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# STRUCTURAL OPTIMIZATION USING BIOLOGICAL GROWTH METHOD IN ANSYS MECHANICAL, PART II

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**Abstract:** *This article focuses on a lesser-known alternative of structural shape optimization, based on morphing the mesh elements using the Biological Growth Method (BGM) and its implementation using the Ansys Mechanical program and newly developed software – M3Opti. The aim of these activities is to improve the properties of a structurally complex parts or assemblies, which requires an advanced materials models and contact or geometrical nonlinearities. The part II of the two-part paper presents the usage of developed software – M3Opti demonstrated on examples. Real-world applications are discussed.*

**Keywords: Structural optimization, shape optimization, Ansys Mechanical, Biological Growth Method, FE mesh morphing.**

## 1. Introduction

Presented work is the second part of the two-part paper dealing with structural optimization utilizing Shape optimization with Biological growth method. In the part I (Čada, 2024) the theoretical background and numerical implementation using Ansys Mechanical have been discussed. In the part II the usage of developed software M3Opti (ACT – Ansys Customization Toolkit) is demonstrated on examples and real-world applications of this tool are discussed.

The reminder of part II presents application of M3Opti for shape optimization of human bone (Sect. 2.1.) and valve housing (Sect. 2.2.). Real world usage and examples are discussed in Sect. 2.3. Suitability of proposed method and developed software are concluded in Chapt. 3.

## 2. Examples of shape optimization

### 2.1. Human bone

The first example we would like to demonstrate is optimization of human bone (Fig. 1). A model of tibia with isotropic linear-elastic material model has been used. Combined stress state has been assumed combining compression and bending. Region of interest, free zone and fixed zone of mesh are shown in Fig. 2. Objective function has been chosen as minimizing maximal principal stress in region of interest.

During the optimization maximal principal stress has been decreasing monotonically (see Fig. 3). After 9 iterations its value dropped from 4.5 MPa to 3.7 MPa which is almost an 18 % difference. Final geometry and corresponding stress distribution is shown in Fig. 3.

### 2.2. Valve housing

In the second example geometry of valve housing has been optimized. This concerns a thermo-structural analysis of a housing body, where the dominant loading is a thermal shock (transient thermal behaviour after heating by inner water). Bilinear isotropic elasto-plastic material model with isotropic hardening has

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been used and the monitored variable has been accumulated plastic strain from three thermal cycles. Geometry with region of interest, fixed and free region are shown in Fig. 4.

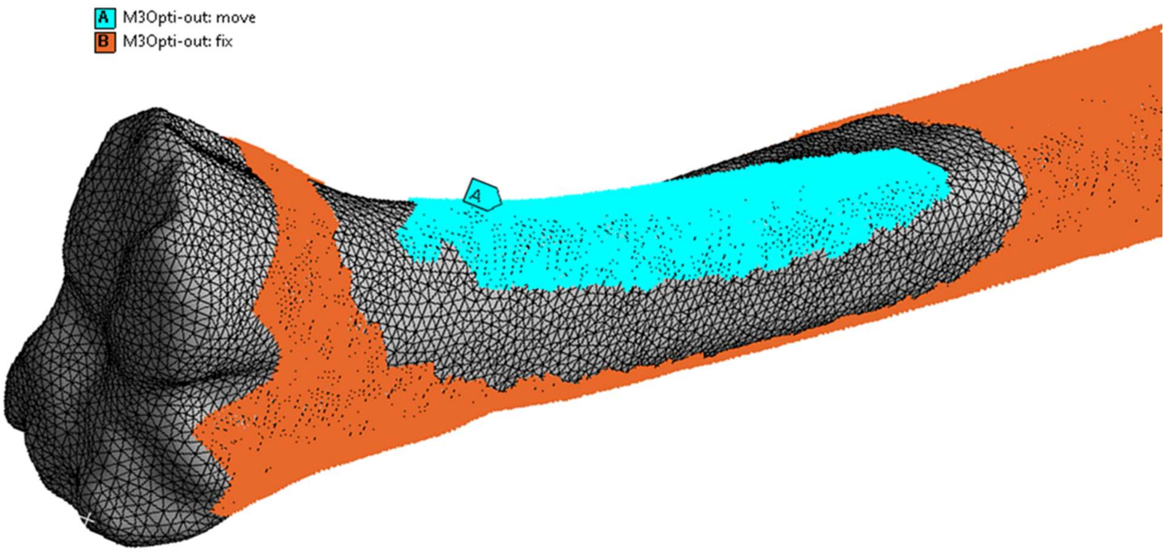


*Fig. 1: Optimization of human bone – region of interest, free zone, fixed zone setup.*

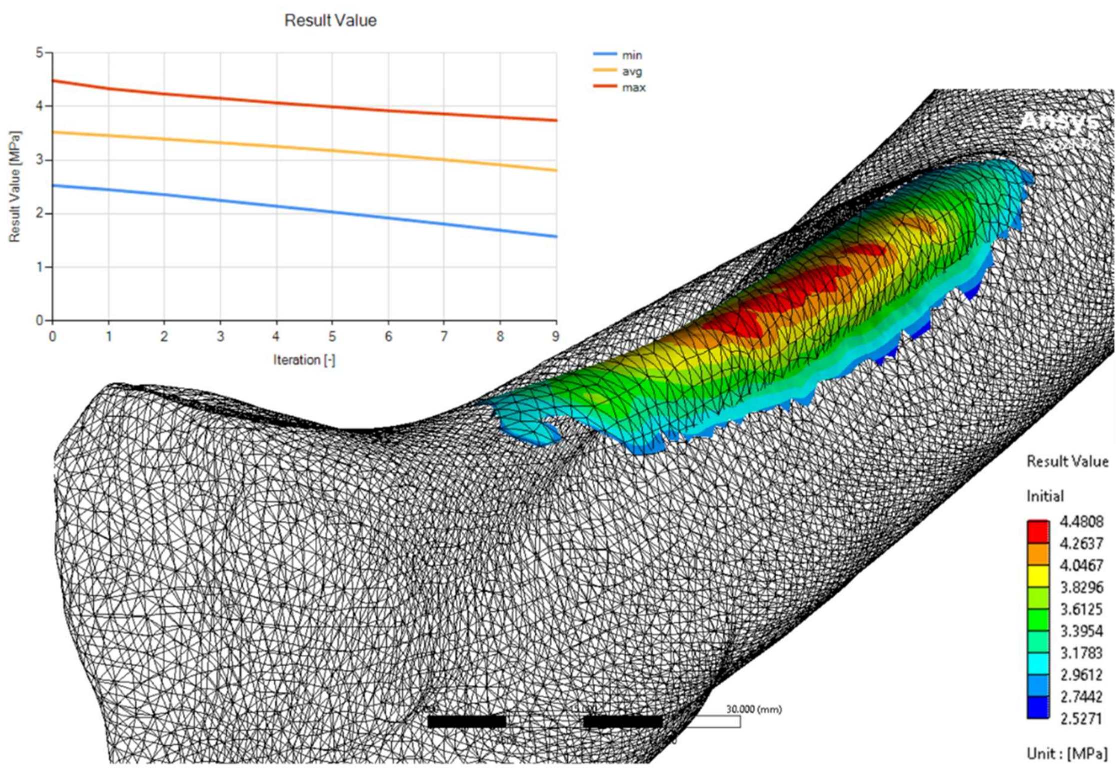


*Fig. 2: Optimization of human bone – optimized shape.*

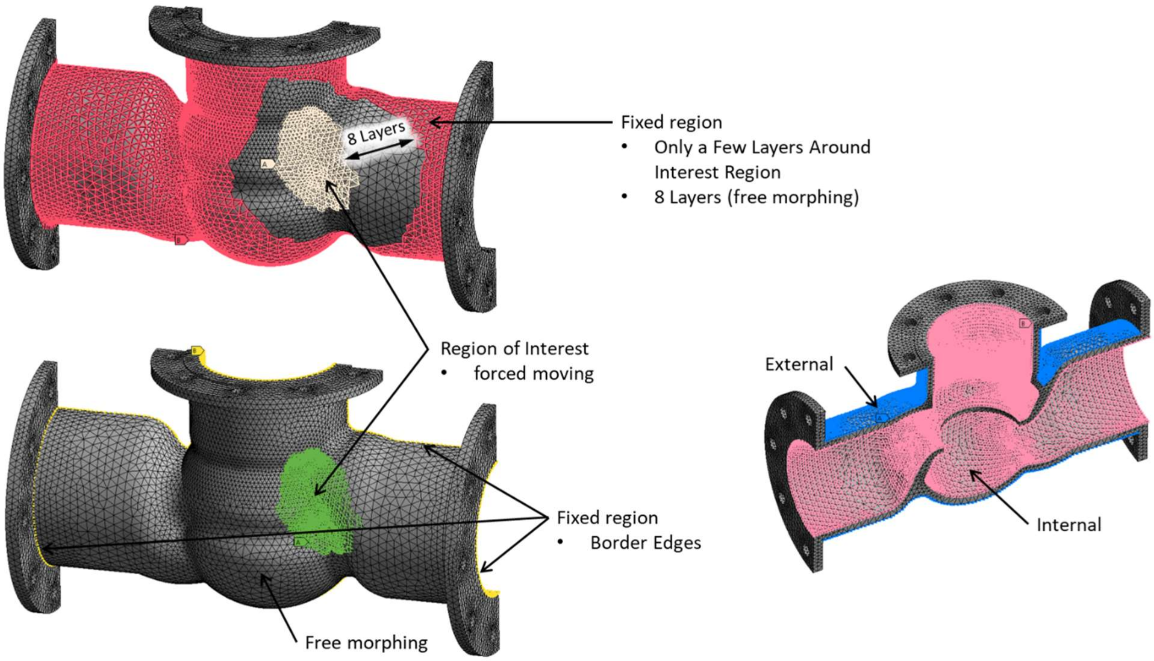


*Fig. 3: Optimization of seal with using thermo-structural analysis – setup.*

Result of optimization shown monotonical decrease of monitored variable – accumulated plastic strain. After 6 iterations accumulated plastic strain decreased from 0.010 to 0.0053 which is drop by almost 50 % (see Fig. 5). It is also clearly visible how was the region with maximal accumulated plastic strain becoming smaller during the iterations.

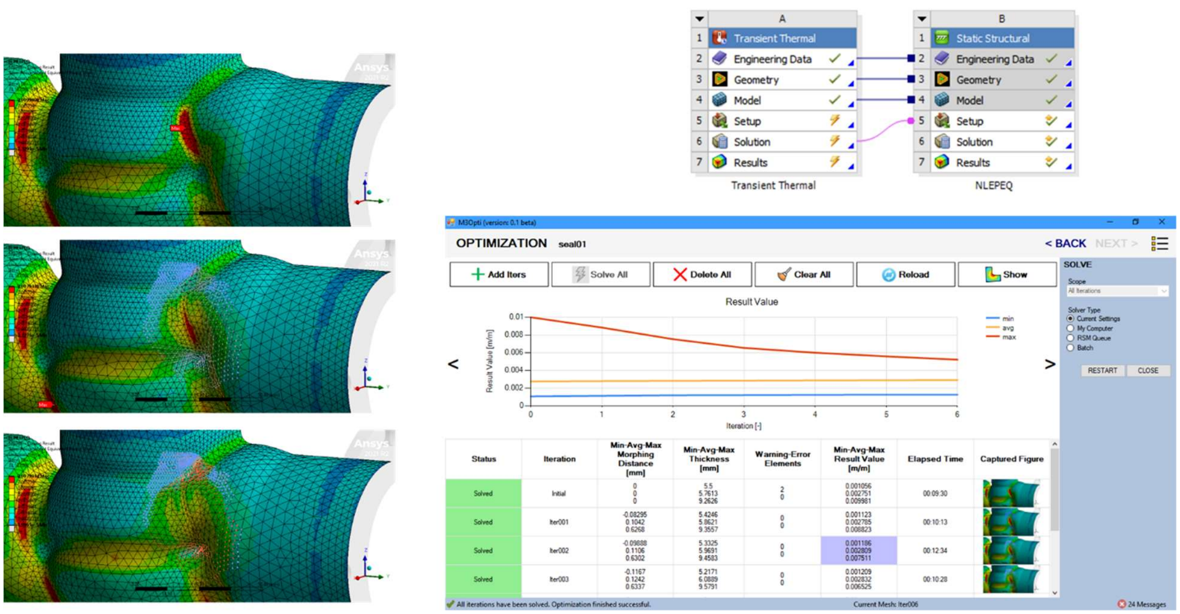


*Fig. 4: Optimization of seal with using thermo-structural analysis – results.*

Fig. 5 shows trajectory of nodes in part of the region of interest with highest accumulated plastic strain. Lines with dots corresponds by colour to the legend of accumulated plastic strain. As can be seen, a relatively small change in the outer surface of the seal housing led to a significant reduction in the maximum value of accumulated plastic strain.

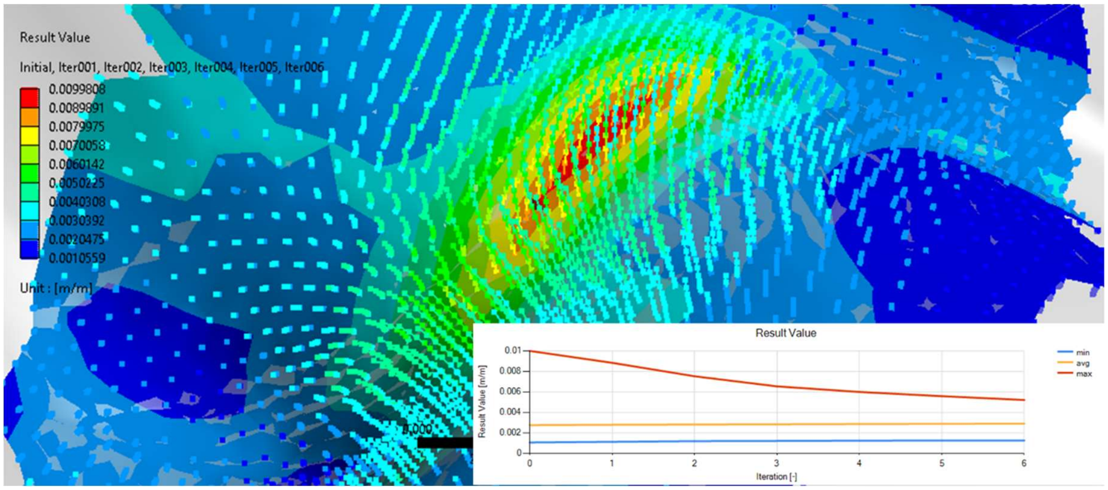


*Fig. 5: Optimization of seal with using thermo-structural analysis – trajectories of nodes.*

### 2.3. General examples, discussion

Two basic examples, mainly for demonstration purposes, has in introduced. However, authors see potential in more complicate models which some of the have already proved its usability in cooperation with commercial companies. The main advantage of developed software M3Opti implementing BGM method is its capability of using arbitrary model including all types of nonlinearities. Optimization can be based on any observable parameter which also gives opportunity to use M3Opti for various types of numerical simulation.

Here are some examples of proposed/tested analyses which are suitable for optimization:

- decreasing stress/strain in nonlinear static structural (material, contact and geometrical nonlinearities),
- decreasing stress/strain in nonlinear dynamic structural (transient, harmonic, spectral),
- decreasing heat flux in thermal analyses,
- increasing fatigue cycles in thermo-structural analysis including plastic material model (Chaboche). Real case tested in cooperation with Garrett Motion.

## 3. Conclusions

The paper demonstrates that Shape Optimization using the BGM is a very interesting method for subtly altering the shape of a structure by adding material in the most stressed areas, which can locally improve, properties of the entire structure. Observed variable used for optimization can be any output parameter such as stress, plastic strain, or fatigue life. Proposed solution has been implemented into computational software – M3Opti that uses functionality of Ansys Mechanical and allows users to easily set-up and optimize their numerical model.

The usage of this method for improving the mechanical properties of structures is mainly beneficial for structurally complex parts, which would be very difficult to parameterize at the CAD model level and can contain any type of nonlinearity. This goes hand in hand with the fact that for these structures, minor changes in shape are commonly tolerated both from an aesthetic and manufacturing process perspective.

Usage of M3Opti has been presented on two demonstration examples. Both shown significant increase in observed variable in relatively small number of iterations and with relatively small morphing of geometry which demonstrates usability of created software with BGM algorithm.

## References

ACT – Ansys Customization Toolkit. https://www.svsfem.cz/act. Accessed 13 February 2024.

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