Simulation of lattice structures in orthopedic corsets

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Introduction

Digitization is affecting more and more industrial sectors. Currently, the orthopedic industry is undergoing profound change. New technologies such as 3D scan and 3D printing are increasingly used in production and replacing classical methods e.g. plaster cast. This opens up new fields of application for the simulation. The example of a scoliosis corset shows how the new technologies intertwine and enable new, individualized products. Scoliosis refers to a spinal curvature that often occurs in girls during adolescence. Depending on the severity, corsets are also used for therapy. The corset production according to the prior art with plaster cast is done by hand and is very complex (Figure 1a, 1b). 3D Scan / 3D printing enables new, customized designs, e.g. with breathable lattice structures (Fig. 1c). As a result, the wearing comfort and acceptance can be increased, which has a positive effect on the success of the therapy.

Figure 1a Plaster cast

Figure 1b State of the art corset (Orthoteam AG)

Figure 1c Corset with breathable lattice structures (Orthoteam AG)

Numerical Model / Simulation

The corset with the lattice structures is imported as stp geometry and subsequently repaired, formed as an union and formed composite faces (Fig. 2a). This ignores the edges between the faces and prepares it for efficient meshing with tetrahedras. The mesh is exported as .mphbin and afterwards imported in a new component (Fig.2b). The mesh is checked for maximum neighbor angle and partitioned where the angle exceeds 40 degree. Fig.2c shows the difference between imported stp geometry and subsequent meshing. The mesh might be a little bit too coarse for precise stress/strain analysis, but is fine enough for a first assessment.

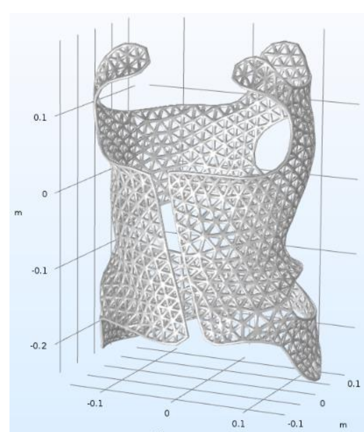

Figure 2a. Corset geometry after formed composite faces

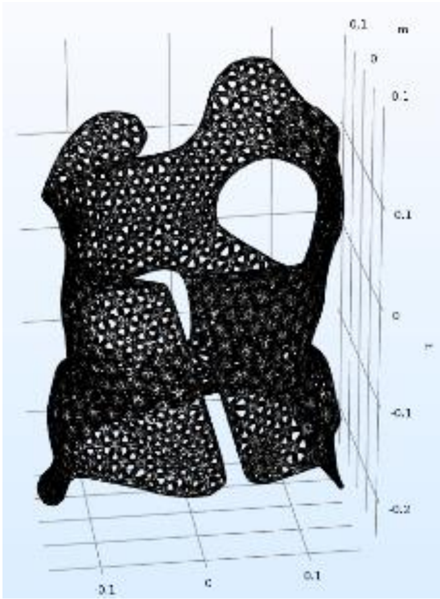

Figure 2b. Corset mesh

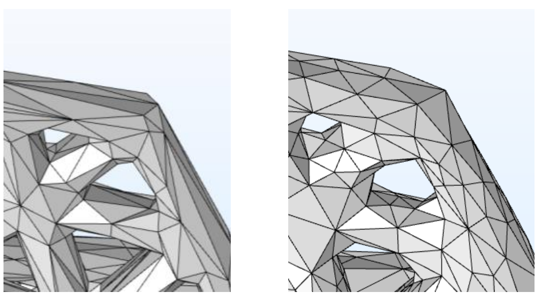

Figure 2c. imported geometry on the left
vs. mesh on the right

Moreover the corset is partitioned at the opening with cylinders where boundary conditions are applied (Fig.2d). One side of the opening is constraint fix, the other one as rigid connector with a prescribed displacement in x-direction, all other DOF free (Fig.3). The material is PA12 which is commonly used for 3D printing in SLS machines. PA12 has a break strain of 20 % in x-/y-direction and 10 % in z-direction. A elastic-plastic material characteristic is used with geometric nonlinearity included.

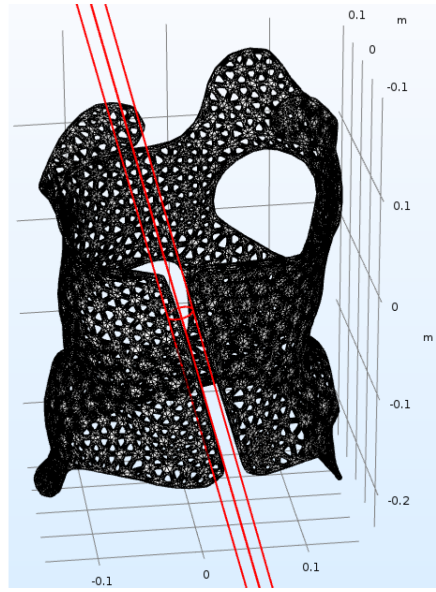

Figure 2d. Partition of
openings with cylinders

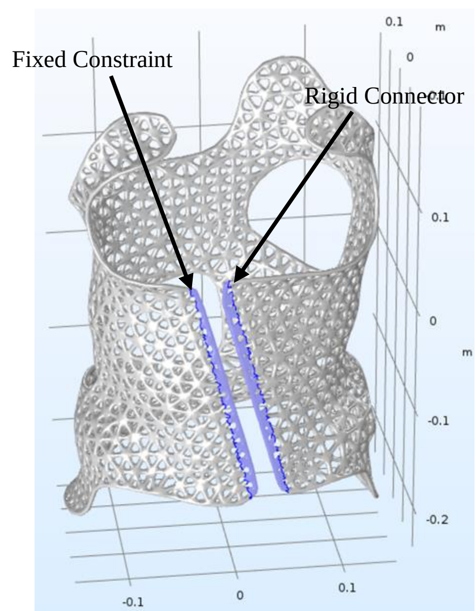

Figure 3. Boundary Conditions

Simulation Results / Discussion

First principal strain reaches a maximum of 4 % which is well below the break strain level in all directions (Fig.4a, 4b). The opening force is calculated as summation of reaction forces in x –direction over all nodes (derived values / volume integration). The opening force can be adjusted by altering the dimensions of the lattice structures.

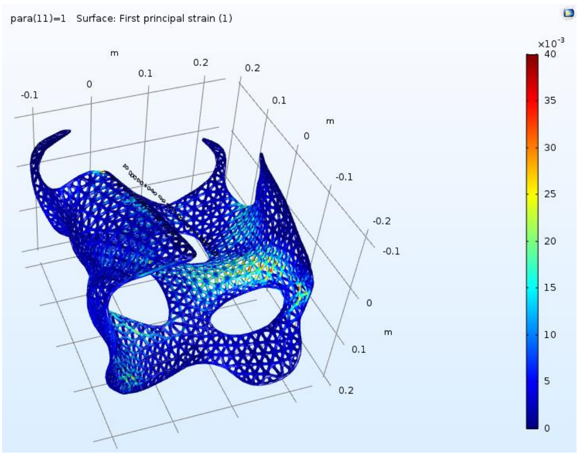

Figure 4a. First principal strain distribution.

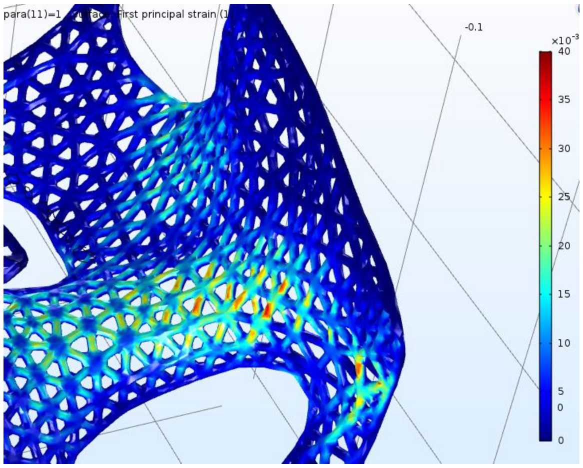

Figure 4b. Maximal first principal strain distribution

Conclusions

Digitization in orthopedic technology offers new possibilities in design e.g. lattice structures. Simulation especially meshing of such complex geometries is a challenge. Comsol can handle it with specific import and meshing capabilities and therefore helps to secure the corset performance regarding maximal principal strain and opening forces. The analysis of pressure distribution of the corsett on the patient is planned for the future. Also an automatization of the whole process which makes it easier to simulate more lattice variants.