Documentation for parameterized RVE generation using Grasshopper® and Rhinoceros®

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1 Introduction

This documentation gives an overview over the developed Grasshopper code in Rhinoceros3D, which can be used to generate a model of a textile-reinforced composite. It has been specifically developed to serve as representative volume element (RVE) within a multiscale framework and is to be analyzed using scaled boundary isogeometric analyis (SBIGA). This results in two main conditions:

1. Due to the multiscale approach, the RVE must be symmetric with respect to the in-plane axes. In addition, the in-plane cross-section of the RVE must be point symmetric to the vertical axis. Therefore, the rovings of the textile are assumed to be orthogonal to each other.

2. Due to the use of SBIGA, the geometries must be star-shaped. Therefore, the model is divided into multiple sub-geometries.

In the following the input parameters for Grasshopper® will be described. For more detailed information on the methods used one can refer to the following literature: for the multiscale method [1], the SBIGA [2] and the use of the parameterized RVE in combination with computed tomography data [3].

2 Parameterized RVE

A parameterized representative volume element (RVE) for the analysis of textile-reinforced composites has been designed. It can be utilized for textiles where the warp and weft direction are oriented orthogonal to each other. In the following, the RVE and its characterizing properties is described. Subsequently, it is explained how to enter these in Grasshopper® to generate a surface model in Rhinoceros®.

2.1 Characteristic properties

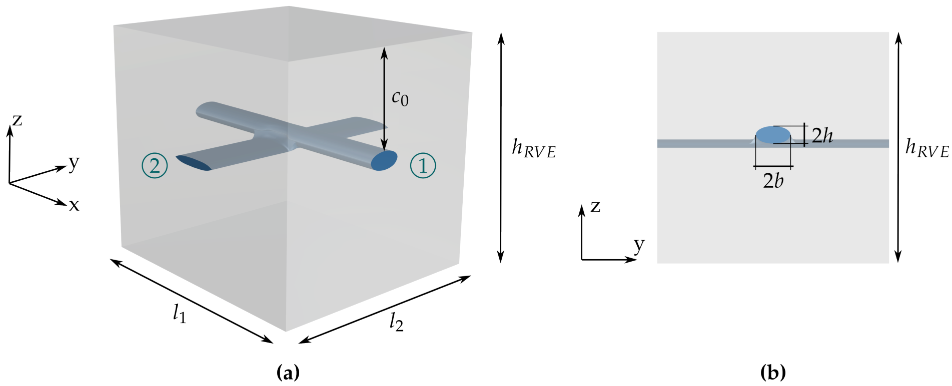

Figure 2.1: (a) perspective and (b) plane view (y-z plane) of parameterized RVE - 1: warp direction, 2: weft direction

Figure 2.1 shows the developed parameterized RVE. The warp and weft directions of the textile will be indicated in the following by the indices 1 and 2, respectively. The following properties can be adjusted.

In-plane dimensions $l_1/\mathbf{l_2}$ The in-plane dimensions of the RVE are denoted by l_1 and l_2. For bi-directional textile reinforcement these values usually correspond to the thread spacing (the distance between the center lines of two rovings).

Thickness $\mathbf{h_{RVE}}$ The thickness of the RVE h_{RVE} corresponds to the structure that is to be analyzed. If the RVE is used for the analysis of textile-reinforce concrete shells, for example, h_{RVE} corresponds to the component thickness [3].

Roving dimensions $\mathbf{b_1/b_2}$ and $\mathbf{h_1/h_2}$ Both rovings are approximated as elliptical and can therefore be described by the radii h_1/b_1 and h_2/b_2 in the warp and weft directions, respectively. Figure 2.1 (b) defines the width $2b$ and height $2h$ of each roving. These dimensions can be determined, for example, on the basis of computed tomography data [3].

Here, it is assumed that the upper edge of the lower elliptical cylinder always coincides with the centerline of the upper elliptical cylinder.

Cover $\mathbf{c_0}$ The cover is defined as the distance between the top surface of the RVE to the top of the roving in warp direction. If the textile is positioned centrally within the RVE the cover can be calculated as

$$c_0 = \frac{h_{RVE} - 2\,h_2 - h_1}{2}. \tag{2.1}$$

2.2 Grasshopper input

The present section explains how to use the associated Grasshopper code to create parameterized RVEs for textile-reinforced composites. It is not intended to be an introduction to Grasshopper and requires a basic familiarity with Grasshopper and Rhinoceros. Grasshopper specific components are indicated by italic text.
Figure 2.5 shows an overview over the canvas in Grasshopper. The components are grouped depending on which geometry part they belong to **Rovings**, **Intersection** or **Matrix**. In the following it is focused on the fourth group, which gathers all components for the **Input & Final Structure**.
Figure 2.2 shows the components which can be used to define the properties of the RVE. *Number Sliders* with floating point accuracy are used for input. The parameters are denoted according to Figure 2.1, so the input should be intuitive. All characteristic prop-

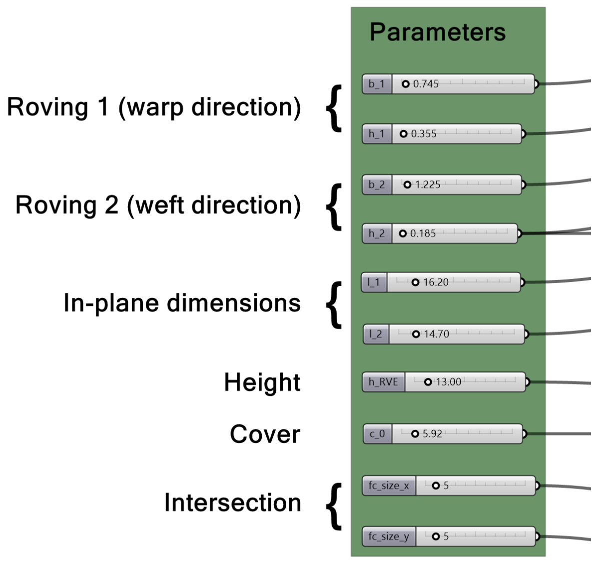

Figure 2.2: Input parameters in Grasshopper

erties have been described in section 2.1, additionally the size of the intersection point can be adjusted. This is denoted by fc_size_x and fc_size_y and should be chosen depending on the roving dimensions. Figure 2.3 shows a plane (x-y-)view of the intersection and indicates which length are denoted by fc_size_x and fc_size_y.

The components describing the final structure are gathered in a red box denoted by

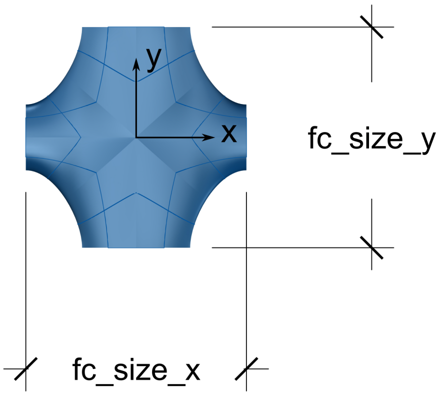

Figure 2.3: Input parameters in Grasshopper

Final Structure, see Figure 2.4. The rovings, intersection and surrounding matrix material can be transferred to Rhinoceros by using the *Bake* functionality. Finally, a surface model describing two orthogonal rovings within a matrix material is obtained. In total, it is divided into 13 star-shaped subgeometries. Initially, all surfaces are modelled with a degree of 3 in both surface directions and using 4 points in each direction. Increasing the degree and/or the number of control points within Grasshopper is planned in the future. The obtained surface model can be utilized as representative volume element within a multiscale framework, where the RVE is analyzed using SBIGA. For information on the analysis please refer to e.g. [1, 2, 3].

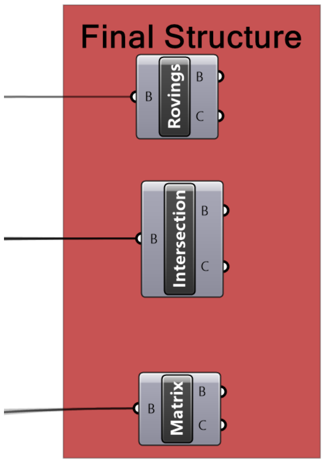

Figure 2.4: Components describing the final structure of the RVE

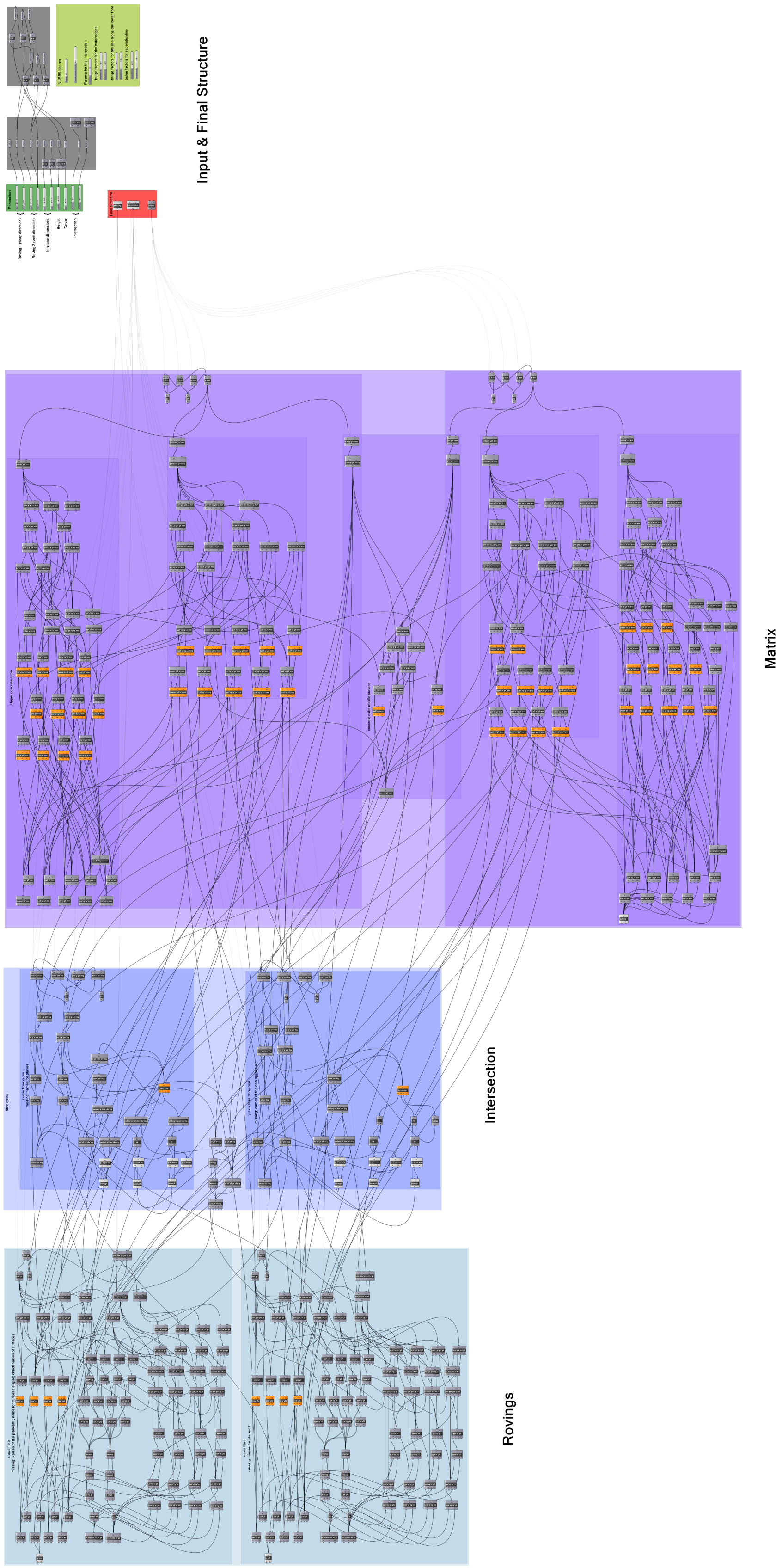

Figure 2.5: Overview over the complete Grasshopper document

3 Acknowledgements

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