The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5 – 9 June 2022, Oslo, Norway

MULTI-OBJECTIVE OPTIMIZATION FOR UNDERSTANDING TREE DESIGN RULES WITH FINITE ELEMENT MODELLING

E. Moreno-Zapata[1]*, J. M. Cabrero[2], G. R. Ruiz[3] and G. Vargas[4]

[1,2,3] Department of Building Construction, Services and Structures, University of Navarra, 31009 Pamplona, Spain. [1] emorenoz@unav.es [2] jcabrero@unav.es [3] gramrui@unav.es
[4] Department of Mechanical Engineering, University of the Basque Country (UPV/EHU), Plaza Europa 1, 20018 Donostia-San Sebastian, Spain, gustavo.vargas@ehu.eus

Key Words: *Multi-Objective Optimization, Tree Mechanics, Wood Failure, FEM, Abaqus*

This research presents an optimization problem, which aims to understand the inherent design rules of the shape of a tree. It makes use of a classical optimization problem, the Nowacki beam, which consists of a cantilever beam with a point load at the end which seeks to obtain the lowest cross-sectional area and bending stress under a set of constraints [1]. Forrester et al. developed an algorithm to address this problem [2] by means of machine learning techniques. They began defining the beam properties and building a distributed random sampling plan and then computed the objective function and constraint functions. The process starts from an initially computed dataset that is used to train Kriging models, which are later used as a filling strategy, and genetic algorithms, as an optimization strategy. The result of each iteration is added to the dataset, and the process is repeated until convergence is found. In this way, the Pareto front with the optimal solutions is obtained.

The problem is adapted to understand the relation between the geometry of the tree trunk, assumed as a natural optimization, and the mechanical properties of its wood. Abaqus, a finite element simulation software, is used to model the training dataset. The model includes different features to adequately model timber. Two objective functions (compressive stress and Ø/height ratio) and four constraint functions (compressive and tensile stress, shear stress and strain) are used in the process. Subsequently, the same filling strategy with Kriging and optimization with genetic algorithms is used to search for the optimal solutions [Fig. 1]. Each trade-off shows the Pareto front for different wood properties and limits. The x-axis shows different Ø/height ratios, and the y-axis represents the highest compressive stress elements of each different tree geometry. The solutions obtained after the optimization process show the relation between the shape of the tree and the material characteristics that define it.

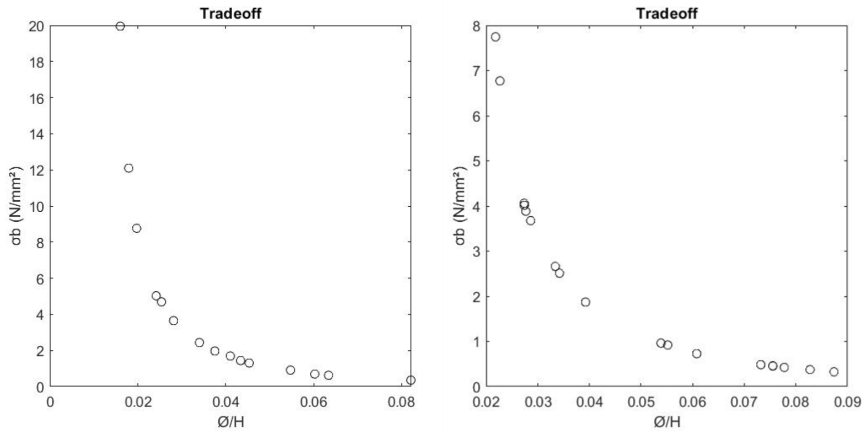

Figure 1. Pareto front Simulation with two different wood properties.

REFERENCES

[1] Horst Nowacki. Modelling of design decisions for CAD. In Computer Aided Design Modelling, Systems Engineering, CAD-Systems, pp. 177-223. Springer, 1980.

[2] Forrester, A. I. J., Sóbester, A., & Keane, A. J. (2008). Engineering Design via Surrogate Modelling. In Engineering Design via Surrogate Modelling.