New 3D warp interlock composite for armouring of vehicles

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Abstract: Since the apparition of new non conventional threats on the battlefield, armoured vehicle manufacturers are looking forward to increase the efficiency of their protections and reduce the mass of components.[1]
The combination between some well-known ballistic alloys and textile composite materials appear as a high potential solution for armour plated protection. Those textile composite materials present some interesting properties such as a very low density compared with steel and good behaviour in term of ballistic efficiency.
This study proposes to test and compare the behaviour and efficiency of two different textile composite structures, used as a backing.

1. Introduction

Some studies have been led in order to improve those textile backing composites (fibrous reinforcement parameters, resin and process). Nevertheless, new treats such as high velocity projectiles (steel projectile accelerated up to 1000 m/s) required more effective protection solution.
It has been established that 3D warp interlock fabrics have different mechanical properties than 2D fabric made of the same fibrous material [2,3,4,5]. Indeed, 3D warp interlock fabric present, due to their unusual bonding between layers, interesting properties during impact [6].

2. Experimental study

In order to study the difference of behaviour of 2D and 3D composite solutions submitted to high speed impact tests, two different kinds of backing have been achieved.
The first backing solution is composed of two 2D laminated composites (first composite of 8mm thick and second composite of 5mm thick), made of several pre-impregnated plies (yarns of 3360 dTex linear density) and assembled under high heat and pressure, which are widely used in hard ballistic protection.

The second type of backing is a new combination of a 3D warp interlock fabric composite (yarns of 3360 dTex linear density and thermoplastic matrix) designed in the GEMTEX laboratory (8mm thick), and a second 2D laminated composite (5mm thick).

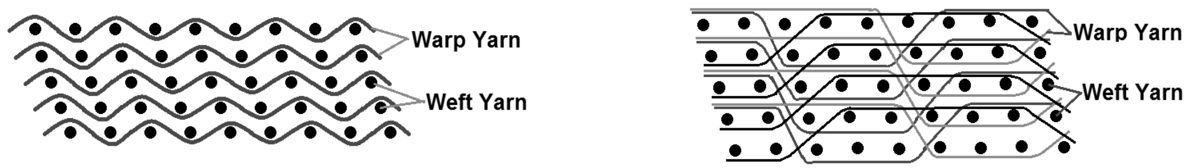

Figure 1: Cross sectional view of a 2D laminated structure (left) and a 3D warp interlock composite (right)

Both those structures were tested at the same value of high speed and with a steel armoured plate on the front face of a given thickness.
This campaign of tests confirm the hypothesis that 2D fabric composite and 3D fabric composite both have a different behaviour under a same impact.

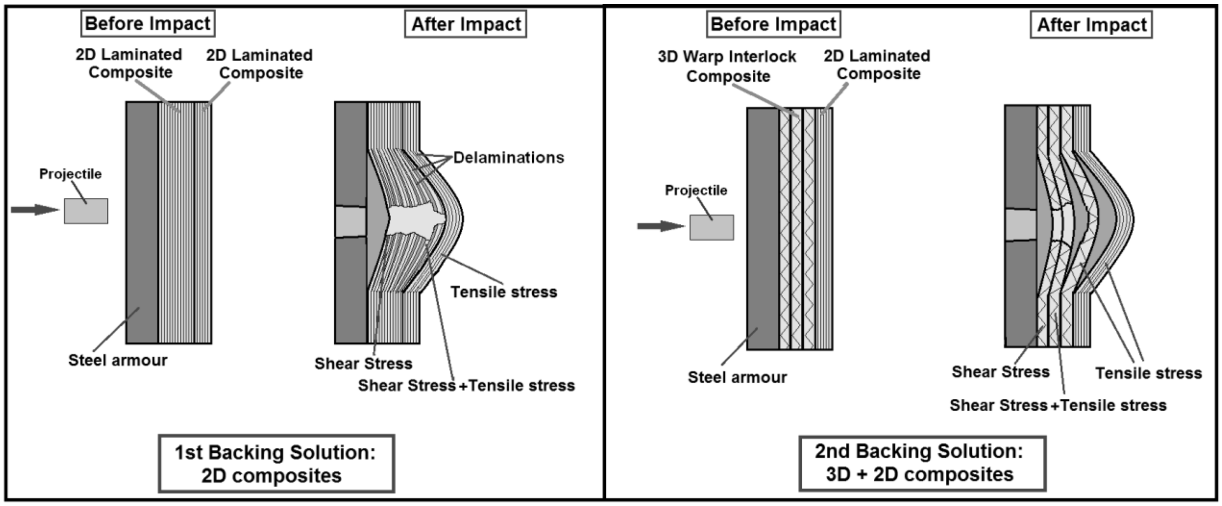

Figure 2: Sectional view of the expected behaviour of the two composites before and after impact

Indeed, 2D fabric composites have an expected mechanical reaction while the 3D fabrics present a new mechanical response and generally, this second innovative solution composed of 3D warp interlock fabrics tends to give better results regarding the protection.

2.1. First backing solution

The first configuration has stopped the projectile. The first part of the backing (8mm) shows an important back-face deformation of 48 mm as well as an important damage area. (See figure 3) This part is entirely perforated. We can observe on this part of the backing that the warp and weft yarns of the fabric were more stress at the impact point since all the broken yarns in this area under shearing stress form the typical cross-shaped damage area on fabric.

The second part of this backing (5mm) presents an important back-face deformation of 49 mm. This part is undamaged even if we can observe the beginning of the tensile fibre breakage on the back-face of the composite due to this important deformation (See figure 3).

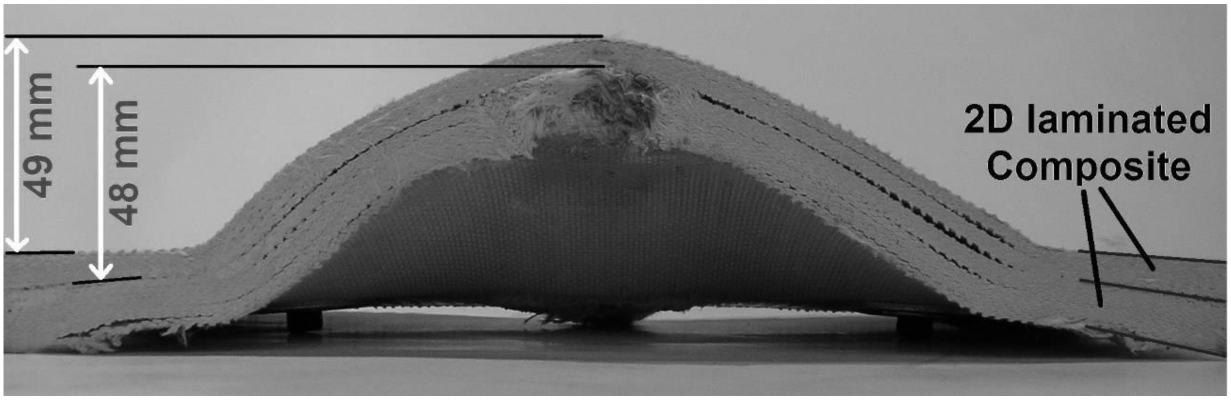

Figure 3: Sectional view of the first configuration composite after impact

2.2. Second Configuration

The second configuration also stopped the projectile. The first part of the backing (8mm) is partially perforated; which means that the projectile has perforated two of the three layers of the composite structure. The back-face deformation is 48 mm height. (See figure 4)
The second part of the backing remains intact although presenting an important deformation of 57mm.
We can observe the beginning of tensile fibre breakage on the back-face of the composite due to an important deformation (See figure 4).

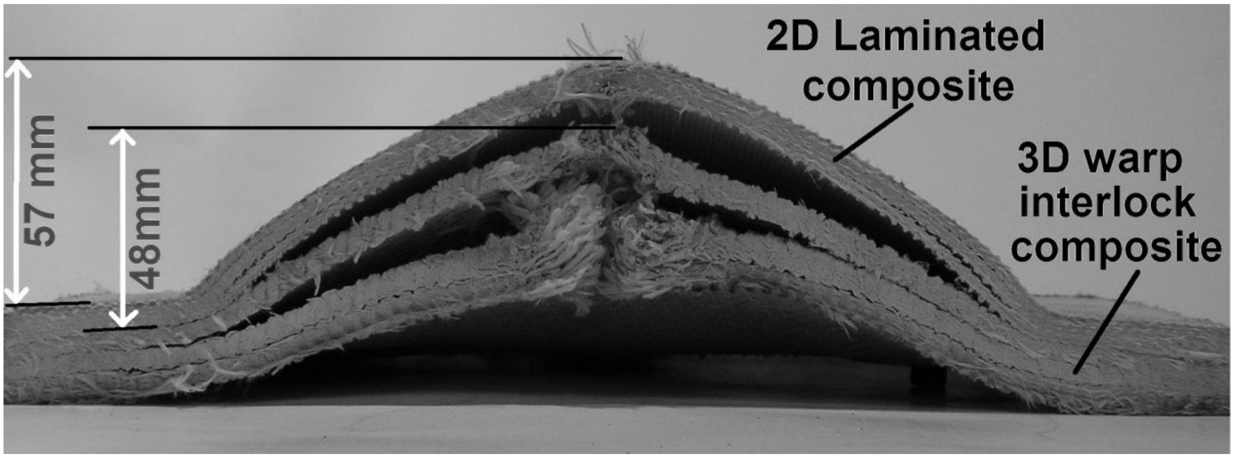

Figure 4: Sectional view of the second configuration composite after impact

3. Conclusion:

This study has revealed that textile composite backings show different behaviours under a same impact according to the different assembly of the composite solution.
In the first configuration, the fully 2D pre-impregnated laminates backing, the first part of 8mm is entirely perforated, while the second part of 5mm still remains almost undamaged.

Considering this second configuration; the 3D warp interlock fabric impregnated with a thermoplastic matrix reveals a first part (8mm) not-fully perforated and an entire un-perforated second part (5mm).

This interesting behaviour of the 3D warp interlock fabric with the thermoplastic matrix can be explained by the improved flexibility of the reinforcement. Indeed, the special bonding of yarns in the thickness direction coupled with the non systematic bonding of yarns on a same layer tend to give a textile structure more elastic and more able to be deformed than a similar structure made of 2D pre-impregnated plies of laminates.

Choice between the different backing parameters such as the resin, its infusion process and the fibrous reinforcement architecture of the textile reinforcement are crucial in order to reach the expected safe protection.
In this study, it has been demonstrated that the better impact behaviour is reached using 3D warp interlock fabric impregnated with thermoplastic matrix.

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