

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

Dipartimento di Ingegneria Meccanica del Politecnico di Milano

M.Sc Thesis of: Pablo Barriga Ruiz

Under Supervision of: Dott. Ing. Fabrizio D'Errico

In rock climbing and mountaineering there is a strong focus on reducing the weight of all the equipment: by reducing the weight of equipment, the climber will expend less energy working against gravity and thus be able to climb further and faster.

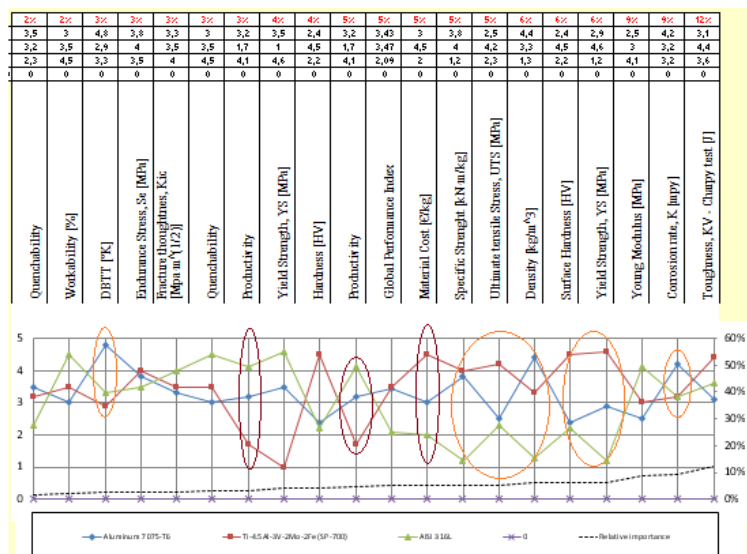
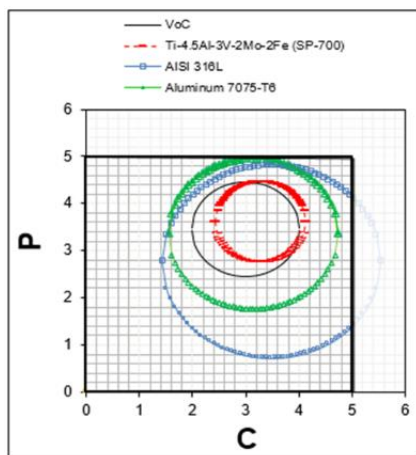
The present thesis scope is the study and design of a lightweight climbing carabiner, employing the material selection criteria assisted by CAE tools. In a simplified way, a climbing carabiner consists in a metallic ring with an openable side: his task is to connect two different objects in an easy, fast and reversible way. In other words, we can define a carabiner as a loop-shaped mechanism equipped with a spring-loaded opening latch or gate that is vital to climbers for connecting climbing ropes to harnesses and other safety gear. Mountain climbers essentially use them to protect themselves from injury or death in the event of a fall. It is important for climbers to know when a carabiner should be retired in order to avoid failure, which can lead to serious injury, or, in some cases, death.

The material selection for a work piece or an object is an important part of the whole product design project. Generally, the material selection processes are based on derivative methods, also known as explicit; alternatively, on non-derivative or implicit methods. The first ones are quantitative while the second ones are qualitative.

This project explores the different materials that can be used for a climbing carabiner, selecting the one which supplies better all the customer's requirements, and therefore is the most suitable for this application, by a total selection material approach that combines the actual material selection strategies.

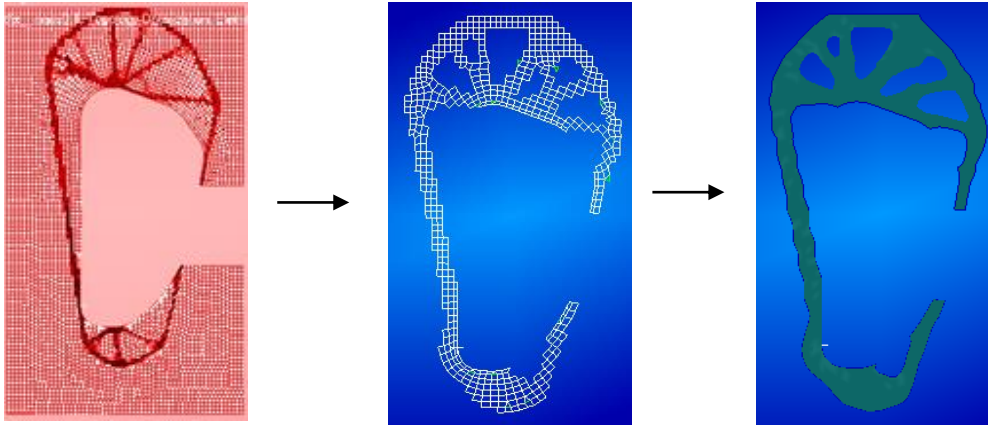
In fact, one of the innovative ideas of this thesis work is the implementation of the hybrid multi-objective method for materials selection (QFD4Mat) that combines the advantages of derivative methods, like Ashby indices, with the simplicity and user-friendly interface that characterizes the QFD (Quality Function Deployment) matrix. In short, the hybrid multi-objective approach has the scope of the interdisciplinary team integration. 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.

Applying this new approach to our case of study, considering an initial set of three possible candidate materials (Aluminum alloy 7075-T6, Titanium alloy - SP 700, Stainless steel - AISI 316L), we obtain the Aluminum alloy 7075-T6 as the material that best suits the necessities established by the costumers' requirements and the main key factors took into account in the selection material strategy.

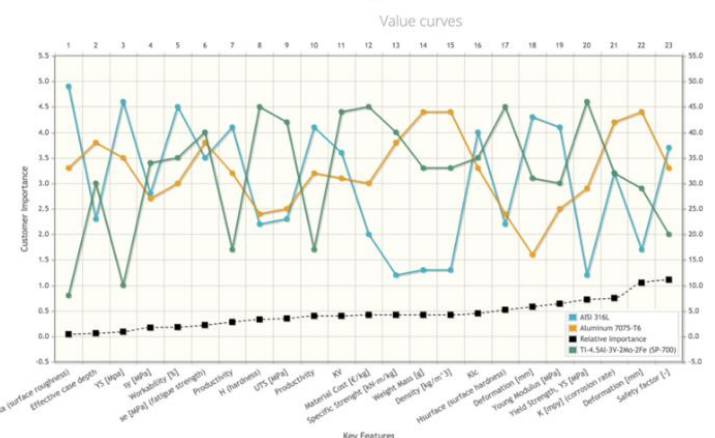
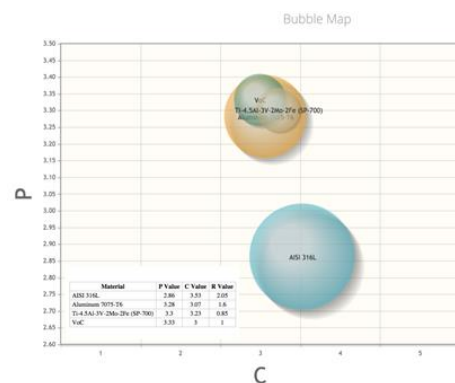
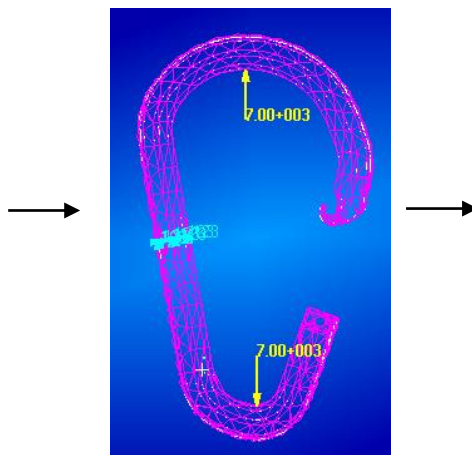
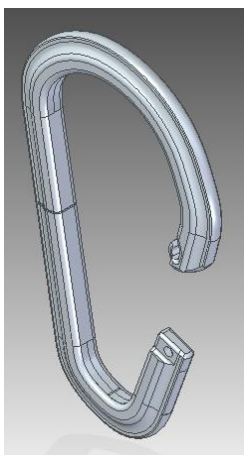


At the same time, we will not only select the most suitable material for our case of study, we will also determine which is the optimal form (shape and section) that respects the operating conditions and bears the loads established by international official regulations by a topology optimization.

The implementation of the topological optimization in the conceptual design of a product, in our case of study is done with the MSC Nastran and Patran software. Topological optimization is a kind of structural optimization developed at software level environments nearly ten years ago and, nowadays, big companies for new design products are introducing it or the improvement of the ones already launched into the market. Initially defining 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. This was possible by using the Optimization functionalities of the MSC Nastran and Patran software.



Finally, we proceed to the integration of the two previous results: the hybrid multi-objective material selection and the topology optimization. Firstly, considering the results from the most precise mesh of the topology optimization and an initial FEM analyze applied to a standard carabiner (also done with the Nastran and Patran software), we redefine a new climbing carabiner form and shape. Then a structural FEM analysis of the optimized climbing carabiner is carried out for each candidate material in order to obtain suitable new parameters such as the climbing carabiner total mass or the safety factor (obtained with the Von Mises stress and the UTS). Subsequently, using the obtained new factors in the QFD4Mat material selection strategy, we reinforce or first analyze obtaining the Aluminum alloy 7075-T6 as the material that best suits the established necessities. In that way there has been an improvement in the effective application of the matrix; since, finally, it has been supplied with specific geometry and design dependant factors.



In general terms, the present thesis work aims, by means of the real application to a climbing carabiner, for showing how the results of topological optimization can be exploited for increasing the efficiency of the materials selection process, being the last section the real pioneer driving force of the thesis work.

Access to summary and full thesis:

Summary: <http://www.iit.upcomillas.es/pfc/resumenes/55dc3c5cec278.pdf>

Full Project: <http://www.iit.upcomillas.es/pfc/resumenes/55f01121246cd.pdf>