NUMERICAL INVESTIGATION OF BRAIDED BASALT FIBER BRAIDS FOR POLYMER COMPOSITES

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Abstract
This paper presents analysis of the possibilities of WiseTex and TexMind Braider for generation of the geometry of flat braids, produced of basalt fibers. Both programs allow save or export to WiseTex fabrics file, which can be used for computing the elastic properties of the composite material with TexComp software. Geometry adjustment of the multifilament yarns with VTMS is as well discussed.

1. Introduction

Basalt fibers have a similar chemical content and properties like glass fibers, but due to their natural origin they are promising to be more sustainable [1]. Compared to carbon and glass fibers they show similar difficulties during the production, and the use of unsuitable sizing and machine elements can lead to several filament breaks during the production. For the prediction of the properties of the basalt fiber braided composites several standard steps are required during the modelling, like the definition of the geometry of the braided structure and the application of some homogenization method or using FEM models. This work presents some possibilities for the geometrical modelling of the braided structures and considerations for the calculations of the different models. The results are applicable on every kind of material, but for the current sample basalt fibers were taken. Because of the unusual short period between acceptance of the abstract and the submission deadline of this manuscript the experimental data for validation was not available at the submission time.

2. Geometrical models

For regular braided structures several people use the same topology generators as for woven structures, as all braided unit cells can be presented as unit cells of woven structures, even if not all woven unit cells can present braided ones. Two programs, which are able to generate flat braided structures or unit cells with different braiding angle and different yarn properties – WiseTex and TexMind Braider are tested and analyzed in this work.

2.1. WiseTex

WiseTex is suitable for a generation of geometry, performing mechanical calculations and exporting the geometry for different packages, developed by KU Leuven [2,3]. The produced flat braided structure has a floating length of two (regular braid, or 1:1-2 according [4]), the modelled unit cell is presented in Figure 1.

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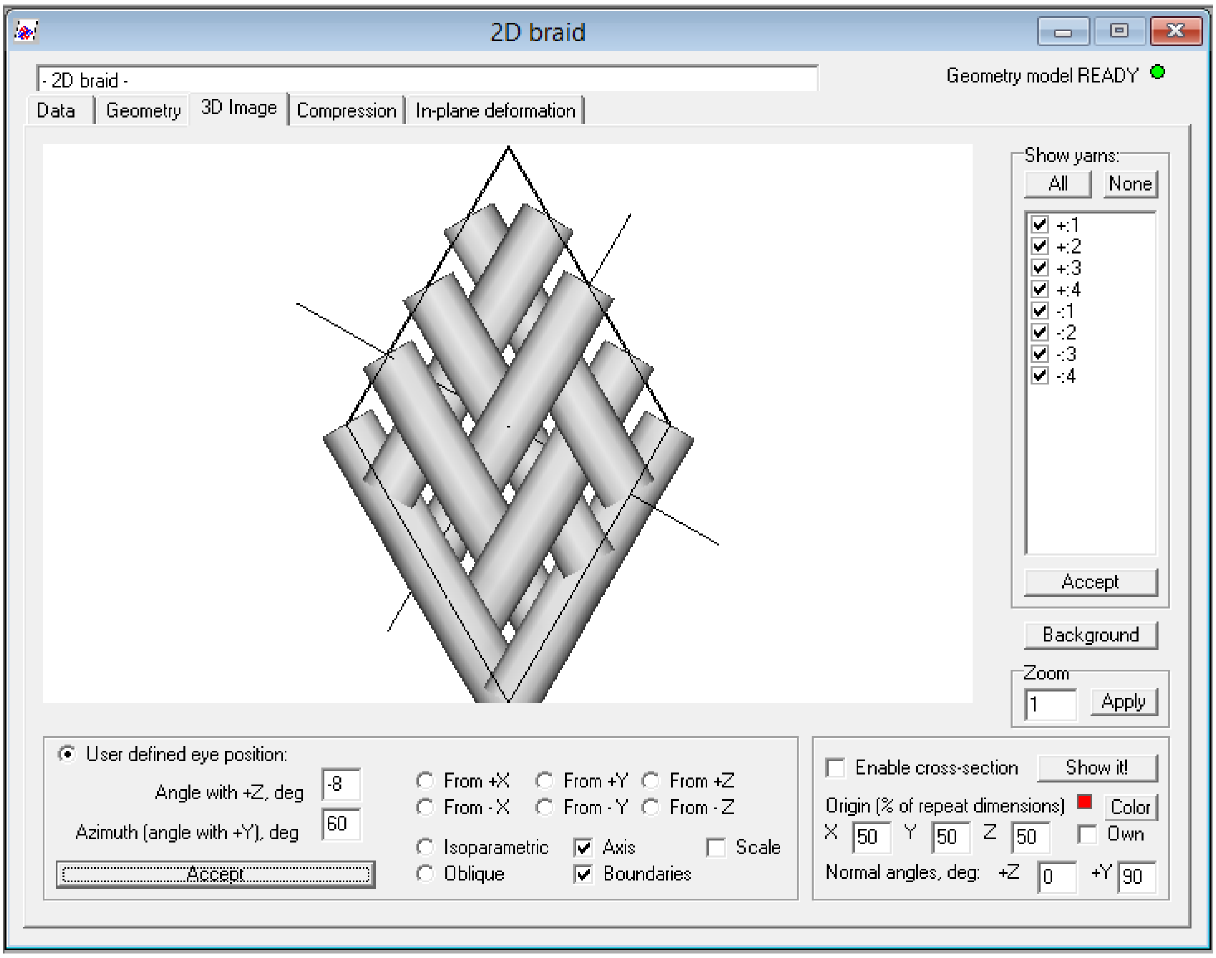

Figure 1. Unit cell of the modelled braid within WiseTex[3]

The yarn geometry in Wisetex during the definition of the topology is with constant cross section with a circular, elliptical or lenticular form. The program stores the number of the filaments in the multifilament yarns and uses these for the fiber volume fraction calculations.

A possible way to calculate the properties of the composite material is through exporting the fabrics geometry as a fabric file and then using the TexComp homogenization software from WiseTex suite, where Mori-Tanaka, Self-Consistent, Iso-Strain and Iso-stress solvers for computing the properties of the reinforced resin material can be used [5]. The geometry of the unit cell can be exported as well in FEM formats but the preparation of this unit cell for a tensile test simulation is connected with the requirement of well chosen boundary conditions and loads on the cell boundaries.

2.2. TexMind Braider

The TexMind Braider software [6] creates the geometry of tubular and flat braids in a form of a complete piece, not as unit cells. The software uses a geometrical model; which is based on the carrier motion emulation, but optimized for a more realistic presentation of the structures [7]. It has several capabilities for filling the yarn volume with single filaments, sweeping predefined distributions of these over the cross section around the yarn axis. Figure 2 (left) demonstrates a simulated geometry, where each yarn is modelled as a single body. The yarn axis in this geometry are giving enough information on the yarn orientation and can be used for the homogenization procedure in the same ways as from Wisetex – since the Braider provides an export to Wisetex (or TexGen) allowing the calculation of the stiffness using TexComp.

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Figure 2 (right) demonstrates a trial to present the yarns as flat multifilament yarns. The presentation of the yarns with several filaments allows the creation of more precise models of the yarn geometry using computational mechanics algorithms.

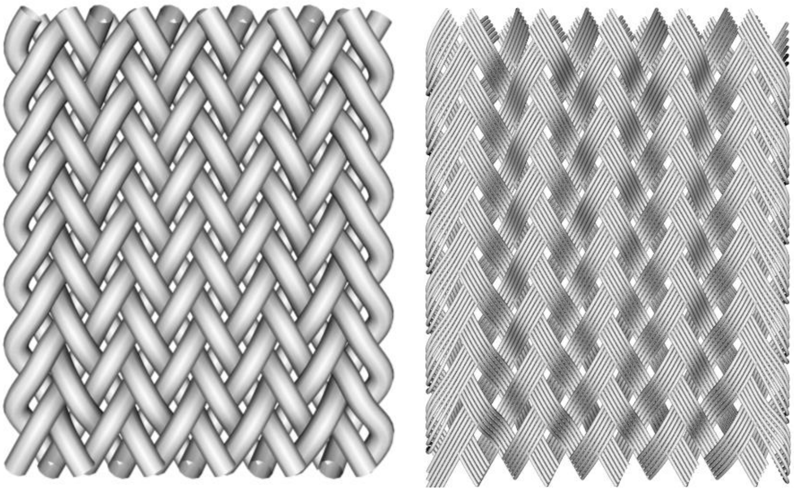

Figure 2. Simulated flat braid with monofilament yarn (left) and flat yarns, represented as multifilaments with 6 single filaments (right), both generated with TexMind Braider

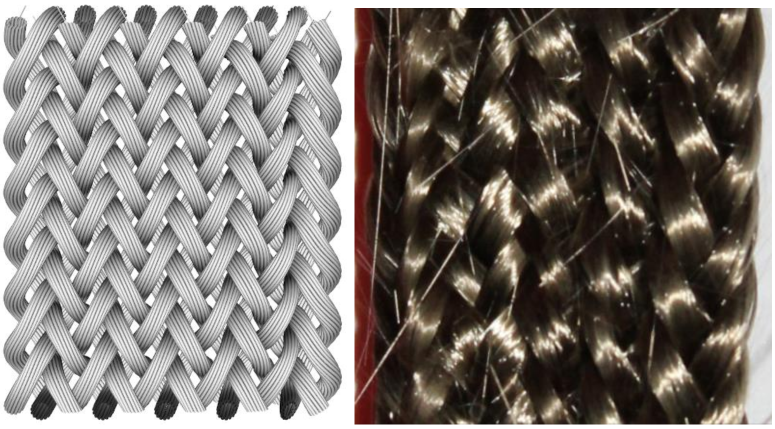

Figure 3. Simulated flat braid with yarns, represented as multifilament yarns with a circular initial cross section (left) with TexMind Braider and a piece of the original braid (right)

Figure 3 also demonstrates a generated model with multifilament yarns and a circular cross section and an image of the real fabric. The image clearly shows the braid with broken single filaments occurring during the braiding process and as well some irregularities within the braided structure. This braid is produced with a high density and has a cover factor of 100% and cannot be represented interpenetration free with geometrical models at the yarn level. Trials to compact it, starting with a relaxation procedure within the VTMS software [7,8] make the fabrics a little more dense, as presented in Figure 4 (right). The relaxation makes the yarns and the fabrics shorter and denser, taking into account and cleaning the contact between the yarns. The application of the same procedure over the multifilament models would be very suitable for the calculation of interpenetration free multifilament geometry of the braids; however it is connected with significantly longer calculation times, if the initial configuration is free from interpenetrations.

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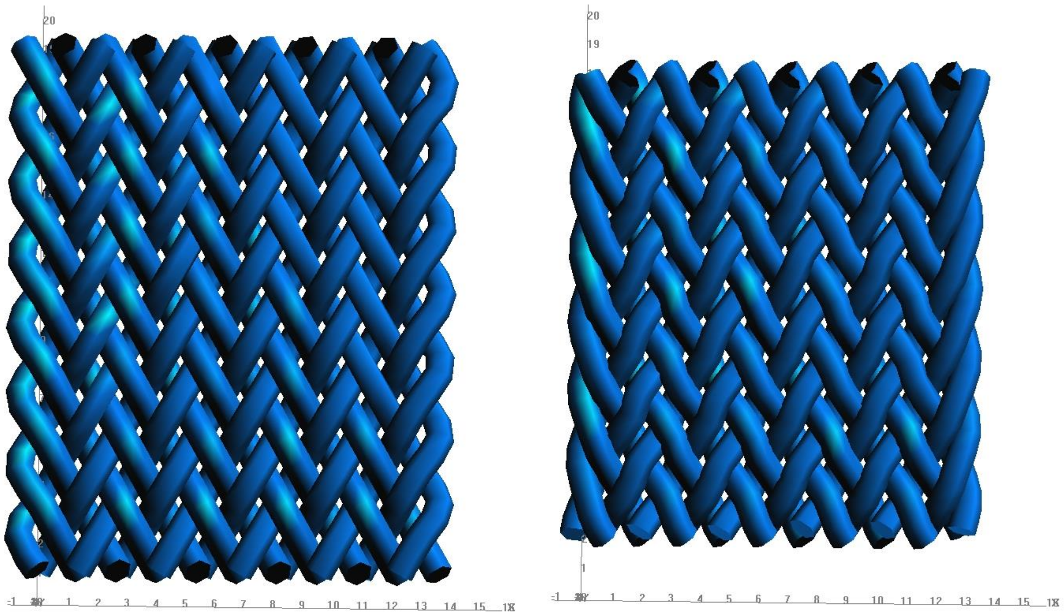

Figure 4. Initial geometry of the flat braid, generated with TexMind Braider and imported into VTMS (left) and after several relaxation steps (right)

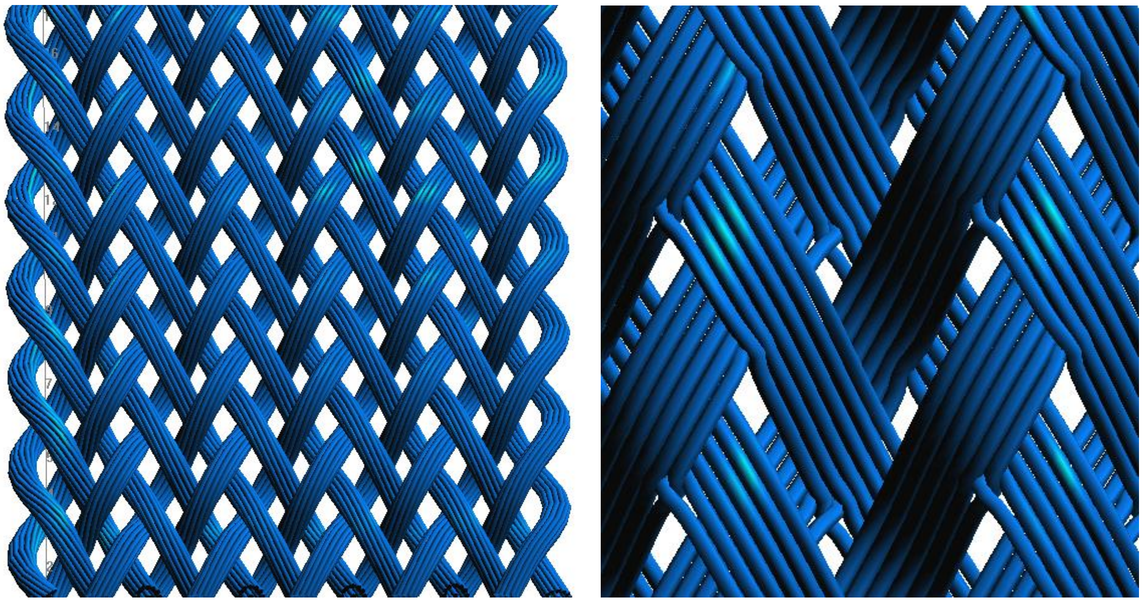

Figure 5. Initial geometry of the flat braid, modelled of multifilament yarns, generated with TexMind Braider as interpenetration free geometry and imported into VTMS (left). Wrong position of single filaments, if the filaments in the initial configuration are calculated as close as possible, and thus - with some interpenetrations of filaments (right).

Figure 5 (left) demonstrates the case, where the braid is generated as an interpenetration free multifilament geometry. In such a case the distance between the yarns is still large enough after 20 relaxation steps, so that the contact between the filaments is not started. If the initial geometry is generated denser with the TexMind Braider, for the current braiding angle some of the single filaments are interpenetrating and after starting the relaxation process they are already softed on the wrong position. This leads to an artificial crimp effect and artificial load, which will lead to wrong results in the mechanical calculations.

3. Summary

The current work shows, that the geometry of the flat basalt fiber braid can be represented well at the yarn level with both WiseTex and TexMind Braider and can be used for stiffness calculations with the TexComp software. If a more accurate multifilament representation is required, the TexMind Braider is able to generate different kinds of multifilament based structures. If these are generated penetration free, they have large spaces between the yarns. If generated dense, then at some places the single filaments of the different yarns are interlaced in an unnatural way. This problem will probably be solved easily in the future, but its computation takes too long if applied on the current normal home computer.

Acknowledgments

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