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# Influence of the Textile Parameters on the Complex Shape Forming Properties of Flax Based Fabrics

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### Abstract

This study examines the ability to develop composite parts with complex geometries without defect. An experimental approach is used to identify and quantify the defects such as buckling caused by the bending of rovings during forming. Solutions are developed to obtain a complex shape such as a tetrahedron without any defect by using specially designed flax based reinforcement architecture. However, this solution may not be sufficient for other types of shapes and that is why the optimisation of the process parameters to prevent occurrence of buckles from commercial fabrics was also investigated.



### Keywords

Preforming; Buckling; Bending; Flax fabrics


## Introduction

Natural fibres such as flax fibres are particularly interesting because they are renewable, have low density and high specific mechanical properties. Recently, lots of works [1-3] have studied the tensile behaviour of individual fibres or group of few fibres of different nature and origin. However, few studies deal with the mechanical behaviour of fibre assemblies or analyse the deformability of these structures.

This work focuses on the forming of fibrous reinforcements. The modification of the structure during this step has a significant impact on the efficiency of resin impregnation, as it modifies local permeabilities due to local fibre volume variations. The defects appearing on the dry reinforcement are detrimental to the properties and the quality of the final composite part [4]. Hence, it is important to understand and prevent them, particularly when complex shapes forming is considered, where double and triple curvatures take place [5].

This paper therefore analyses the feasibility of forming complex tetrahedron geometry with flax fibres based fabrics. The bending of the rovings is particularly discussed and a solution to prevent the occurence of buckling defect is presented [6].

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## Experimental Procedure

### Experimental set-up

A device specially designed to analyse the local strains during the forming of fabrics is used and presented on Figure 1a. It consists of a tetrahedron punch associated to an open die and a classical blank holder system.

The punch is moved by a piloted electric jack, the stroke of which goes from 0 and 160 mm to form woven fabrics, whereas the blank holders are associated to pneumatic jacks to restrain the fabric during stamping. Variable pressures on each of these blank holders are investigated and their influence on the quality of final preform is analyzed. The local strains during the process are measured with cameras coupled to a marks tracking technique. Results with a tetrahedron punch and its associated blank holders (Figure 1b) are presented in this paper.

### Flax based fabrics

The flax fabric illustrated on Figure 2a is used for this study. It is a plain 1/1 woven fabric manufactured by Group Depestele [7] that weights about 280g/m². It is constituted of continuous and un-twisted 500tex rovings (Figure 2b) which exhibit a rectangular shape thank to a dedicated treatment. This reinforcement fabric is not balanced, as the width of warps is equal to 77% of the width of wefts and the warp nominal construction is 1,8 times higher than the weft one.

## Results and Discussion

### Global preform analysis

The first tests are carried out with an orientation 0°. First the blank holders' pressure is set to 1bar. The preform in its final state is presented on Figure 3. The final shape is in good agreement with the expected tetrahedron punch without wrinkle or un-weaving on the useful zone. At the local scale, on faces and edges, defects of buckling (Figure 3a) and misalignment of rovings (Figure 3b) are identified. The first only takes place on the C face and on the opposed edge (between A and B faces) whereas the second is observed on all faces.

The buckles are localized on a zone between the bottom of the preform and the top of the tetrahedron, called triple point. These defects are the consequence of out of plane bending of warp rovings perpendicular to weft rovings passing by this triple point, which are more stressed than the horizontal warp rovings. The observed misalignment of the warp rovings on face C illustrates this stress difference between the warp rovings and the weft rovings. The warp rovings are curved around the weft rovings, and this phenomenon is probably at the origin of the appearance of the buckles. Several tests have been carried out with same or different initial conditions of process and the same buckling defects appear on each formed preform.

### Influence of the initial positioning

First, the initial positioning of the fabrics is studied with a blank holders' pressure of 1bar. In the case of the 0° orientation, buckles only appear on the middle of face C and on the opposed edge. A misalignment of rovings is observed on each face and the bending

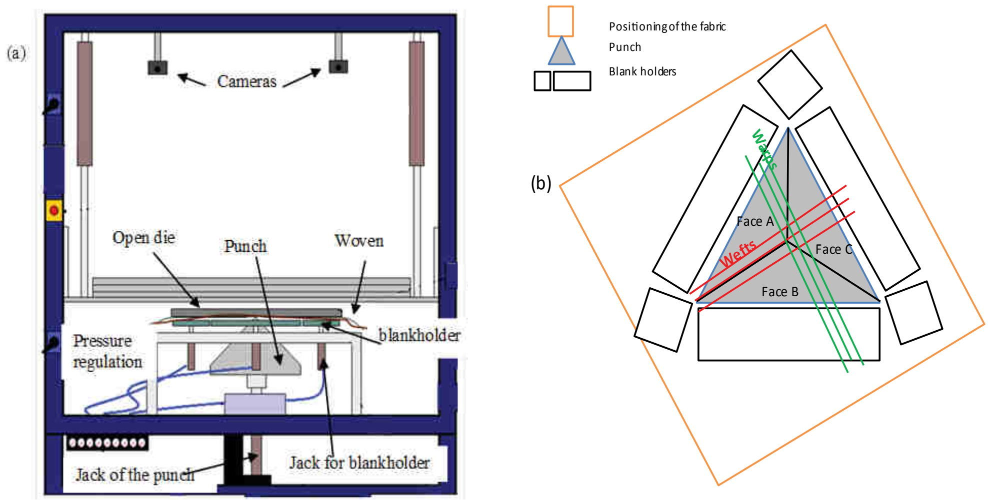


**Figure 1:** (a) Description of the device (b) Positioning of fabric with orientation 0°.

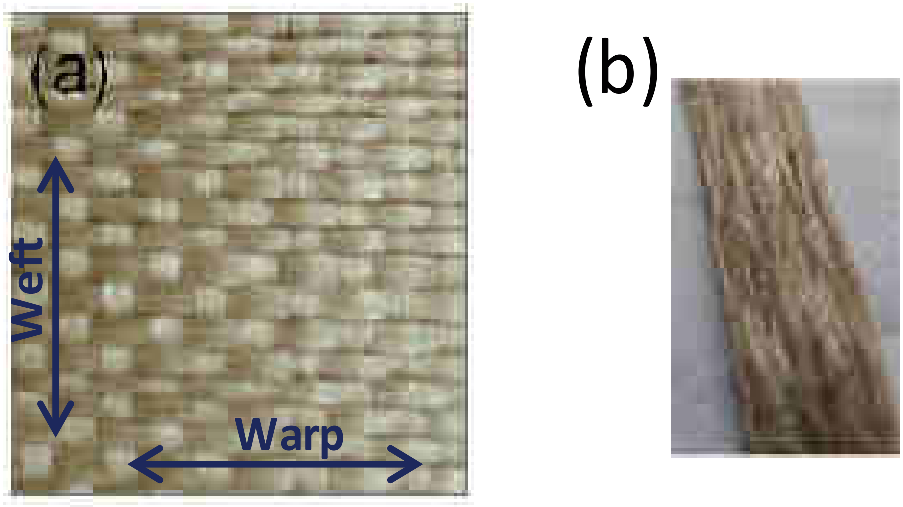


**Figure 2:** (a) Flax fabric (b) Flax roving.

(a) (b)

**Figure 3:** (a) Buckling on face (b) Rovings' orientation.

angles of these rovings are measured (Table 1). The results show that the bending angle measured on the face C is more important than the ones on faces A and B. However, the different angles are globally in the same range of values. Concerning the 90° orientation, the buckles are not located on the face C anymore but on faces A and B. The measured bending angles (Table 1) are located in the same range of values as the ones measured for 0° orientation.

As a consequence, the magnitude of the roving bending angles is not responsible for the changes of buckles position between the two orientations of the fabric.

## Solution to prevent buckling based on design of specific fabrics

The first hypothesis of a link between the appearance of buckles and the misalignment of rovings does not lead to satisfactory conclusions. Indeed, there is no significant difference between the values of measured bending angles on faces having buckles and on faces without buckle. Nevertheless, the orientation of the fabric at the initial state has an influence on the location of buckles on the final preform. Indeed, for the two orientations the buckles appear on the warp rovings (on the face C and its opposed edge for 0°orientation and on faces A and B for the 90°orientation). The architecture of the fabric seems to be a key parameter.

**Table 1:** Influence of the initial positioning of the fabric on the device.

| Initial orientation | Face A | Face B | Face C |
|---|---|---|---|
| 0° | 138° ± 5° | 136° ± 5° | 146° ± 4° |
| 90° | 138° ± 5° | 141° ± 5° | 143° ± 4° |

The fabric considered in this study is not balanced since an important spacing is observed between the weft rovings whereas it is almost non-existent between the warp rovings as shown schematically in Figure 4a. This space controls the appearance of buckles. Its presence between the weft rovings allows the warp rovings to bend out of plane but its lack between the warp rovings prevents the movement of the weft rovings. As a consequence, a balanced fabric with no space between two consecutive warp and weft roving could prevent buckling (Figure 4b).

This new fabric with the same un-twisted rovings was manufactured by Group Depestele [7] and tested under the same process conditions as the previous studied fabric. The results presented in Figure 5 confirm the absence of buckles when the space between

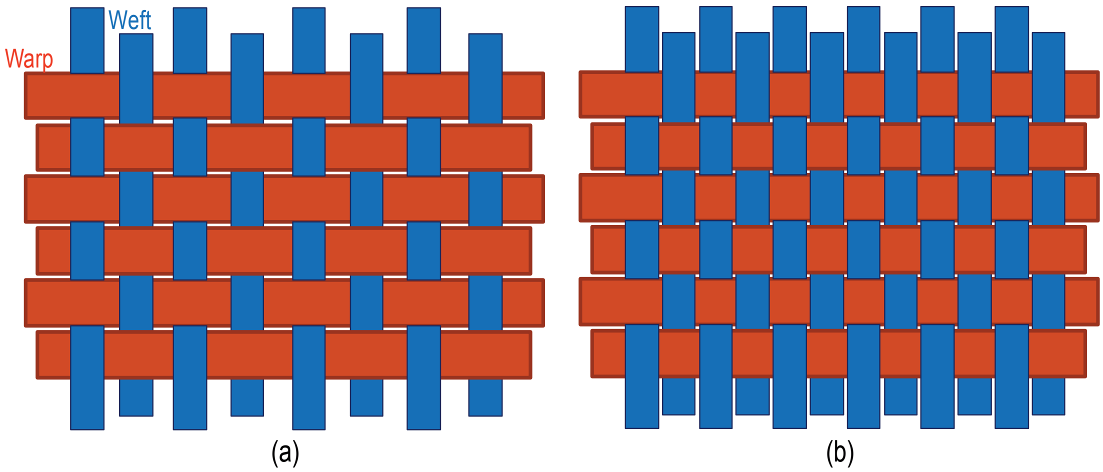


**Figure 4:** (a) Un-balanced fabric model (b) Specific designed fabric model.

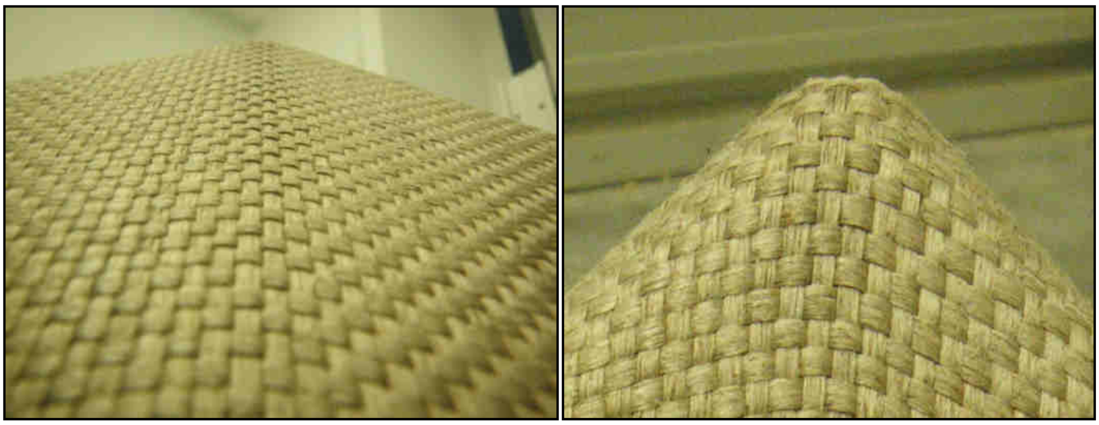

**Figure 5:** Preform of specific fabric without buckling defect.

rovings is suppressed.

## Conclusions

This study shows that the buckling defect can be prevented using different solutions. One of them is presented here. The optimised balanced fabric shows good results with the same process parameters, but its weight is higher (about 440g/m²) and the tight architecture may prevent in certain case the forming of complex shapes without defects.

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