



# Effect of frictions on ballistic performance of a 3D warp interlock fabric: Numerical analysis

Presented by François BOUSSU

Authors:

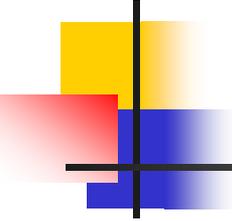
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# Outline

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**1. 3D woven fabrics**

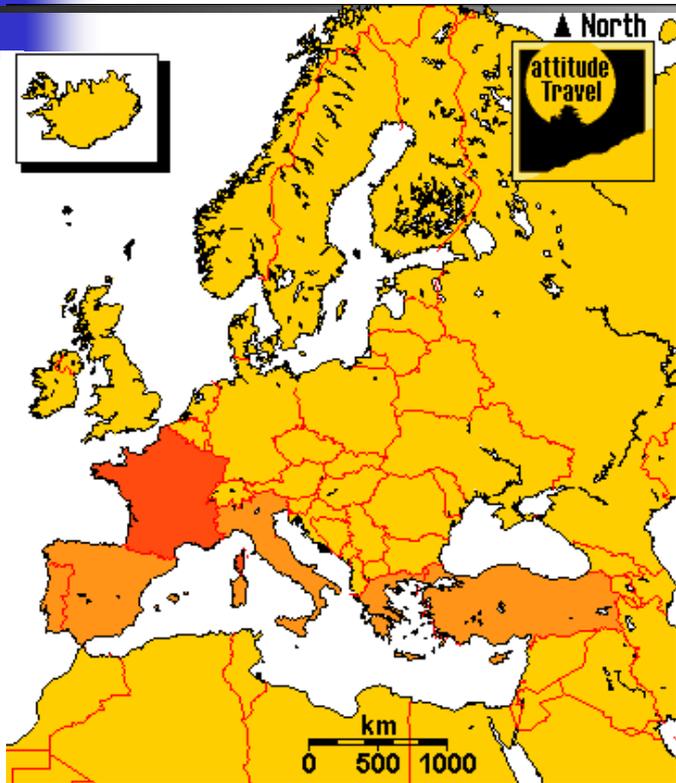
**2. Overview onto geometrical modeling of 3D woven fabrics**

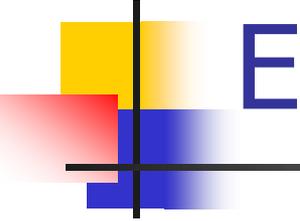
**3. New numerical tool and application in studying friction effects during ballistic impact onto a 3D fabric**

**4. Works in progress**

**5. Conclusions and Perspectives**

# North of France





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since 1881

National Textile Institute



# GEMTEX Laboratory Equipment



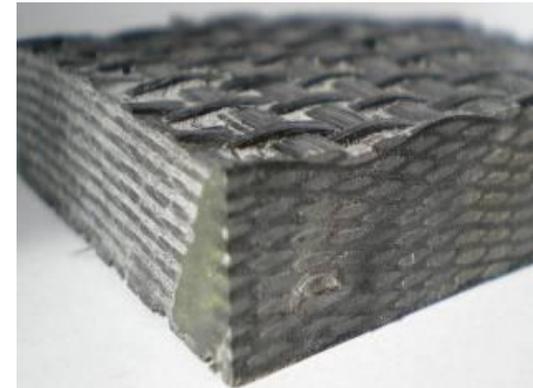
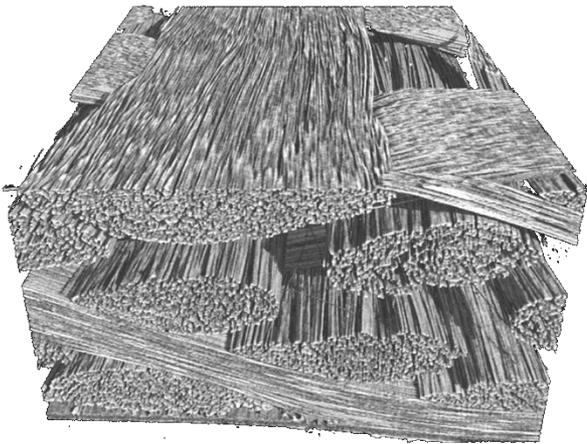
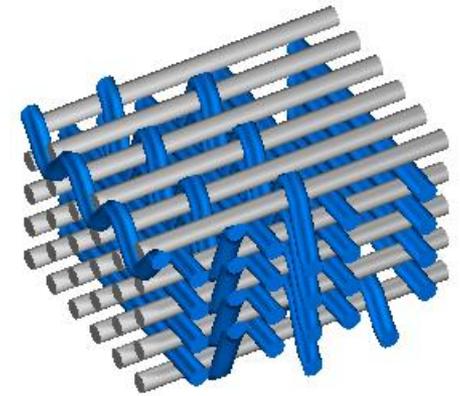
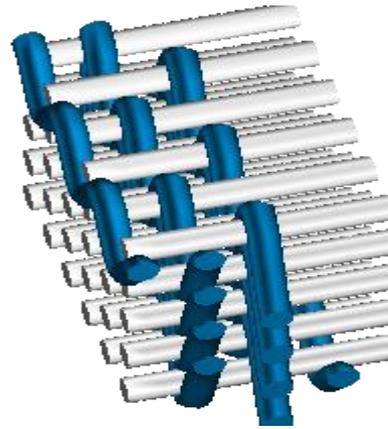
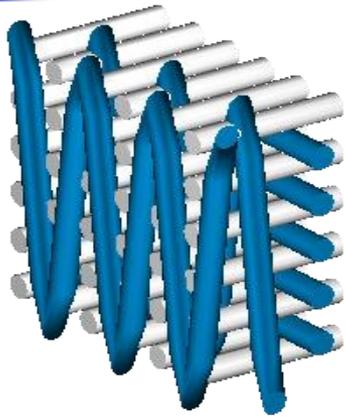
Side view of the automatic multi-layer weaving machine and its specific warp beams creel

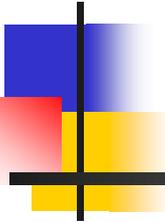


Adaptation of a 24 frames dobby weaving machine for aramid yarns.



# 3D Warp Interlock Fabric

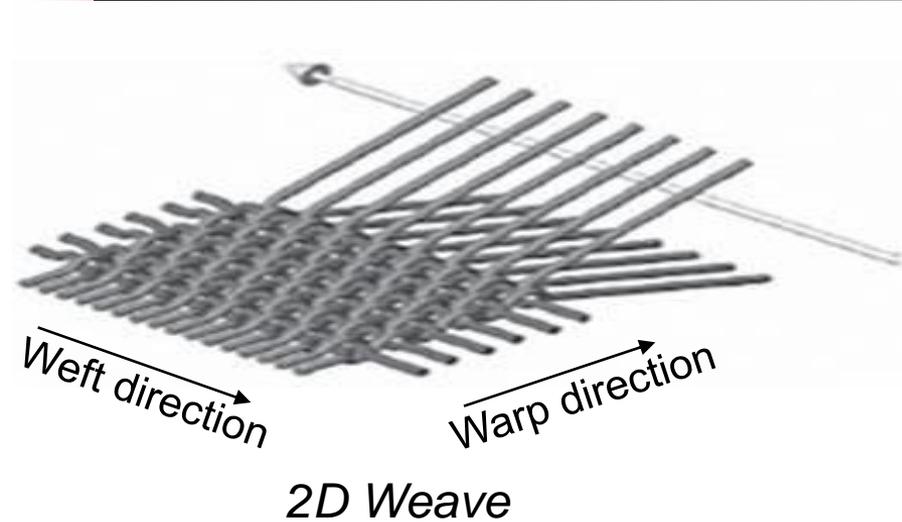




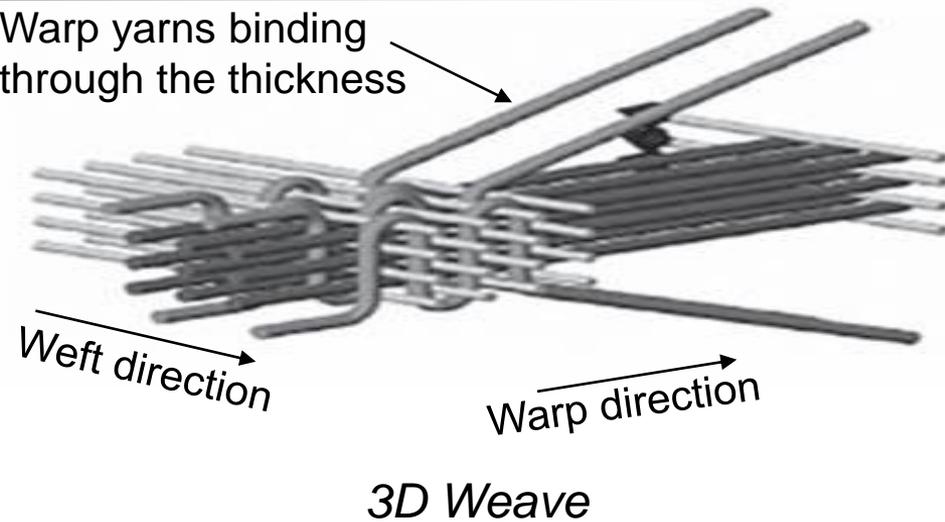
# 1. 3D woven fabrics

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# 1. 3D woven fabrics



Warp yarns binding through the thickness

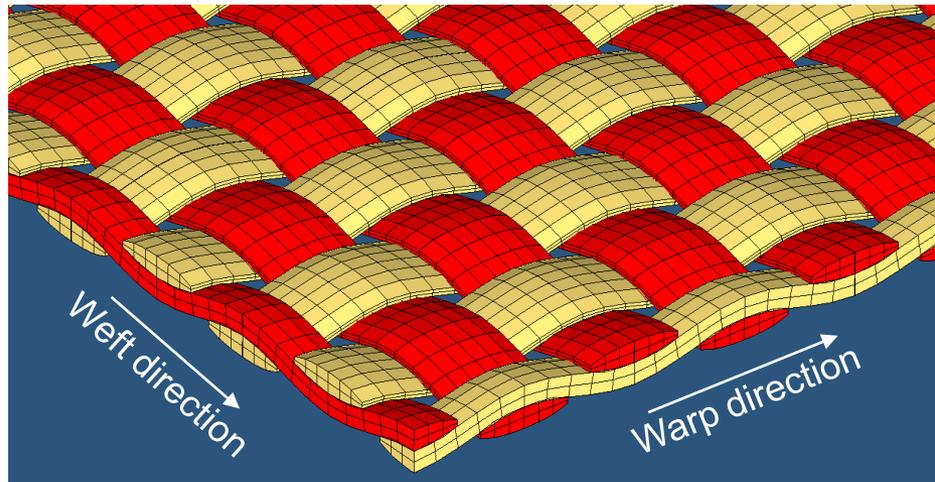


## **Main advantages of 3D woven fabrics regarding to 2D woven ones:**

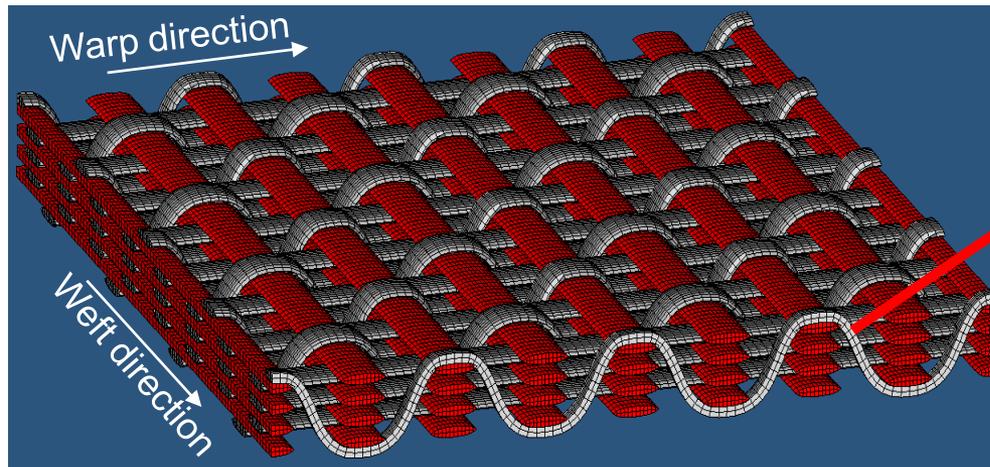
1. Facility in creating complex structures by the near-net-shape technology
2. Better mechanical interlaminar and through-the-thickness properties
3. Higher ballistic multi-impact damage resistance

# 1. 3D woven fabrics

*A 2D fabric*

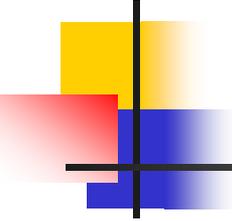


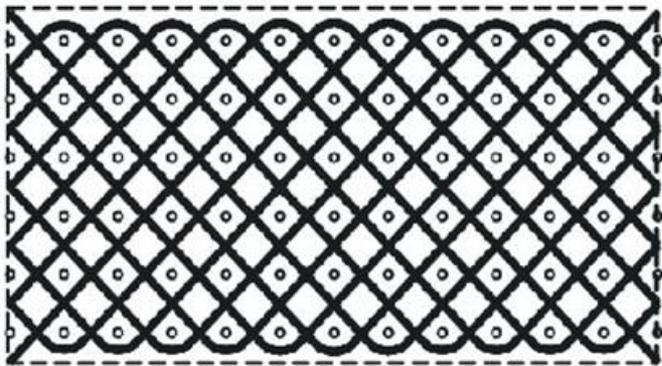
*A 3D fabric*



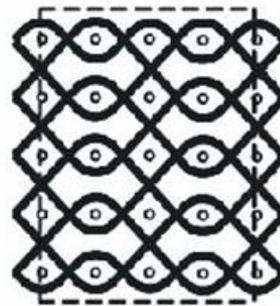
Warp yarn  
binding through  
the thickness

# 1. 3D woven fabrics

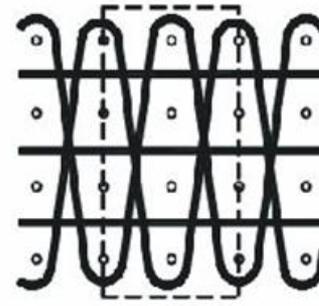
- 
- Depth through the thickness
- Path of binding warp yarns
- Crimp angle
1. AT: Angle – Through the thickness
  2. AL: Angle – Layer to layer
  3. OT: Orthogonal – Through the thickness
  4. OL: Orthogonal – Layer to layer



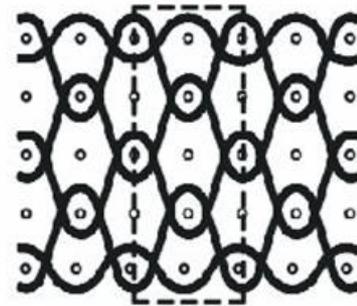
AT Fabric



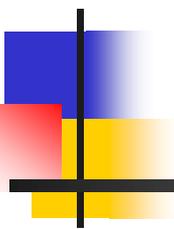
AL Fabric



OT Fabric



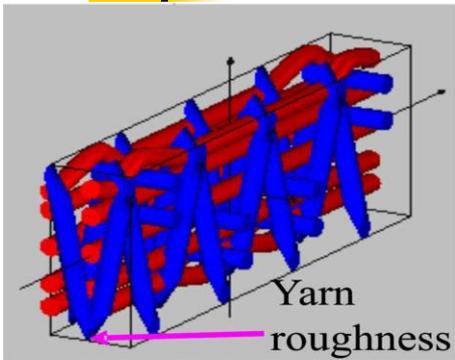
OL Fabric



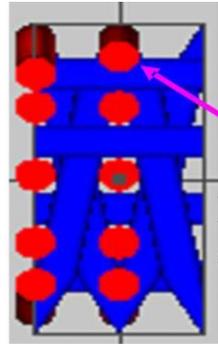
## 2. Overview onto geometrical modeling of 3D woven fabrics

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# Overview onto geometrical modeling of 3D woven fabric



(a)

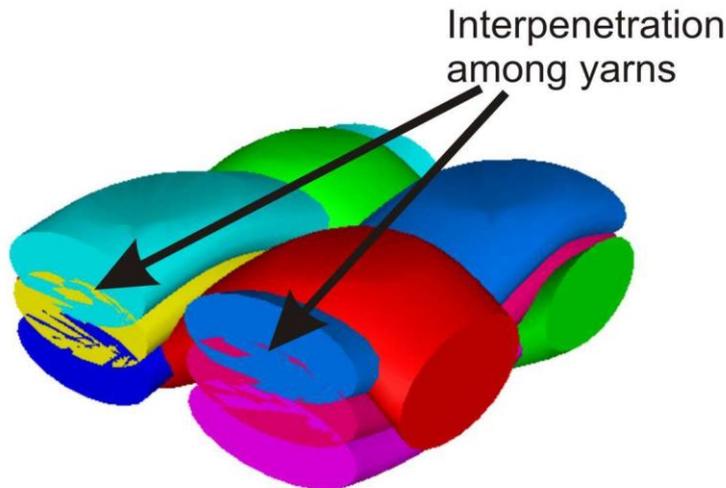


(b)

A geometrical model of the 3D orthogonal 5-layer fabric in WiseTex: (a) 3D view; (b) Side view

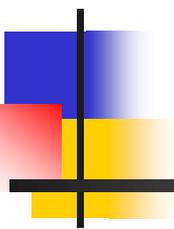
## Disadvantages of current softwares:

1. Limited application only for a few fabric types
2. Difficulty in use because users cannot correct errors in a graphic interface of these softwares
3. Interpenetration between yarns
4. Roughness of yarn path in fabric
5. Incompatibility between these softwares and popular finite element codes



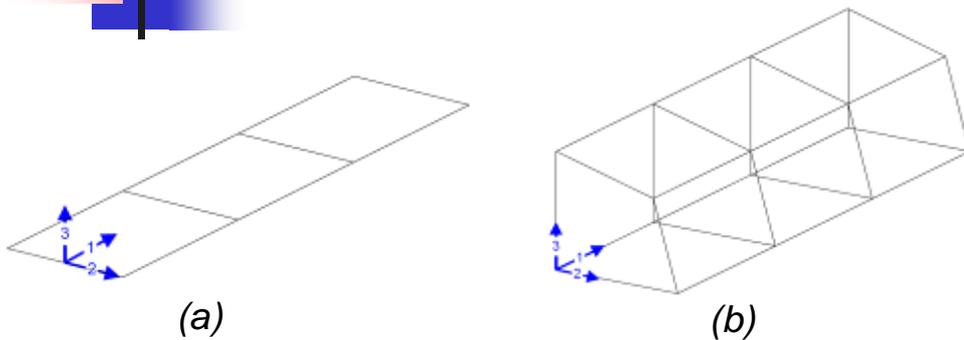
A geometrical model of the 3D orthogonal 3-layer fabric in TexGen

3. New numerical tool and in studying friction effects during ballistic impact onto a 3D fabric



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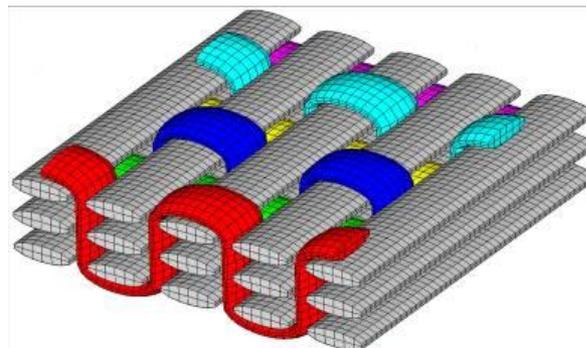
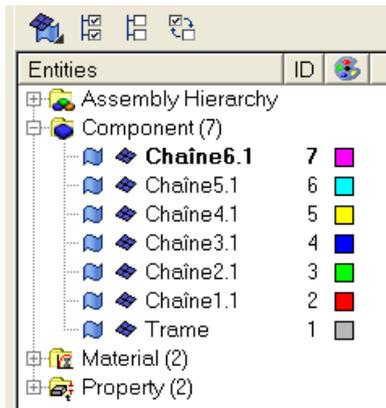
# New numerical tool



Orientation of the local axes of a solid element in a yarn:  
(a) Shell elements; (b) Solid elements

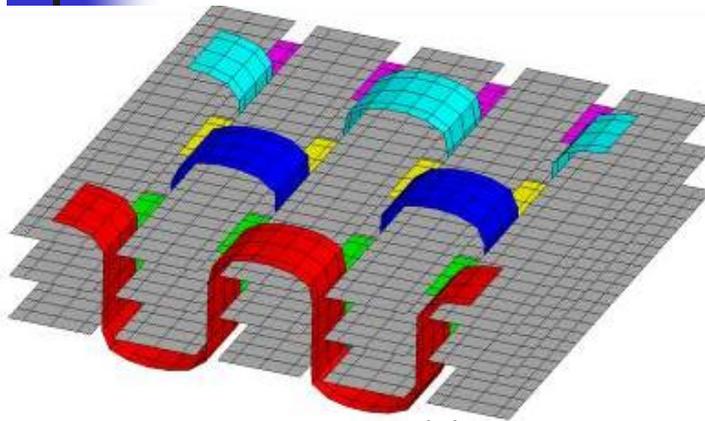
## Advantages of new numerical tool:

1. Large application for all types of woven fabrics
2. Regular smoothness of yarn paths & Exclusion of interpenetrations between yarns
3. Orientation of local axes of elements along yarn direction
4. Automatic contact between yarns
5. Compatibility with popular finite element codes: Abaqus, Ansys, Radioss ...

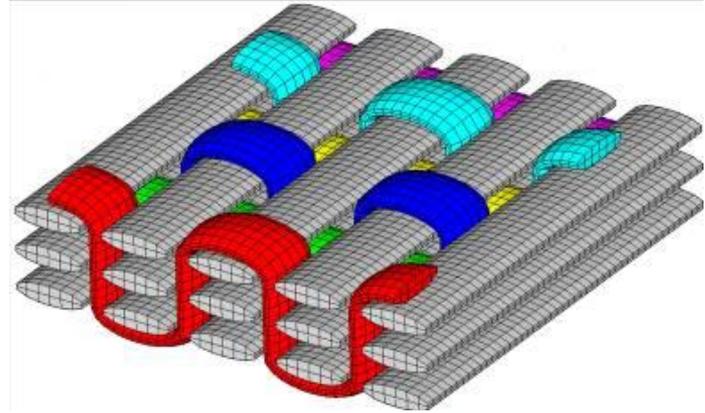


Organization of yarns and elements in groups on a friendly graphic interface

# Results of new numerical tool

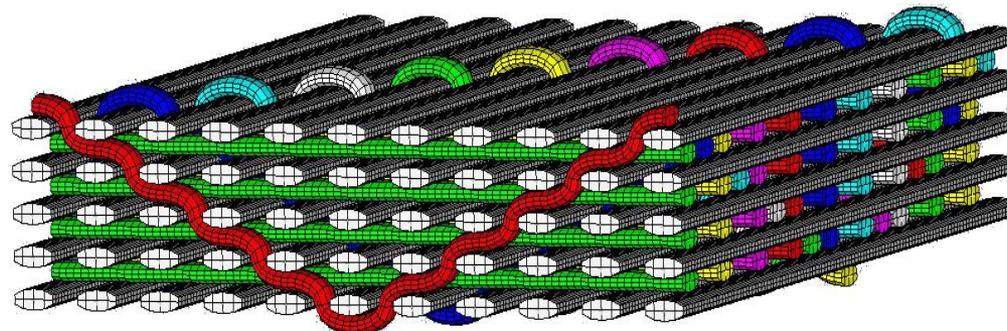


(a)



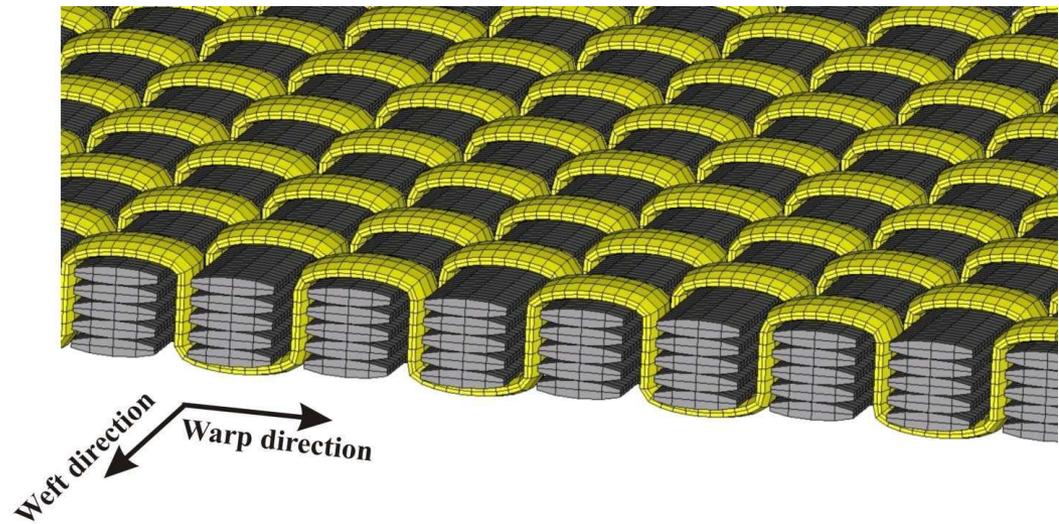
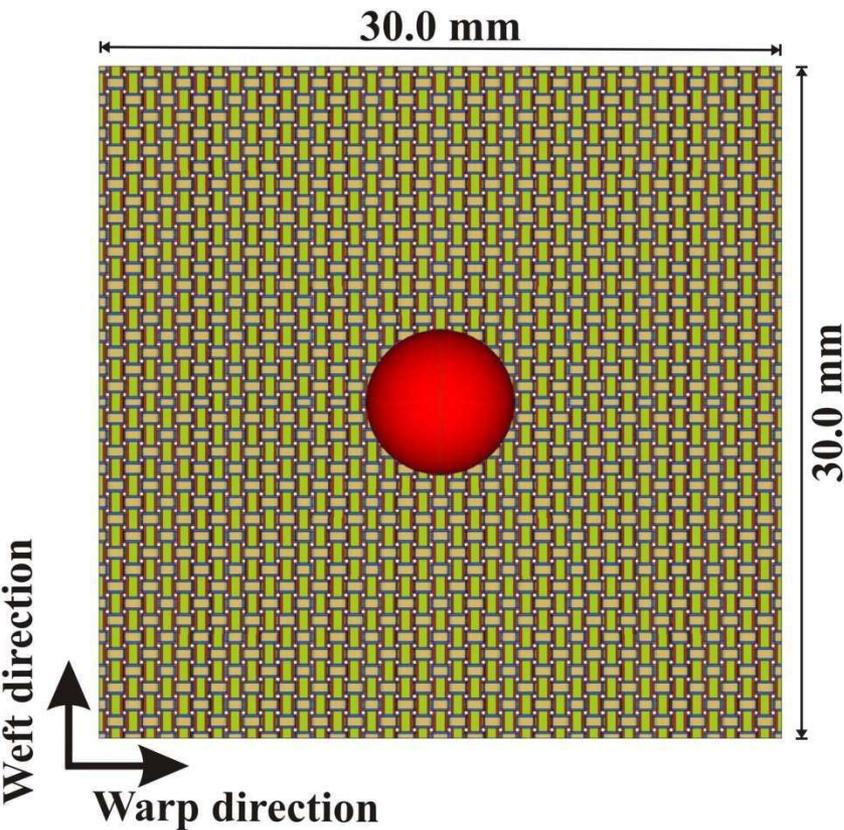
(b)

*A geometrical model of the 3D orthogonal 3-layer fabric created by new tool: (a) Shell elements; (b) Solid elements*



*A geometrical model of the 3D orthogonal 5-layer fabric created by new tool: (a) Shell elements; (b) Solid elements*

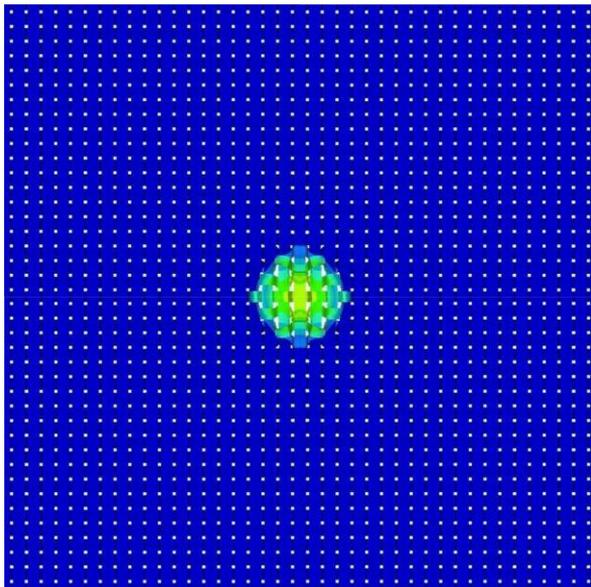
# Configuration of the impact onto 3D fabric



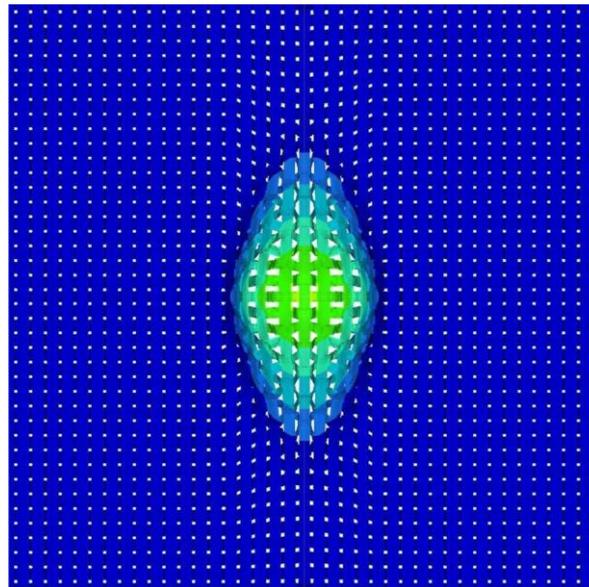
*Geometry of the 3D orthogonal 5-layer woven fabric*

*Configuration of a 900 m/s impact on the 3D orthogonal 5-layer woven fabric*

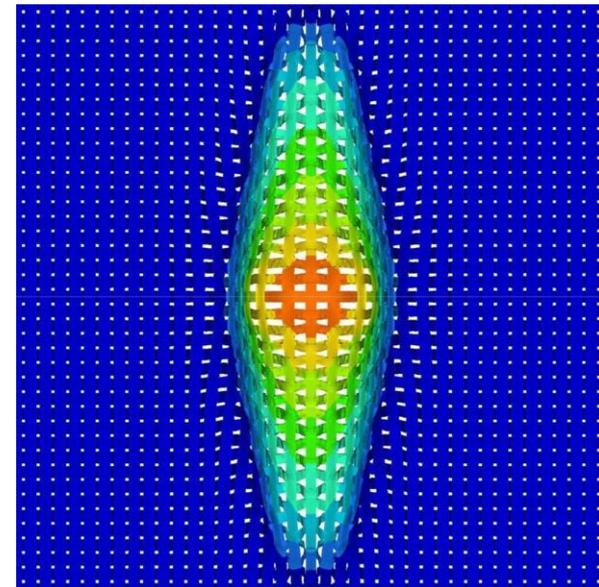
# Results of numerical simulation



(a)



(b)

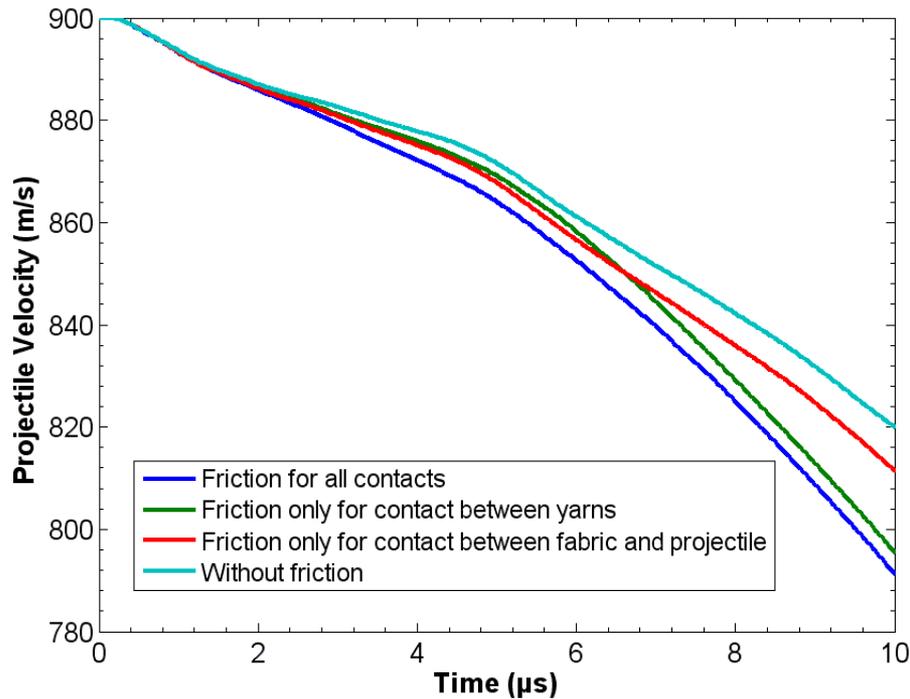


(c)

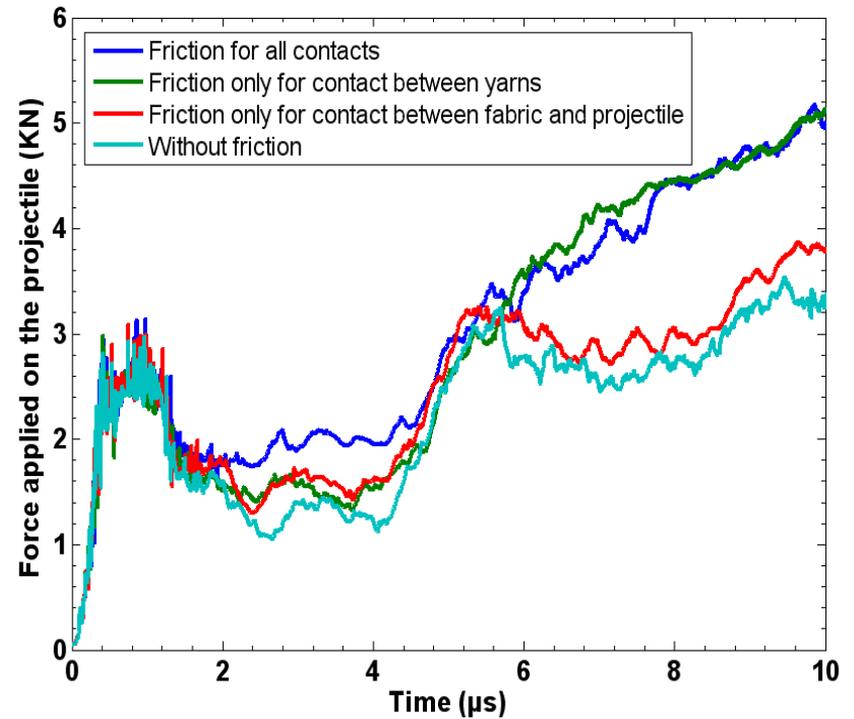
***Behavior of the 3D orthogonal 5-layer woven fabric subjected to a 900 m/s ballistic impact :***

***(a) at 1.5  $\mu$ s; (b) at 6  $\mu$ s ; (c) at 10  $\mu$ s***

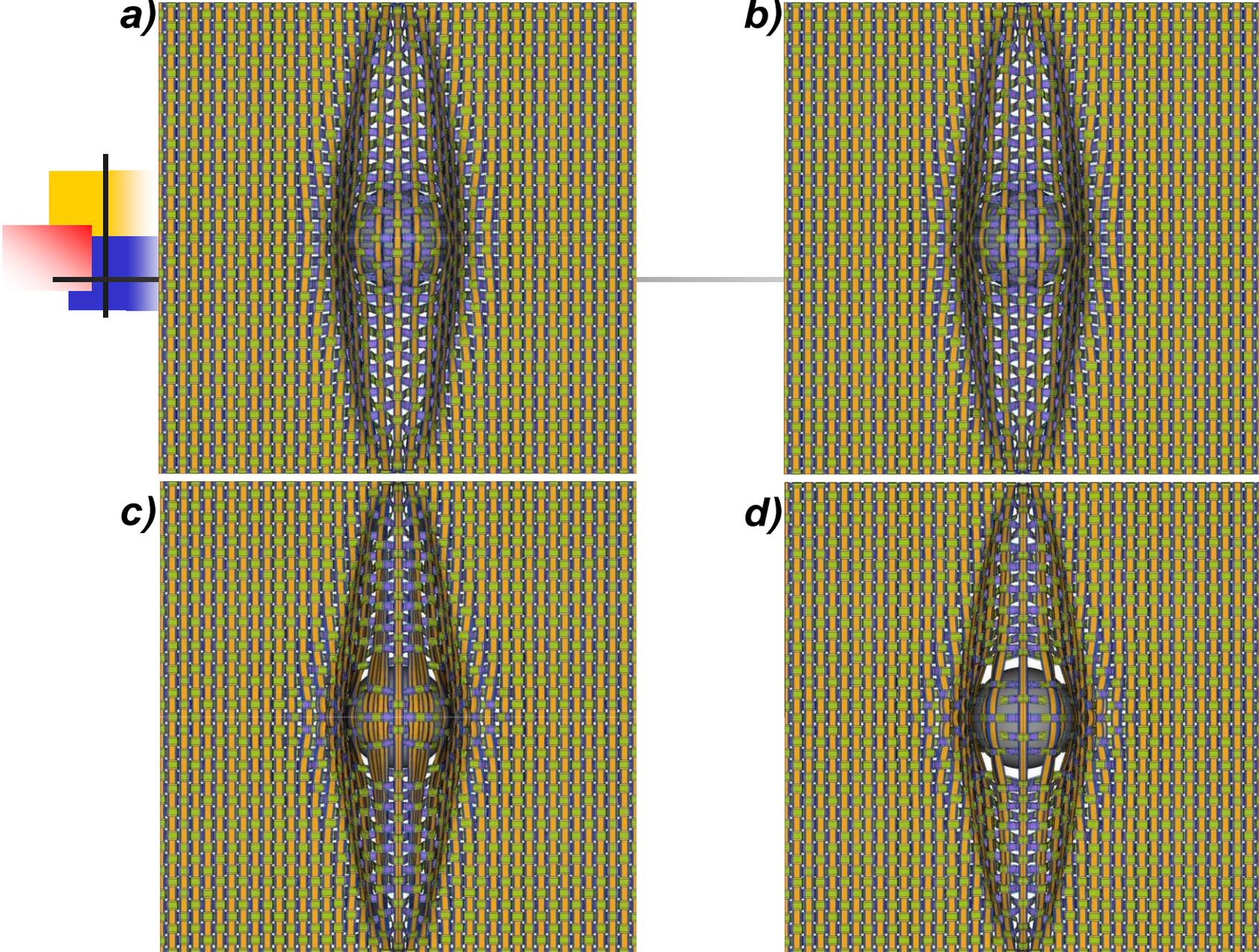
# Results of numerical simulation



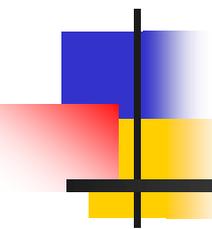
*Projectile velocity versus time during a 900 m/s impact on the 3D orthogonal 5-layer woven fabric*



*Force applied on the projectile during a 900 m/s impact on the 3D orthogonal 5-layer woven fabric*

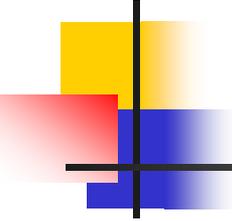


Configurations of the 3D orthogonal 5-layer fabric subjected to 900 m/s impact at 10 μs :  
 a) Friction at all contacts; b) Friction only at the contact between yarns;  
 c) Friction only at the contact between fabric and projectile; d) Without friction



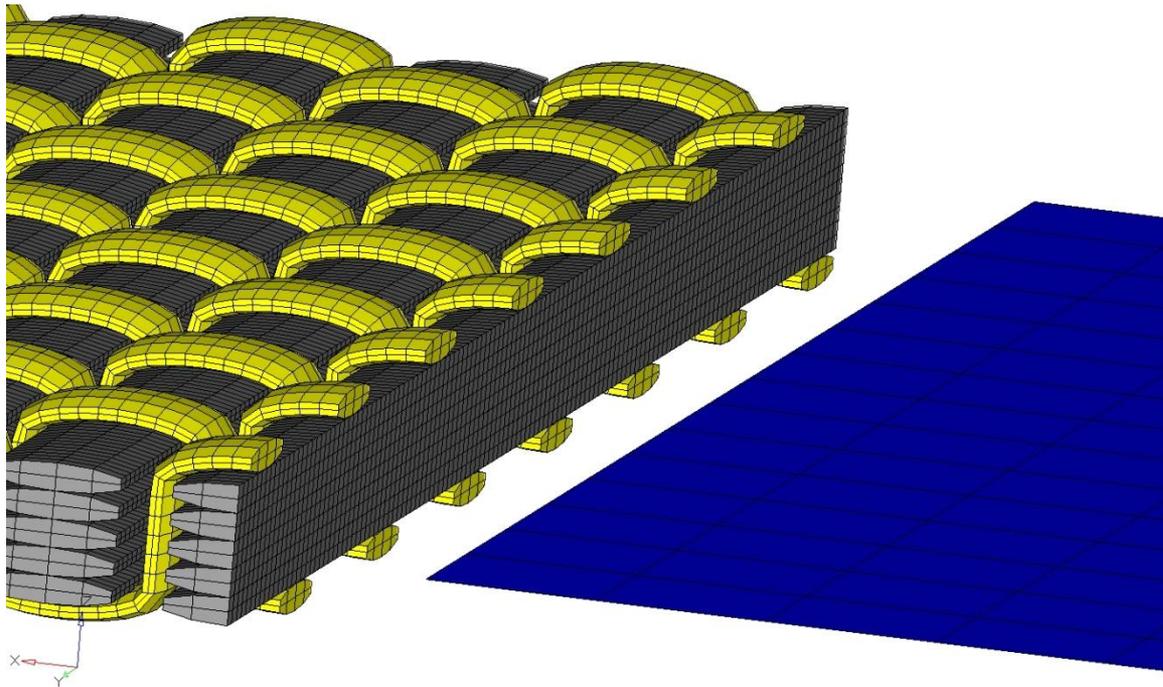
## 4. Works in progress

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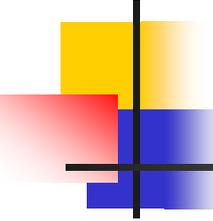


# Works in progress

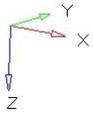
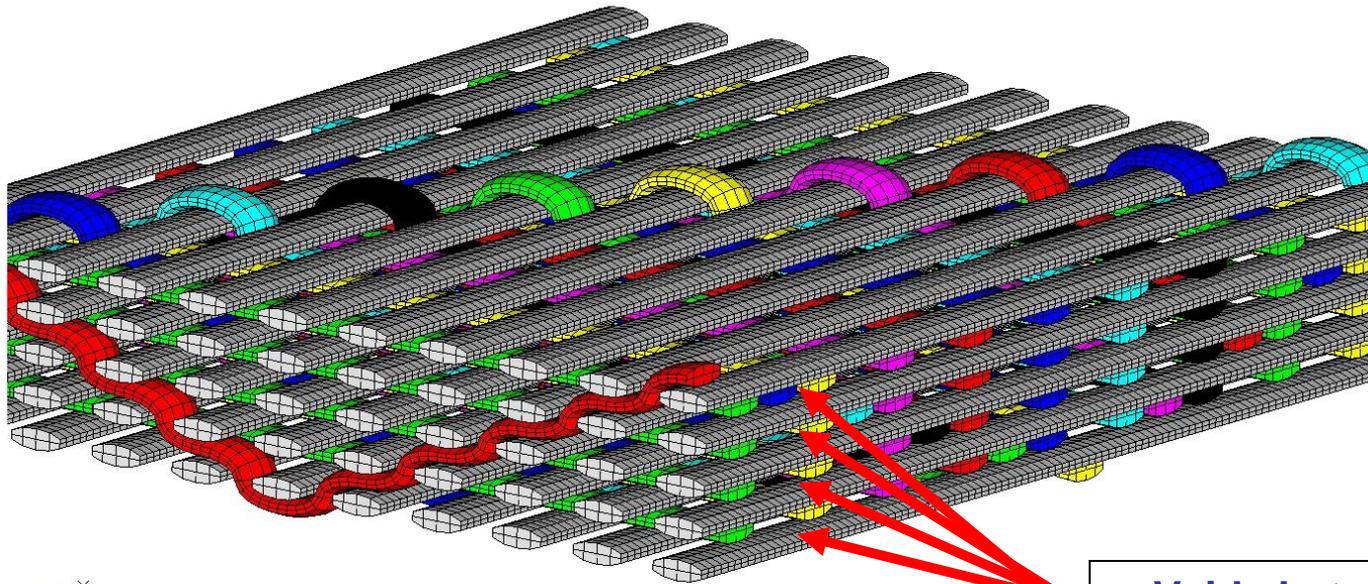
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*Connection between macroscopic and mesoscopic zones in 3D woven fabrics*

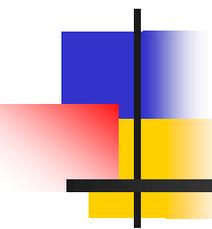


# Works in progress



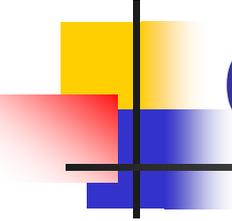
**Voids between  
straight weft yarns**

***Voids in the interlock-warp woven fabric due to straight weft yarns***



# 5. Conclusions and perspectives

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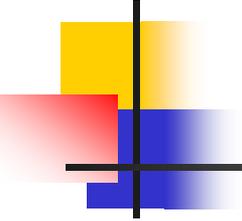
# Conclusions

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**An effective numerical tool – Ktex\_pattern is successfully created for geometrical representation and finite element modeling of textile woven fabrics**

**With Ktex\_pattern, the ballistic impact behavior of a 3D interlock warp woven fabric and friction effects are studied numerically**

# Perspectives



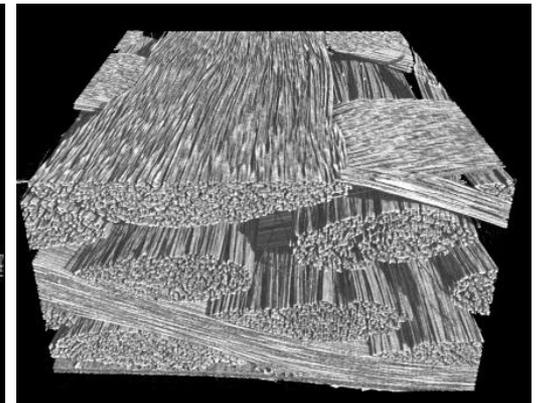
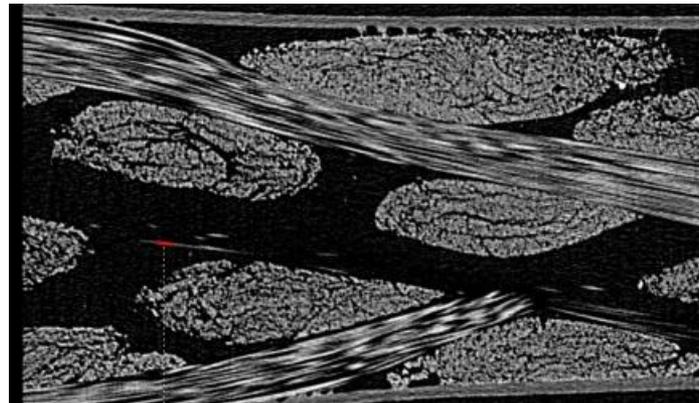
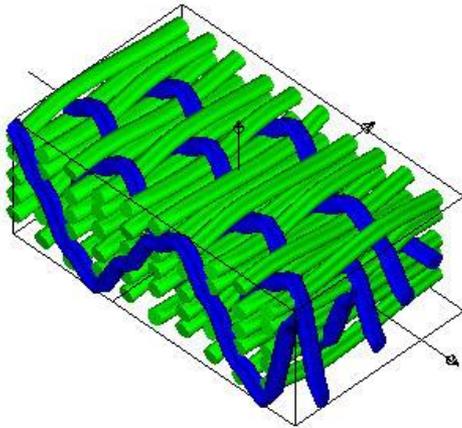
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**Improvement of the algorithm of the numerical geometric tool Ktex\_pattern for creating automatically more realistic models**

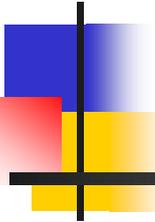
**New numerical technique for the connection between two macroscopic and mesoscopic zones the 3D woven fabrics**

# Perspectives

**Create a more realistic geometric model and then, an impact finite element model of the 3D fabrics from tomographic images**



Description of warp interlock fabric  
(left) Wisetex modelling geometric view  
(middle) photomicrographs of longitudinal sections  
(right) 3D tomography view in weft direction



Thank you for your attention

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Acknowledgment: We would like to thank the EDA for the financial support to conduct this study