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DEFINITION OF AN INNOVATIVE DESIGN METHODOLOGY THROUGH TOPOLOGICAL OPTIMIZATION APPLIED TO WELDED STRUCTURES

Andrea Blengino

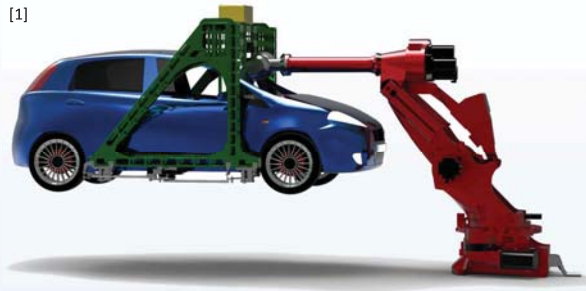
Department of Mechanical and Aerospace Engineering, Polytechnic University of Turin, Turin, Italy

COMAU

INTRODUCTION

The activity was born from the collaboration between Aurelio Somà, professor of DIMEAS (Department of Mechanical and Aerospace Engineering) of the Polytechnic University of Turin and Comau SpA, a worldwide leader in industrial automation and robotics. The aim of this work is to define an **innovative design methodology** that allows to design welded structures through **topological optimization**. This allows to find an optimal form already in the early stages of design, avoiding subsequent analysis and structural corrections, with time-to-market reduction; another important aspect is that it makes possible to obtain **lighter and more durable products**, optimizing the use of material only where this is really necessary.

[1]



DEFINITION OF METHODOLOGY

With topological optimization, **optimal shapes** can be obtained, easily achievable with additive manufacturing, but impossible with traditional mechanical machining like welding or milling. In order to easily deal with this complex problem, the design process has been divided into **five steps**, each focusing on a particular aspect.

ROUGHING — Purpose of the roughing is to remove portions of material structurally not relevant, giving an **outline** of the optimal shape. At this stage, the strain energy is minimized and the frequency of the first natural mode of vibration is maximized.

OPTIMIZING — This phase captures **details** of the optimized shape in order to realize more clearly where to position plates and tubes of the welded structure. As in roughing, the strain energy is minimized and the frequency of the first natural mode of vibration is maximized.

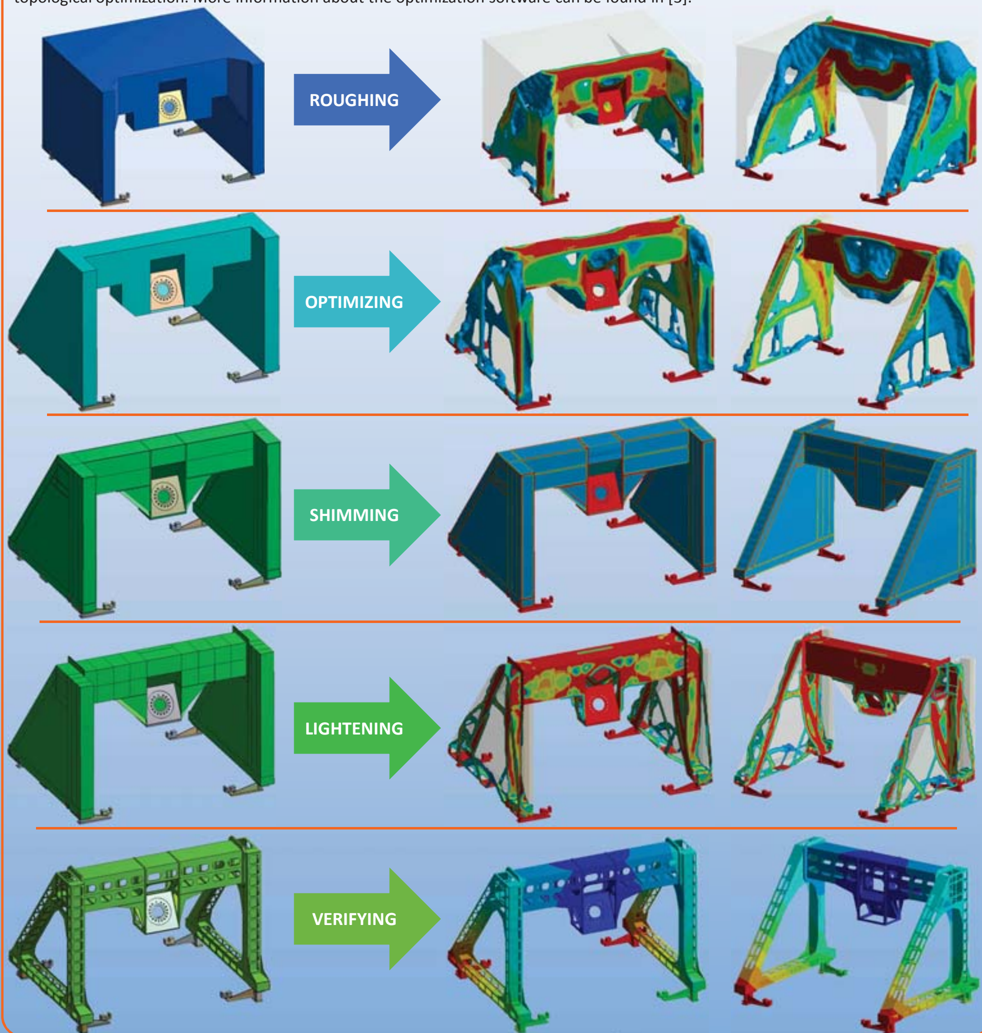
SHIMMING — This step allows to define the **thickness** of welded plates and tubes. From this stage, the overall form of the product is defined and optimization focuses on detail aspects. Shimming minimizes the percentage mass fraction while maintaining stresses below a threshold.

LIGHTENING — Lightening suggests where to **pierce** the plates and tubes in order to further reduce the weight of the product. In this step, as for shimming, the percentage mass fraction is minimized while maintaining the stresses below a threshold.

VERIFYING — Last design phase consists of **checking** design constraints and structural stability of the product. Stresses, natural frequencies of vibration, mass and inertia moments of the product are under investigation, with respect to the payload of the robot. Stresses in weldings have been verified according to [2].

CASE STUDY

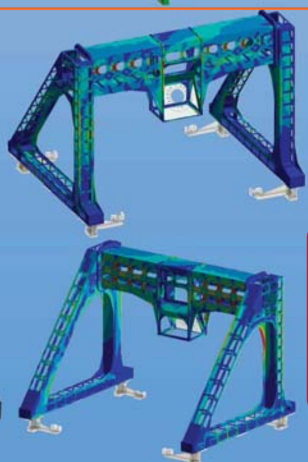
The defined methodology was used to design a steel **gripper**, which is an interface device between a vehicle body to be transported and an anthropomorphic robot; its task is to allow the gripping and handling of the element. Load conditions considered are accelerations in the plan parallel to the floor and the modal analysis of the structure. A reconstruction phase by CAD software follows each step of topological optimization. More information about the optimization software can be found in [3].



RESULTS

In order to evaluate the product, it is compared with two other grippers, one made of **steel** and the other of **aluminum**, previously designed for the same application through traditional design process. Comparison parameters are the **percentage variation in mass** Δm and the **percentage variation in the frequency of the first natural mode** of vibration Δf. In comparison with the steel solution, at equal mass, the optimized product is considerably more rigid; the negligible mass variation is due to the lightening of the original steel gripper, in order to respect the payload of the robot; lightening is not optimal with respect to stiffness. In comparison with the aluminum gripper there is a good reduction in mass, balanced by a reduction in stiffness; this is due to the reinforcement of the original aluminum model to ensure its structural stability, so it is not optimal with respect to weight.

[1]



Comparison gripper	Δm	Δf
Steel model	-1%	+23%
Aluminium model	-18%	-21%

CONCLUSIONS

Looking at the results, the optimized product is competitive in comparison with other traditional design solutions. It is interesting to see stresses in the optimized model, slightly high, but admissible in each welding. Topological optimization has made possible to obtain an optimal design respect to multiple aspects, saving time and improving product performance.

REFERENCES

[1] Qualitative representation of the task of the gripper. In green the gripper, in red a Comau robot, in blue a FIAT vehicle.

[2] International Institute of Welding, *Recommendations for fatigue design of welded joints and components*, IIW document IIW-1823-07, 2008.

[3] Garret N. Vanderplaats, *Multidiscipline design optimization*, Vanderplaats Research and Development, Inc., 2007.