

Dynamic stress strain investigation

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ABSTRACT

In engineering and materials science, a stress–strain curve for a material gives the relationship between stress and strain. It is obtained by gradually applying load to a test coupon and measuring the deformation, from which the stress and strain can be determined. Within this paper, a study has been conducted with a 20mm round fired from a Phalanx CIWS at an aluminium plate to measure the stress and strain on the material. This investigation uses the Johnson-Cook damage model to calculate the amount of force being exerted on the material.

1 INTRODUCTION

In this investigation the dynamic stress and strain were observed with a 20mm shell impacting a 300mm aluminium armoured plate, the purpose of this investigation is to test the viability of armoured plating against anti air rounds. The shell is from a Phalanx CIWS (Close in Weapon system) and uses a discarding sabot with a fire rate of 3,000 rounds per minute. The software used was Abaqus a system developed by Dassault used to measure a range of engineering tasks such as thermodynamics, stress and impact. This lends well to the investigation as the software allows the user to set different parameters of materials and damage models.

2 THEORY

Stress is the name given to forces applied to a material during its deformation. The equation for stress is denoted as:

$$\sigma = F/A$$

where σ is the stress, F is the force and A is the area of the which the force is applied. There are two main types of stress *Tensile* and *Compressive*. Tensile stress is the process of a material being stretched and elongating and Compressive stress is the process of compressed and may become shorter. Strain is the deformation of the material from stress of which there are two types of strain. Strain that is perpendicular to the cross section is called normal strain whereas strain that is applied parallel to the cross section is called shear strain. This investigation also uses the Johnson Cook damage model was used in this investigation and is primarily used to predict the plastic deformation and failures of materials. One important aspect of the model is its incorporation of a damage parameter to account for the progressive degradation of material strength as it undergoes plastic deformation. The equation is denoted as:

The investigation used the program Abaqus which is an application designed by Dassault systems to measure a multitude of different engineering applications such as thermal analysis, geotechnical engineering, structural analysis and multiphysical equations. This was used in the investigation for the visualisation of dynamic stress and strain.

3 METHODS

3.1 Procedure

Using abaqus the investigation required implementing the correct material data for the materials used. This was done by using the dialogue box to input the parameters including the plasticity and the damage constants. The simulation was created using a 2 part model made of the armoured plate and the 20mm shell. The simulations were changed to have different speeds of the round hitting the armoured plate the values were 400m/s, 600m/s and 1000m/s this affects the amount of stress applied to the material. At 400m/s the stress is lower due to the round having lower kinetic energy and so less transferable energy.

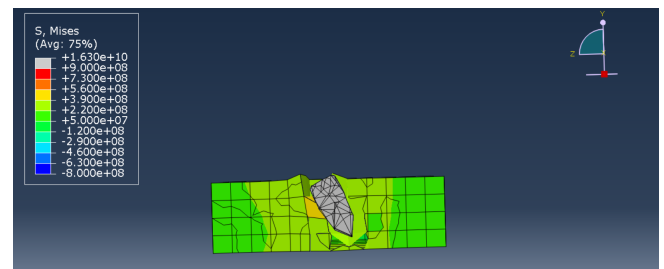


Fig. 1. The 20mm calibre penetrating the aluminium armour

As can be seen from figure 1, the amount of stress being applied to the armoured plate is much less than that being applied to the because the tip of the bullet has a much smaller cross sectional area leading to a more concentrated force at the area of impact. The maximum stress applied to the armoured plate is $3.900e+08 \sigma$ Pa where as the is above $9.100e+09 \sigma$ Pa.

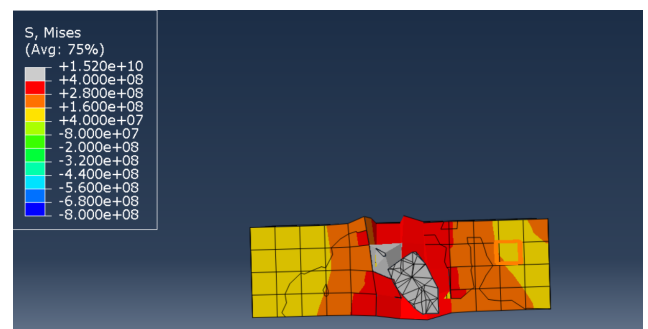


Fig. 2. The 20mm further through its penetration

4 RESULTS

The results data gained from this investigation can be seen in figures 1 and 2 respectively and show the stress and strain values of the shell hitting the armoured plate using the figures above it can be inferred that the energy is transferred throughout the plate.

5 DISCUSSION

5.1 Analysis

As can be seen from the above images a 20mm shell is more than capable of penetrating a 300mm armoured plate. It can be inferred that the main outcome for this test would be spalling from the ejection of the shell, a separate study would have to be conducted to see the extent of the spalling.

5.2 Recommendations

When doing this investigation due to the limited time available a solid grasp of the program was not possible, so having a longer exposure time to

abaqus and its features may have yielded better and more precise results. It may also be useful to have a practical demonstration carried out from a reputable manufacturer such as Qinetiq who do testing of various rounds against different materials for proof firings.

6 CONCLUSION

The results obtained from this Abaqus simulation can inform design modifications, material selection, and overall armor optimization, contributing to enhanced protective capabilities against high-caliber threats. The ability to visualize stress and strain patterns in a virtual environment allows for a deeper understanding of the structural behavior, facilitating informed decision-making in the development and improvement of armor systems to meet the demanding requirements of real-world ballistic scenarios. In summary, the application of Abaqus in this context not only advances the understanding of armor performance but also supports the ongoing efforts to enhance the protective capabilities of materials and structures against ballistic impacts.