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ABAQUS Lab Report

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the degree of OME

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Abstract

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1 Introduction

1.1 What was the purpose of the Practical?

The test was undertaken so that the best material for a 120mm projectile would become certain. However, would the best material correlate to a practical application within the Defence industry?

1.2 What is being tested?

Within our practical, we tested three different materials; Aluminium, Titanium and Concrete. We measured the direct and shear stress exerted onto the metal plate. This was done as direct and shear stress are both quantitative results. Due to this, our observations are more reliable than that of results taken from a qualitative test. This also eliminates the potential of anomalies skewing the findings. After carrying out the test, we will then compare our results and see if the 'best' tested material would also be cost effective for widespread use.

1.2.1 Variables

The variables identified prior to commencing the experiment became clear. Our dependant variable was the Johnson Cook Damage model for each material, this is because our simulations depended on this data being correct for reliable and accurate results. Our independent was the projectile. The projectile dimensions and velocity were not changed at all during the experiment. The control variable was a low alloy steel (Q345C Steel). This was used as our control variable due to low alloy steel being one of the most common metal alloys used throughout the world.

1.3 The Hypothesis

The hypothesis made before carrying out the experiment was that our concrete material (ZR-CEM) would perform the 'best' under the test conditions. This hypothesis was made due to the melting point of the concrete being 2703K (Degrees Kelvin). We knew that the material would be stable until being exposed to temperatures above 2473K. The concrete also has high strength so we believe it will perform the 'best'.

2 Results

2.1 Screengrabs from ABAQUS

2.2 Observations

After testing each material, we noticed that the projectile would cause a hertzian ring to form on the surface of the metal plate, this was observed as early as 4.88 microseconds into the tests. Similarly, a hertzian cone could also be seen forming at the same time. After monitoring the progression of both the ring and the cone, we could see that the ring was formed due to the amount of direct stress exerted onto the surface of the plate and the cone was formed entirely because of the high levels of shear stress.

2.2.1 Titanium

Reviewing our results for Titanium, the direct stress experienced by the metal plate was seen to be less than our control variable (Q345C). The density of Titanium is lower than Q345Cs (4428kgm⁻³ compared to 7500kgm⁻³), more density means more mass and (as force is proportional to mass) results in the density rich material applying more direct pressure onto the metal plate. The observation made for the shear stress exerted onto the metal plate by the Titanium projectile was taken in the positive direction but our control variables' shear stress was taken in the negative direction. As these forces are acting in opposite directions, they will not be compared. Instead, the colour-coded scales have been compared, this did decrease the accuracy of the results as we relied on the quality of the colours within ABAQUS and have assumed they're correct, this also increased the chance of human error effecting the comparison. The shear stress exerted on the plate by Q345C was higher than that exerted by the Titanium. This illustrates that the structural damage done to the metal plate by Titanium was lower. As a result of this, Titanium would not be a good choice of material for a projectile.

2.2.2 Aluminium

The direct stress applied by the Aluminium projectile was, again, less than that of the low alloy steel. Aluminium has a density of 2700kgm^{-3} compared to Q345C which has a higher density of 7500kgm^{-3} . Applying the same reasoning mentioned above, we can conclude that the direct stresses of Aluminium was less due to the density being lower. Overall, with regards to direct stress, we see a higher value exerted by the Aluminium (176.9 Giga Pascals {GPa}) compared to our control which had a maximum direct stress of 71.49 GPa. With regards to shear stress, our observed values were both in different directions (this was dictated by the positive and negative symbols). The shear stress exercised by Q345C is higher than that of Aluminium however, we could see that the metal plate experienced a consistently higher stress throughout the whole structure with Aluminium.

Aluminium was also the only material to experience plastic deformation without fracturing. It is believed that this was due to the Aluminium's Young's Modulus (YM) being dramatically higher than that of our control variable. (73.2 GPa compared to 2.730 GPa). Aluminium is a very brittle metal however the fracture point is high resulting in the metal being plastically deformed. We also believe that the YM influences the consistency of the shear stress across the structure of the metal plate.

2.2.3 Concrete

Zirconia cement (ZR-CEM) was our final material. We took all the values for the YM and the Johnson Cook Damage Model (JCDM) as the solidified concrete state of this material. The direct stress observed was similar to that of the low alloy steel (121.61 GPa compared to 168.97 GPa). This was due to the high strength of the hardened concrete. Despite Q345C's density being higher, there was not much difference between the two material with regards to direct stress. With regards to shear stress exerted onto the metal plate, the values for both our control variable and the concrete are very similar. It is believed that this is caused by the high strength of the concrete material. Despite having a lower YM, ZR-CEM performed really well during the test when compared to the low alloy steel.

3 Discussion

3.1 Theoretical Physical Concepts

3.2 Practicability of the results

ZR-CEM performed the 'best' under the conditions of the simulation thus this begs the question: would the concrete withstand the pressures a projectile experiences inside the bore of a weapon system? In order to determine this, we must compare the results of the test to pressure values experienced by an INERT proof shot within a 120mm bore.

3.2.1 Possibility of widespread applications

The possibility of widespread applications of the materials used during this test is limited. The concrete, being the 'best' performing material, would naturally be the first choice of material for a wide range of applications within the Defence Industry. As concrete requires a mould to hold its shape whilst the cement is drying, the only practical application for concrete within the Defence industry would be INERT proof shots. INERT proof shots are shells with no explosive substances within, they're just a mass of metal forged into the shape of a shell. They're mainly used for testing purposes. Concrete could be used as an alternative material for these INERT proof shots however it would require a mould to hold the shape during the drying process.

3.3 Limitations of the Practical

The limitations experienced during the experiment was mostly knowledge of the ABAQUS software. We did not have long to get savvy with the software which resulted in some minor setbacks during testing. One of these setbacks was that the projectile was not perpendicular to the metal sheet which caused further calculations to determine what the Y and Z components of the velocity were. Furthermore, the models of both the projectile and the metal sheet were not at the origin of the axis within ABAQUS, this resulted in losing the models multiple times during testing which wasted a lot of laboratory time.

3.4 Theory vs Practice

The simulation was completed using the ABAQUS software. Despite this software being very high quality within the engineering sector, it did have its limitations when compared to a practical test. Physical phenomenon's like gravity and air resistance cannot easily be replicated within ABAQUS. Due to this, our results cannot be used as certainties nor expected outcomes if a similar experiment were to be conducted in the real world. The reliability of software simulation results are undoubtedly inferior when compared to observations made during a practical test. This could, however, change with time. The quality of technology has increased rapidly within the last 80 years. Based on this, it would be safe to assume that in the near future simulation softwares will be able to simulate physical concepts like gravity with ease.

4 Conclusion

4.1 Do the results support the Hypothesis?

Overall, the hypothesis was supported by the results taken. The concrete material did perform the 'best' under the test conditions. However, concrete would not be a very practical material for widespread use for projectiles due to concrete requires a mould to hold the shape whilst the cement dries. In reality, the most practical use for concrete within the defence industry would be for INERT proof shots. As INERT proof shots are just metal crafted into the shape of a projectile for testing purposes, a mould could easily be used for swift mass production. The only downside would be that you could not create a High Explosive shell out of concrete.

4.2 Future testing

Future testing should be focused on materials with similar properties to concrete to find a material that is high in strength, has a high YM and is relatively cheap to purchase. If a material like this was found, the Defence Industry could save a lot of money on shell manufacturing.

