Case Study

e-Xstream ENGINEERING
MSC Software Company

Digital material design for spinal disc prosthesis

Designing spinal disc prosthess implants using short fiber reinforced composites

Challenge

Spinal injury and the gradual deterioration of spinal discs are the leading causes of back pain and spinal disorders. Today the most effective way of permanently treating these illnesses are through surgical intervention. One of the most promising surgical options under continuous development is the use of artificial implants to replace the patient's natural spinal disc.

The materials used in these artificial discs are an important factor in the development of this technology. The discs must be made from materials that are safe to be implanted in the human body, do not cause allergic reactions, and are also wear resistant and compatible with medical imaging (MRI for example). Fiber reinforced plastics and elastomers are used more and more in today's orthopedic implants because of their resistance to wear and improved mechanical properties.

The challenge when designing implants made of these materials is the ability to take advantage of the flexible performance of the material based on the manufacturing process used to create it.

The mechanical properties of an implant designed with fiber-reinforced plastics can vary widely depending on the properties of the constituent materials (i.e. fibers and matrix) and the process used to manufacture them into the final part.

The injection or compression molding process used to manufacture the implant will affect the fiber orientations throughout the part. The common method for analyzing these components is to assume a uniform isotropic material behavior throughout the part. However in reality the fiber orientations vary considerably throughout the implant, resulting in a highly non-uniform, anisotropic material behavior. Not accounting for the fibers' effect on material performance can lead to a softer or stiffer prediction of the implant's performance which leads to a poorly designed implant and even premature failure. Digimat solves this problem by adding a multi-scale modeling approach to the implant design process.

Solution

Digimat produces a much more accurate prediction of the material behavior for materials such as fiber reinforced plastics. The process is simple. Start with the same finite element model of the implant that is used for the existing analysis. Digimat will work with any major finite element solver. Next, request the injection mold simulation results from the manufacturer.

This analysis is usually performed separately to optimize the manufacturing process used to create the implant. The results of this analysis can be used to create a coupled simulation with the FEA analysis by using Digimat. This can be done by, mapping the fiber orientations, residual temperatures and residual stresses onto the structural analysis model. The next step is to select or create an intelligent material model of the reinforced plastic using the tools provided by Digimat.

The intelligent material model is a function of fiber orientations instead of a static value, allowing Digimat to adjust the material stiffness at every integration point throughout the entire implant simulation. Finally, conduct the analysis as normal with one exception, the static value for material stiffness will be replaced by a Digimat material model.

Key Highlights:

Customer: MEDICREA

Digimat solution: Micromechanical material simulation

Industry: Medical

Materials: Fiber-reinforced plastic

Benefits:

- More accurate simulations
- Cost and time savings
- Reduce test/analysis iterations
- Improve performance predictions

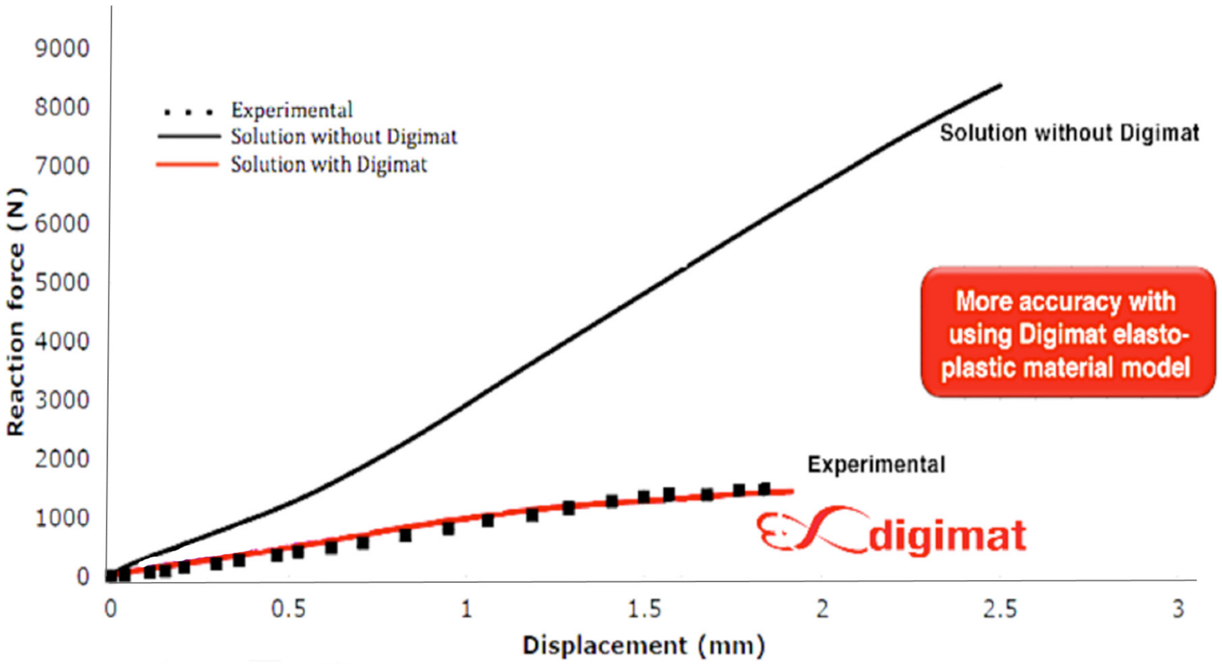
Digimat takes care of tying the intelligent material into the analysis solution so that the analyst can focus on designing the implant's performance, not guessing at which material property might give the best results.

Figure 1: Digimat delivers fiber only and matrix only stresses and strains. The counter shows high compressive stresses in the plastic matrix near the inside of the endplate.

Results/Benefits

The attention to material details result in more accurate simulations that reduce test/analysis iterations and improve performance predictions. In the case of the Medicrea design, the original isotropic simulation over-predicted the implant's stiffness by as much as 170%!

The same simulation using a Digimat material model that accounted for both changes in fiber orientations as well as plastic deformations matched the test results almost perfectly.



> ***"Simulations allow both optimization of production process and mechanical efficiency of implants. They will reduce the development process for range extension already planned."***
>
> Thomas Mosnier, R&D Manager, Medicrea

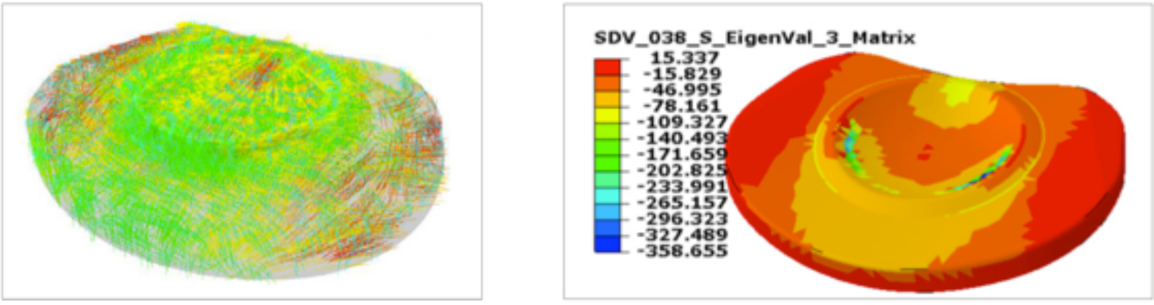


Figure 2&3: Injection mold simulation results for fiber orientations. Red shows more aligned fibers, blue shows less aligned fibers.

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