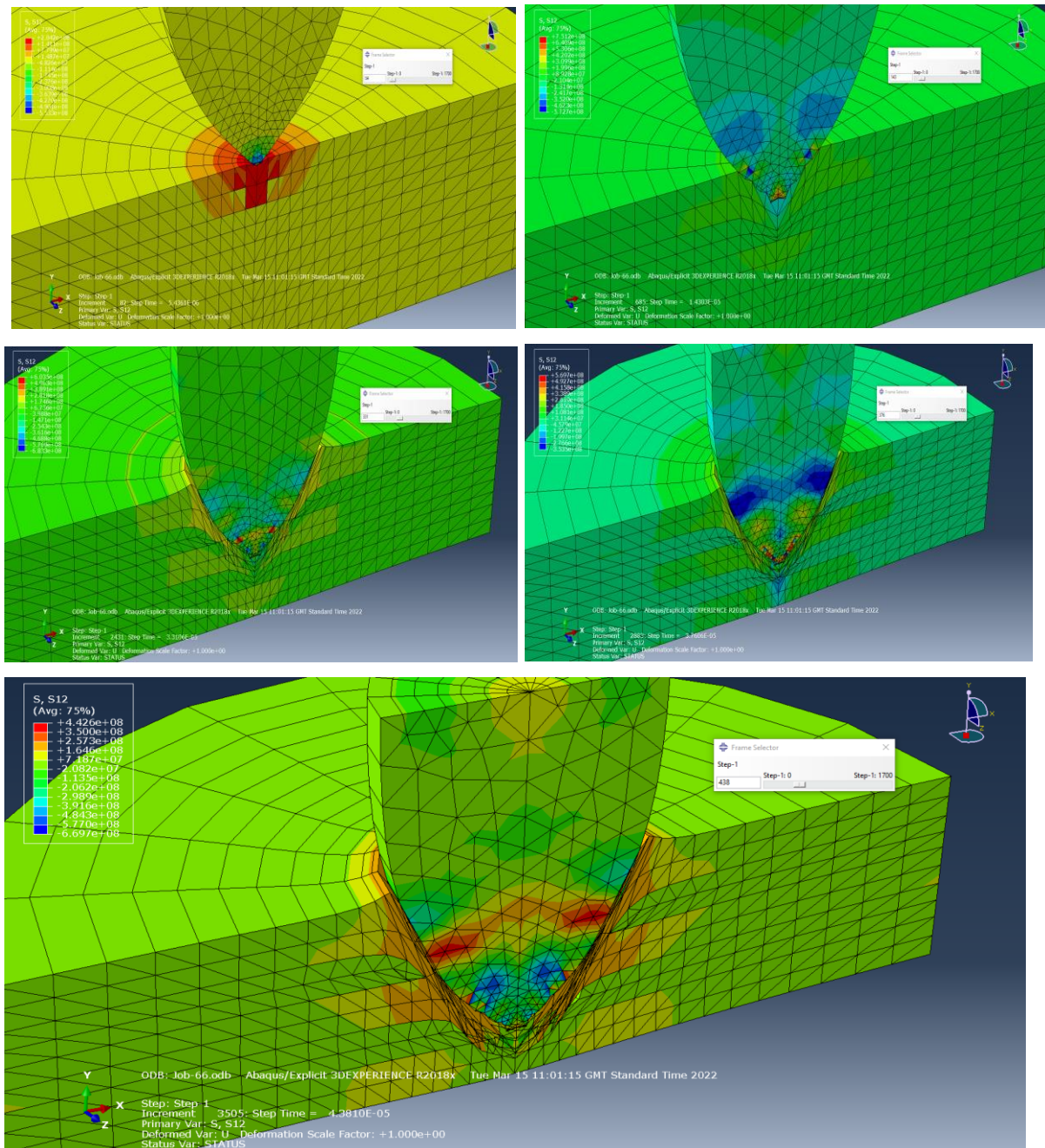


Figure 10

See figures 7 as the bullet first hits the laminated plate. This is done in S,S12 on ABAQUS setting. S,S12, Shear stress, is along the second cross-section axis caused by shear force and, for beam elements in space, torsion. [3] You can see in step 54 the laminated plates and bullet are at a majority of $1.487\text{e}+07$. The tip of the

bullet in step 54 go between stress levels of $-5.533\text{e}+08$ up to $-4826\text{e}+07$ the further out it goes. On the other hand the point of contact on the laminated plate is between stress figures of $2.042\text{e}+08$ and $7.799\text{e}+07$. The main colours on the tip of bullet are blue and green whereas in contrast the entry on the plates are red and orange in colour. This shows the majority of the stress is at the top of the laminated plates where the bullet first hits. The next screen, step 143, shows a massive change of colour and according to scale majority of bullet and laminated plates is at $8.928\text{e}+07$ with minimal stress on the laminated plate. The bullet here takes all ranges of stress. This pattern continues during the next three screenshots and stress starts to increase gradually on the aluminium plates as seen before on maximum principle.

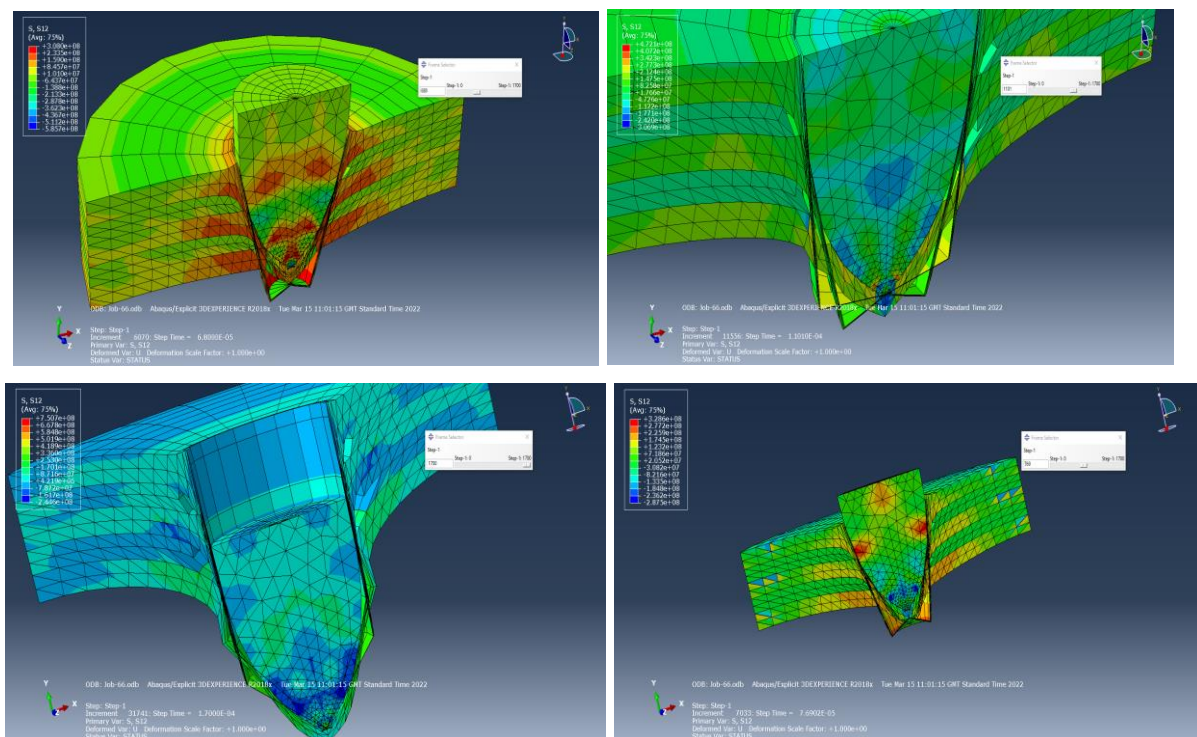


Figure 11

In figure 11 Similar trends can be seen with the aluminium material having higher stress levels when in contact with the bullet. Through steps 680 to 1101 the stress of both the bullet and laminated plate is at $-6.437\text{e}+07$. Step 680 the stress ranges between $3.080\text{e}+08$ and the $-6.437\text{e}+07$ whereas in contrast step 1101 starts at $-6.437\text{e}+07$ and decrease to $-3.069\text{e}+08$ near the tip of the bullet. On the last step, 1700, the main trend was ranging from $8.716\text{e}+07$ down to $-2.446\text{e}+08$.

As visible fragments are disappearing near the bottom of the laminated plates as the bullet passes through.

Section 7- Discussion

This experiment was successful as the bullet managed to penetrate the laminated plate completely. The mild steel performed well against the aluminium and plastic. Aluminium is shown throughout to have higher levels of stress than the plastic. If this laminated plate was fully made from plastic the mild steel bullet may have found it more difficult to penetrate fully. On the other hand, if known the laminated plate was of a even higher stress than aluminium you could guarantee an even quicker penetration from the bullet. This was so successful because of the correct Johnson cook damage values, elastic and plastic values. The simple shape of the bullet against the laminated plate must have helped as the sharp tip can split the laminated plate with that level of force very easily. If a stronger metal or a different shape was used though this could mean a cleaner cut through the plate. As you can see there is a bend in the shape of the plates at the end of the simulations. Ideally, the plate would have been split clean in half with minimal deformation of the plates. Fragments from these models can be seen to disappear. This is because all of the nodes connected to the elements is over the fracture energy put in when material figures were calculated.

Section 8- Conclusion

In conclusion, both sections of this experiment, the bullet and laminated plate, both are affected by levels of stress when hit together. Plastic is shown to have better resistance to stress when in contact with Mild steel over aluminium. This experiment showed a great insight into ballistics and material models. Through failing and fixing values to get these results it is learned how important it is to get correct figures and understand how to input them into ABAQUS software.

References

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