BEHAVIOR OF WOVEN FABRIC COMPOSITES MATERIAL BY BALLISTIC IMPACT

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Abstract

Ballistic impact is generally a low-mass high velocity impact caused by a propelling source. Natural fiber composites are mainly price-driven commodity composites that have useable structural properties at relatively low cost. The manufacture, use and removal of traditional composite structures usually made of glass, carbon and aramid fibres are considered critically because of the growing environmental consciousness. Advantages of natural fibers over traditional reinforcing fibers such as glass and carbon are: low cost, low density, acceptable specific properties, ease of separation, enhanced energy recovery, CO_2 and biodegradability. There is a growing interest in the use of natural/ biofibres as reinforcing components for thermoplastics and thermosets. Although thermoplastics have the added advantage of recycling possibilities; thermosets are targeted to obtain much improved mechanical properties as compared to thermoplastics in the resulting bio-composites.

1. Introduction

Ballistic impact is a high velocity impact by a small mass object.. It is important to study the response of materials to ballistic impact loads. Applications of this research include body armor, armored vehicles and fortified buildings, as well as the protection of essential equipment, such as the jet engines of an airliner. The impact and perforation of fabric and compliant laminates are functions of a number of parameters including the materials properties of the yarns, the fabric structure the projectile geometry and velocity the interaction of multiple plies.

2. Damage mechanisms

Ballistic impact is generally a low-mass high velocity impact by a projectile propelled by a source onto a target. Since ballistic impact is a high velocity event, the effects on the target can be only near the location of impact. During ballistic impact, energy transfer takes place from the projectile to the target. Based on the target material properties and projectile parameters.
The following are possible

(1) The projectile perforates the target and exits with certain velocity. This indicates that the projectile initial energy was more than the energy that the target can absorb.

(2) The projectile partially penetrates the target. This indicates that the projectile initial energy was less than the energy that the target can absorb. Based on the target material properties, the projectile can either be stuck within the target or would rebound.

(3) The projectile perforates the target completely with zero exit velocity. For such a case, the initial velocity of the projectile of a given mass is termed as ballistic limit. For this case the entire energy of the projectile is just absorbed by the target.

3. Ballistic Impact Mechanisms of Materials

At low impact velocities (say a few hundred meters per second), the penetration resistance of a material is governed by the dynamic deformation mechanisms within the projectile and target. However, as the impact velocity increases into the hypervelocity regime (several thousand meters per second), hydrodynamic effects dominate and the penetration response becomes controlled by only the density of the impacted material and projectile. Since the resistance of a material to penetration by low velocity projectiles is controlled by dynamic deformation and fracture mechanisms, the materials science community has been greatly interested in their optimization. In general the mechanisms that are activated depend upon the thickness, strength, ductility, toughness, acoustic impedance and density of both the target material and projectile and the velocity of the projectile.

4. Energy absorbed due to shear plugging

Cantwell and Morton observed frustum shaped shear cut-out zone on impacting carbon fibre reinforced angle ply laminates with steel spherical bullets. Lee and Sun and Ellis reported shear plugging to be one of the major damage modes on impact of angle ply graphite/ bismaleimide by blunt/flat projectiles. Figure which is given below, shows schematic arrangement of plug formation during ballistic impact. Shear plug formation is not observed for glass reinforced composites which have high failure strain at high strain rates.

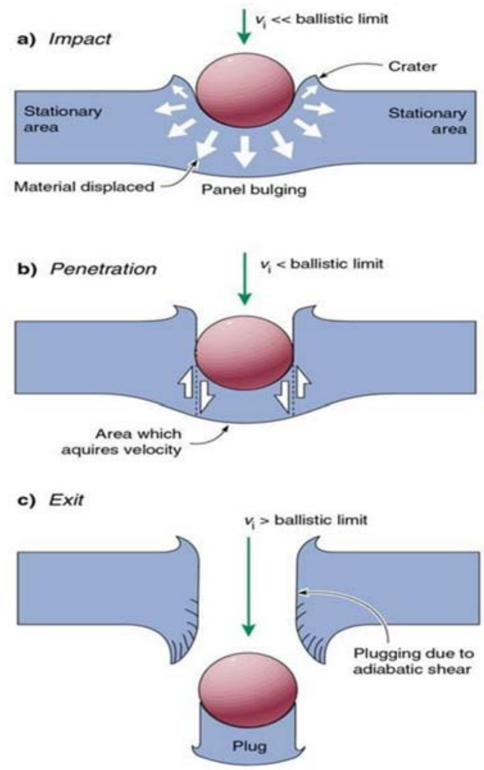

Figure 1: Example of the projectile penetration mechanisms for a soft material impacted by a hard project

5. Energy absorbed due to friction between projectile and target

Target penetration takes place when, either all the fibres fail due to tension or all the layers fail due to shear plugging or due to the combined effect of both the mechanisms. Even after tensile failure of all the yarns or shear plug formation, the projectile has to overcome frictional resistance provided by the damaged laminate. In case when the projectile has just enough energy to fracture all the yarns but not enough energy to overcome the frictional resistance, it may get stuck up in the target. The frictional resistance depends on the type of fit between the projectile and the damaged target. And accordingly, it can result in local temperature rise. Some researchers have developed a relation between these different types of energy.

6. Energy absorbed due to tensile failure of primary yarns

The yarns directly below the projectile, known as the primary yarns, fail in direct tension. All the primary yarns within one layer do not fail at one instant of time. As and when the strain of a particular yarn reaches the dynamic failure strain in tension, the yarn fails. It may be noted that the length of yarns/fibres failing in tension is twice the distance covered by the longitudinal wave. Also, the complete length of a primary yarn is not strained to the same extent as explained earlier.

7. Fibre treatment

The raw PALF (Pineapple leaf fibre) and sisal fibres are washed with 2% detergent solution at 70^0C for 1 h, then washed with deionised water and finally dried in a vacuum oven at 70^0C. The dried fibres are designated as untreated fibres. The untreated sisal fibres are subjected to various surface treatments.

7.1 Alkali treatment

The fibres are first dewaxed by soaking, batches of sisal fibres in 1:2 mixture of ethanol and benzene for 72 h at 50 ^{0}C, followed by washing with deionised water and then air dried. The dewaxed fibres are immersed in 5 and 10% NaOH solution for 1 h at 30 ^{0}C, then washed thoroughly with deionised water and air dried to get 5 and 10% alkali treated fibres respectively.

7.2 Cyanoethylation

The dewaxed sisal fibres are refluxed with acrylonitrile (AN), acetone and pyridine (as catalyst) at a temperature of 60 ^{0}C for 2 h, then washed with acetic acid and acetone followed by washing with deionised water and finally vacuum dried to get cyanoethylated fibres.

7.3 Acetylation

The alkali treated sisal fibres are soaked in glacial acetic acid for 1 h at 30 ^{0}C, decanted, and then soaked in 50 ml of acetic anhydride containing one drop of concentrated H_2SO_4 for 5 min. The fibres are then filtered, washed with conductivity water and finally air-dried.

8. References

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