STUDY OF A HIGHLY INTEGRATED APPROACH FOR LIGHTWEIGHT BICYCLE FRAME DESIGN BY MULTI-OBJECTIVE MATERIAL SELECTION AND CAE TOOLS

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In road bicycle racing there is a strong focus on reducing the weight of the main structure of the bike: the frame. In the last decades we have attended to a fast innovation trend in material science applied to lightweight design. First racing bicycle frames were made of heavy steel alloys. Nowadays, the competition ones, are made of carbon fiber resulting in structures even lighter than a common laptop.

Although material science has already been significantly improved in terms of lightweight optimization, design has still room for improvement making structural optimization a highly potential method in new design approaches. This thesis work aimed to study and design a road bicycle frame integrating multi-objective material selection with structural topology optimization.

Therefore, the first innovative idea of this thesis work is the implementation of the hybrid multi-objective method for materials selection. This method combines the advantages of derivative methods, like Ashby indices, with the simplicity and user-friendly interface that characterizes the QFD (Quality Function Deployment) matrix. In short, the hybrid multi-objective approach has the scope of integrating interdisciplinary teams. Actually, the marketing manager, example given, and the fracture mechanics engineer could contribute to the vision of the product characteristics with the same working tool.

The second great innovative idea of the thesis work is the implementation of the topological optimization in the conceptual design of a product; in this case of study: the bicycle frame. Topological optimization is a kind of structural optimization developed at software level environments nearly ten years ago and. Nowadays, it is being introduced by big companies for new design products or the improvement of the ones already launched into the market. Starting from the definition of a design space, boundary conditions and the external loads; topology optimization finds the stiffest structure feasible with the weight spare percentage assessed by the engineer.

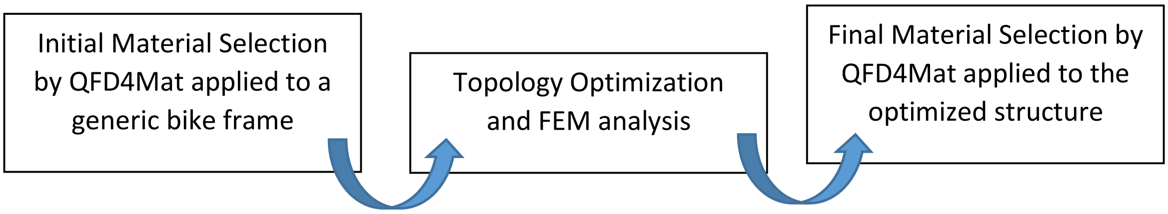

Figure 1. Design and material selection workflow

Topology optimization has been implemented using the Patran graphic interface and Nastran numeric solver. Shell elements were chosen to mesh the workspace. Patran/Nastran software was also used for the FEM analysis of each candidate material.

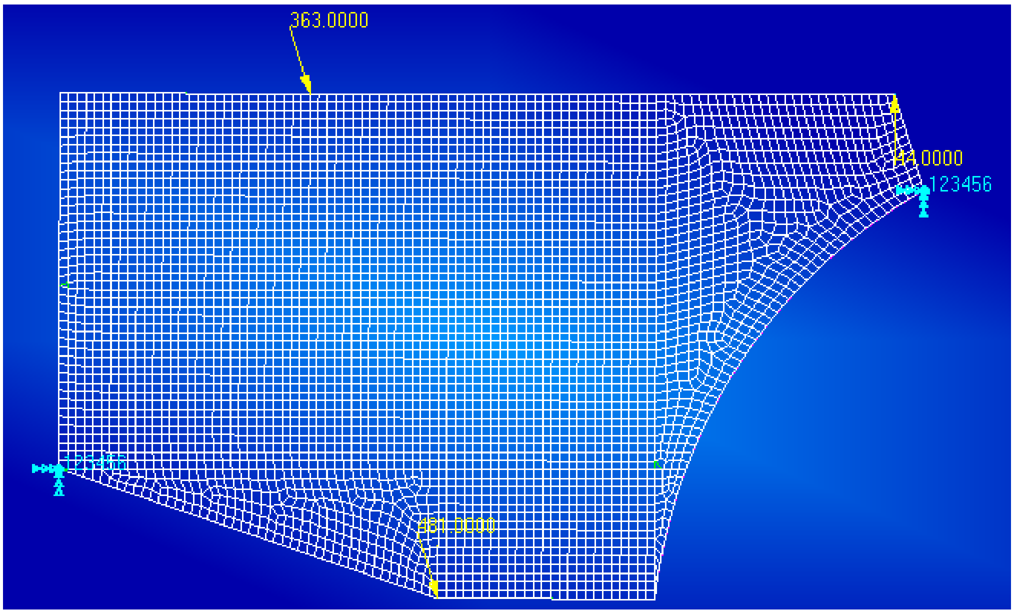

Figure 2. 2-D meshing of the workspace

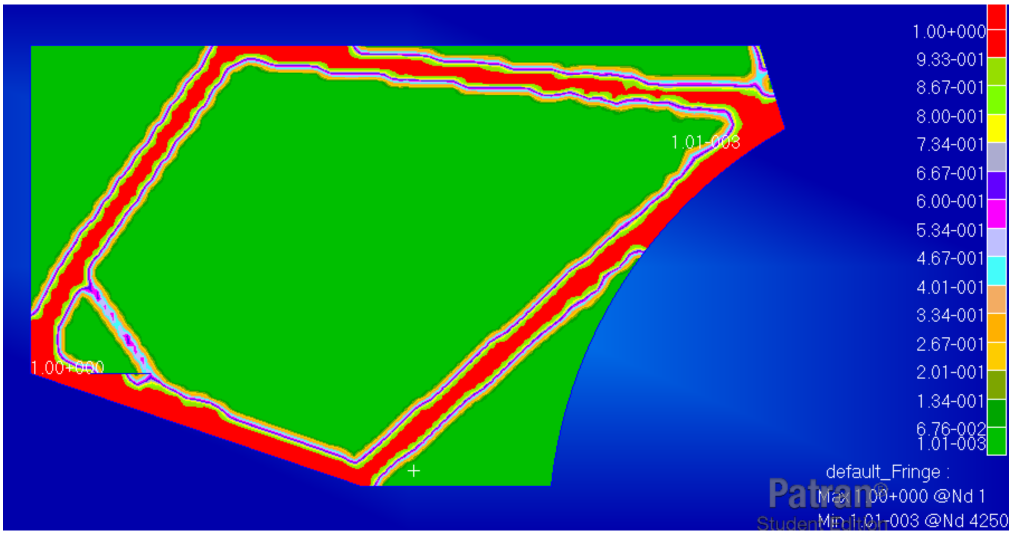

Figure 3. Topology optimized frame. Mass target = 20%

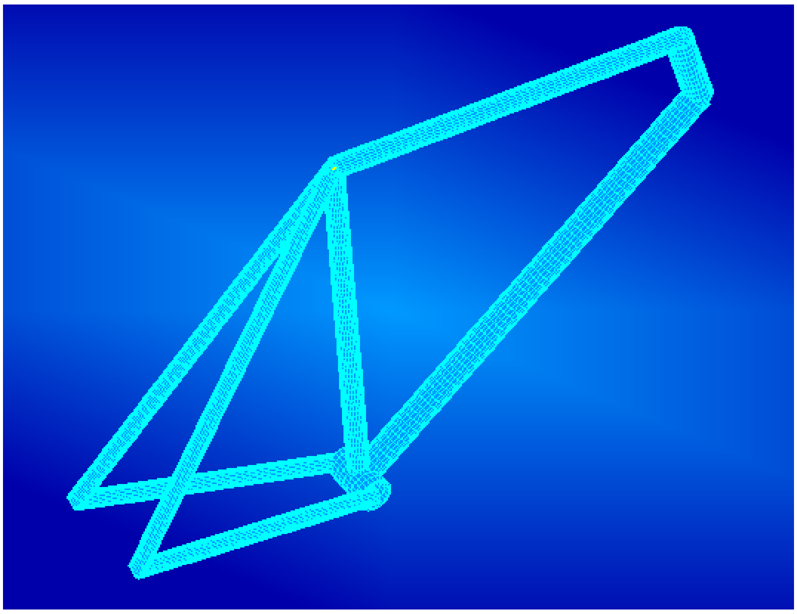

Figure 4. FE beam optimized model

In conclusion, the whole workflow gave the lightest frame design possible and selected Titanium 3Al-2.5V (9 grade) as the most competitive material for its manufacturing.

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