

Experimental investigations of the impact behavior of a warp interlock fabric

Cuong Ha-Minh^{1,2}, François Boussu^{1,2}, Jan Van Roey^{1,3}, Toufik Kanit¹, David Crépin^{1,2}, Abdellatif Imad¹

¹ Univ. Lille Nord de France, F-59000 Lille, France;

² ENSAIT, GEMTEX, F-59100 Roubaix, France;

³ Royal Military Academy, Renaissancelaan 30, 1000 Brussel, Belgium

Introduction

Textile 3D warp interlock structures are a new material applied in ballistic protection [1]. However, the advantages of this material over 2D structures have been confirmed [1, 2, 3, 4, and 5]. We can summarize two main advantages of 3D textile structures in comparison with the 2D ones: (1) Higher resistance to multi-impacts (less damage for an impact); (2) Easier and cheaper achievement of complex shape structures.

To characterize impact behavior of 2D woven fabrics, many papers are published [1, 2, 3, 4 and 5]. Van Roey et al. [6] presented a technique to measure continuously the projectile velocity during ballistic impact onto plain-woven fabrics using radar. However, investigation on 3D structures remains modest. Lefevre et al. [7] present ballistic tests on a few samples of 3D fabrics. Variation of energy absorption versus the number of layers is analyzed in their paper.

In this paper, the technique of Van Roey et al. [6] is used to study the impact behavior of a 3D 4-layers-warp-interlock-woven fabric. A method fixing fabrics in clamps is presented. Samples are shot in the range of impact velocity from 82 m/s to 249 m/s.

Experimental

Materials

The tested fabric is a 3D 4-layers-angle-interlock structure with two orthogonal yarns: weft and warp yarns (Fig. 1). In the fabric plane, density of warp yarns is 20 ends/cm and 27.8 picks/cm for weft yarns. All yarns are Twaron 3360 dTex that induces a surface density of 1.66 kg/m² for this fabric. Projectile is a steel sphere of 12.7 mm diameter with a mass of 8.4 grams. Deformation of this projectile is negligible in this study.

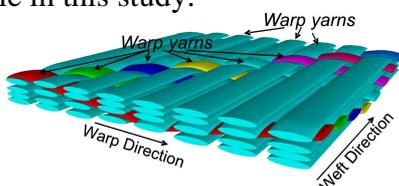


Fig 1: Structure of studied 3D warp interlock woven fabric

Apparatus and Procedures

The 3D fabric is fixed only at two edges of warp yarns with a free dimension of 15 cm×15 cm (Fig. 2). Configurations of tests are recorded by high-speed camera. Impact velocity is measured by four optical screens and a 10.525 GHz Weibel Doppler radar [6]. Continuous evolution of projectile velocity during impact is determined by a 26 GHz wave Doppler radar.

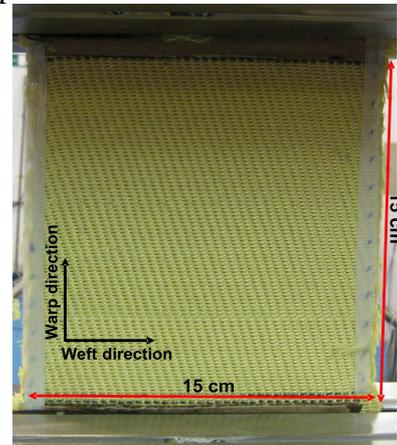


Fig 2: Fixation of fabrics in two clamps

Results and Discussion

Five tests are executed with impact velocities from 82 m/s to 249 m/s (Table 1). No yarn is failed in all tests. Projectiles are rebounded or passing through the fabric due to slipping at fixed edges (Fig. 3). However, slipping of fabrics takes place only with three high impact velocities superior to 200 m/s. This indicates that the fixation method in this study is limited for these velocities.

Table 1: Details of ballistic tests

Tests	Fabrics	Impact velocity	Slipping of fabric out of clamps
Test 1	New fabric	82 (m/s)	No
Test 2	Fabric tested with test 1	235 (m/s)	Yes
Test 3	New fabric	215 (m/s)	Yes
Test 4	Fabric tested with test 3 without carton	249 (m/s)	Yes
Test 5	New fabric	89 (m/s)	No

Three main damages phases of the 3D fabric are observed (Fig. 3): (1) Slipping of fabric out of clamps; (2) Deformation of yarns at the impact point; (3) Pull-out of yarns at free edges.

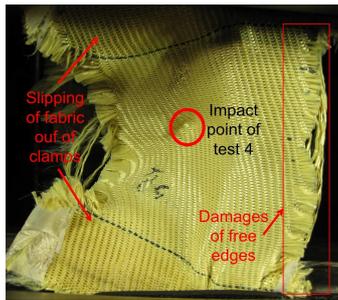


Fig 3: Damage phases of the observed fabric after test 4

Figure 4 shows the continuous evolution of projectile velocity from the impact moment $0 \mu\text{s}$ to $290 \mu\text{s}$ in test 4. We can see that during the first $30 \mu\text{s}$, the velocity decreases slightly. In fact, in this period, yarns follow essentially de-crimping mechanism due to their high undulation in the warp interlock structure. Moreover, it is too early for strain waves to propagate so far. From $40 \mu\text{s}$ to $155 \mu\text{s}$, deceleration of projectile increases strongly with quantity of materials contributing to stop the projectile. During this period, the observed pyramid at the moment $166 \mu\text{s}$ in figure 5 is built. From $155 \mu\text{s}$ to $240 \mu\text{s}$, projectile velocity seems to be constant and restarts to decrease but slightly from 240 to $290 \mu\text{s}$. This phenomenon is explained by slipping of fabrics observed in configurations of test 4 at $166 \mu\text{s}$, $333 \mu\text{s}$ and $500 \mu\text{s}$ (Fig. 5).

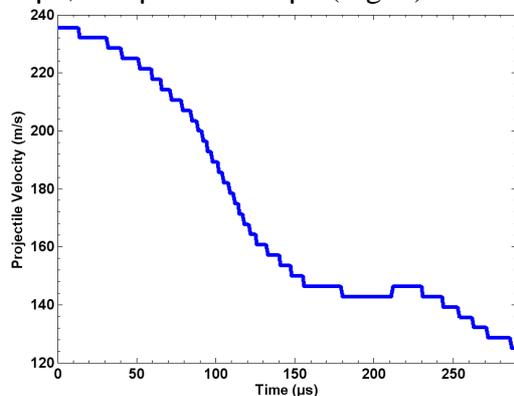


Fig 4: Evolution of the projectile velocity versus time of the test 4

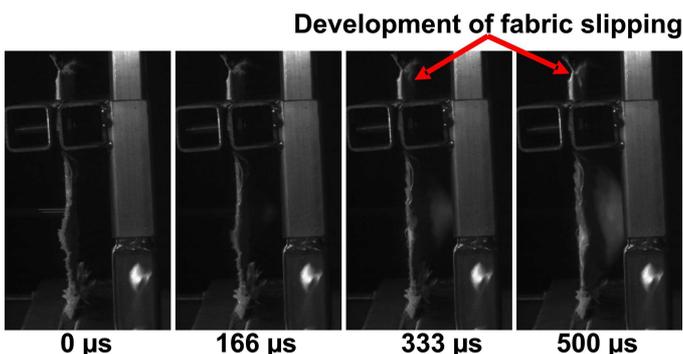


Fig 5: Configurations of test 4 with time step = $167 \mu\text{s}$

Conclusion

Ballistic tests on a 3D warp interlock woven fabric have been carried out with five different impact velocities. The limitation of used fixation method is observed at high velocities. Damage phases of the fabric are analyzed. Evolution of projectile velocity is investigated with different configurations during impact.

References

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