MODELING AND SIMULATION OF AUXETIC MATERIALS FOR BALISTIC PROTECTION

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ABSTRACT

A type of structural metamaterials known as auxetics has a negative Poisson’s ratio. Auxetic structural materials have been found to possess a number of better qualities when compared to traditional ones, including: greater energy absorption, stronger indentation resistance, and enhanced mechanical properties. As a result, auxetic structures are becoming more known as a high-performance, lightweight defensive construction that can survive collisions and blasts.

KEYWORDS: modeling, simulation, auxetic materials, balistic protection

1. Introduction

Auxetic materials are of interest due to their counterintuitive behavior under deformation and enhanced properties due to negative values of Poisson’s ratio. Auxetic materials' qualities must in some way correspond to the fundamental requirements of the application to be useful. Numerous elements and considerations must be taken into account when deciding which auxetic cell structure to use in a certain application [1-10].

An application's fundamental criteria must be identified first. For instance, auxetic structures are employed in some applications because of their capacity to enlarge under strain, with the size of the negative Poisson ratio (NPR) being the attribute to be focused on [11-15]. However, a minimal degree of stiffness might be necessary. Each unit cell's characteristics and constraints will reveal how well-suit it is. By altering the geometry of the unit cell, structural qualities can be changed, which will ultimately affect how the cell can be optimized for an application. If it is subjected to a stretch greater than a small one, some unit cells quickly lose their auxetic characteristics. Additionally, during the same stretch, some unit cells will suffer a localized maximum stress intensity in comparison to others. Some unit cells display auxetic activity for only one type of strain or are more restricted in that strain due to the geometry of their structure. It is crucial to take an application's required extents into account. The 2D or 3D nature of an auxetic unit cell is a crucial consideration [16-21].

2. Experimental procedure

In this study, the ballistic impact behavior of auxetic sandwich composite armour was investigated.
program was used. The 3D model proposed is presented in Figure 1. The results were compared with monolithic armour under the same boundary conditions and speeds. The auxetic core was constructed from discrete re-entrant cellular units using 3D Inventor modeling software. The parametric geometry of the unit cell is presented in Figure 2. The Momentum and Kinetic Energy impulse of the model was converged with a fine mesh of solid tetrahedral and hexahedral elements for the auxetic armour models, with 463,835 elements and 418,512 nodes. The width of ballistic protection is 40 mm.

3. Results and discussions

Following the numerical experiments performed on the 3D model proposed, the analysis demonstrates that the auxetic structure, as opposed to the monolithic panel, experiences a larger energy translation of a projectile's kinetic energy into elastic energy as a result of the elastic deformation of the unit cells. The auxetic structure outperforms the monolithic panel due to its better absorption capacity.

Although the auxetic model experiences more deformation than the monolithic panel, the rear plate is unaffected by this deformation, elastic's dissipation. In the auxetic structure, elastic energy dissipation is stronger. The threat level is greatly decreased by the auxetic structure, which may be used at higher speeds and is secure up to 450 m/s.

The Figure 4 shows the projectile penetration and response behavior of the auxetic core. In the, the penetration is minimal and the energy absorption is mostly elastic, shown by deformation patterns in auxetic cells. It was noticed that the front face was slightly damaged after projectile impact. Auxetic cells could be observed vibrating frequently as the projectile was ricocheting.

It has been shown that due to the sufficient densification and indentation resistance provided by the auxetic core, the projectile cannot penetrate the rear face plate, up to a projectile velocity of 450 m/s. The auxetic structure is safe up to 450 m/s and can be used at higher speed, significantly reducing the threat level. At 650 m/s, the rear face is damaged.
4. Conclusions

The ballistic impact behavior of composite armour was examined in this work using an auxetic sandwich. The Inventor Nastran program was used to simulate the effect of a projectile traveling at various speeds on composite auxetic sandwich armour. The results were compared with monolithic armour under the same boundary conditions and speeds. From the research, the following conclusions were drawn:

1. The auxetic structure outperforms the monolithic panel due to its better absorption capacity.

2. The threat level is greatly decreased by the auxetic structure, which may be used at higher speeds and is secure up to 450 m/s.

3. The auxetic method can be considered appropriate for the application if the advantages of auxetic structures satisfy the fundamental requirements of the application and the constraints are not of concern.

References