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MODERN APPROACHES IN THE DESIGN OF TRANSPORT HANDLING EQUIPMENT

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Abstract:
The article deals with modern software technologies that can be used in the creation of structural elements to optimize their shape, weight, and stiffness. Basic information on generative design and topological optimization as well as the methodology of their operation and their possible applications are described. The main differences between these technologies are also described and the most well-known CAD software in which these modules are implemented are mentioned. In the practical part of the article, concrete examples of shapes of structural elements obtained by topological optimization and generative design are given. One of the criteria for generating the shapes of the structures was their target weight. To compare the elements generated in this way with classical examples of structures, the resulting weight value is also given in the paper. In the conclusion of the paper, the advantages and disadvantages of these modern technologies are also discussed in the context of the manufacturing process.

Key words:
generative design; topology optimalization

1 INTRODUCTION

These days, product design is a challenging field to succeed in. Products become more complex as more technologies and manufacturing techniques are incorporated into them. The competition to reach the market first is shortening timelines. Due to their numerous responsibilities, engineers are searching for the best option for a workable design (Chad Jackson, 2017).

With the optimization of geometric shapes and material savings, topological optimization technology is often used. This technology allows products to be designed with significant volume and therefore weight savings under known boundary conditions. Computational algorithms in optimization use simulation calculations using the finite element method (Chad Jackson, 2017).

An alternative computational method is Generative Design. Using artificial intelligence and computational algorithms, generative design is a state-of-the-art method for designing and engineering complex designs that maximizes results. It is especially well-liked in disciplines like product design, engineering, architecture, and more. It happens in situations where an engineer specifies requirements for the technology to meet. Engineers can see software's capabilities thanks to generative design. Because of autonomous software, engineers are able to examine a far greater number of options than they would normally (Chad Jackson, 2017).

In generative design, a set of input parameters and constraints are used to automatically generate design alternatives through the use of algorithms and computer programs. This makes it possible to be highly innovative and creative, frequently beyond what a human designer could imagine (S. Bagassi, 2016).

Fig. 1 *Optimization with topology and generative design*
Source: (Graitec, 2017)

Several product visualizations are typically created in a design, after which a few alternatives are assessed through optimizations in accordance with the engineer's objectives. In generative design, the software employs algorithms to generate a number of designs based on the input conditions and constraints that the engineer first defines. The software then presents the engineer with a detailed analysis of the optimal alternative after the generation process is finished. This drastically reduces the amount of time needed for the design phase without requiring the engineer to become involved in every aspect of it (Siemens e-book, 2017),(Siemens, 2017).

Imagine the following situation: a designer wants to plan how a mechanism will be built. He can give the software the mechanical properties, material, loads, and other details rather than going through the design and then experimenting with a few shapes (Trautmann Laura, 2021).

2 METHODS AND METHODOLOGY

2.1 Differences between Generative Design and Topological Optimization

In the realm of design and design in CAD environments, generative design and topological optimization have gained popularity. However, contrary to popular belief, the two fields are not even synonymous (Formlabs, 2020).

Topological optimization is a mathematical technique that is not all that new and has long been included in some CAD programs. The first step is to create a model, after which input conditions and parameters must be specified. The engineer then reviews the best shape that the software has produced for the model. To put it briefly, Topological Optimization needs a foundational model to work from the beginning, which establishes the parameters of the procedure. Though generative design is partially based on topo-logical optimization (Formlabs, 2020).

By taking over this task based on the constraints provided by the engineer and doing away with the need for the engineer to create a model from the beginning, generative design elevates this process to a higher level. Still, a human performs the fundamental tasks of design, including knowing and being able to precisely specify the constraints that must be met in order for the software to produce the final visualizations. Therefore, the engineer will have to keep creating and refining the Generative Design algorithms and the details that go along with them for the time being (ResearchGate, 2018).

	DIFFERENCES	
	Generative design	Topology optimization
Input geometry	Bonds, surfaces, bodies	3D model
3D model	Not required	✓
Result of the study	Plenty of suggestions	One proposal
Number of materials	More than one	1
Additional modifications	Not required	✓
Length of study	Tens of minutes	Minutes
Criteria	Obstacles + preserved geometry	Maximum volume + geometry preserved

Fig. 2 *Differences between Generative design and Topology optimization*
Source: (authors)

2.2 Software for Generative design and Topology optimization

Numerous industries, including the automotive, aerospace, and architectural sectors, use generative design and topology optimization. Generative Design primarily concentrates on cost reduction, performance enhancement, or weight loss when designing in various domains. Experienced engineers with CAD can transition to generative design with ease. Beyond the standard CAD software features, this program offers additional options for entering material, force, mechanical property, and other data (Formlabs, 2020).

Considering the requirements of the software, this is a short list. The section that follows provides an introduction to generative lay-up software (Bigrep, 2020):

- Fusion 360 (Autodesk)
- Creo generative Design (PTC)
- nTop (nTopology)

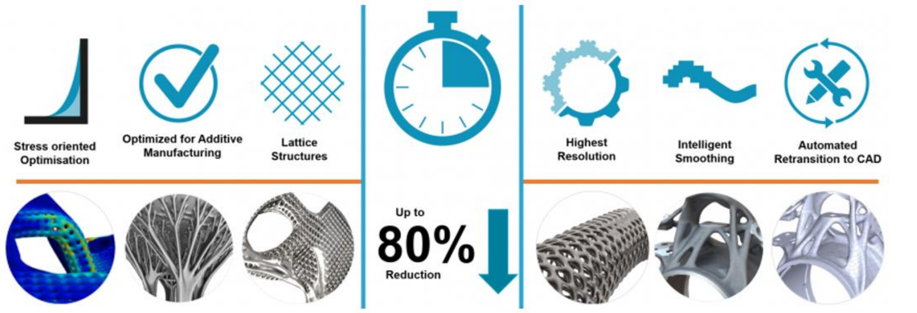
- NX (Siemens)
- Solidworks (SolidWorks)

Although each user has the freedom to select the software they want, there are a few important considerations to make when selecting the best program (All3dp, 2020):

- Where can generative design be used in the process?
- What scope of parameters does the software allow for definition?
- After GD is applied, what manufacturing options will be available?
- Can the created designs be used in the future with different assessment techniques?

2.3 Software for Generative design and Topology optimization

Advantages and disadvantages of generative design are shown in figure 3.



ADVANTAGES	DISADVANTAGES
High performance products	The quality of the output depends on the quality of the input parameters
Reduce costs and waste	Scope of requirements
Extending innovation	High initial costs
Fast time to market	
Lots of suggestions in a short time	

Fig. 3 *Advantages and disadvantages of Generative design*
Source: (Dassault systems, 2022), (Vectornator, 2017)

3 RESULTS

For a practical demonstration of these advanced technologies, we have chosen a statically indeterminate double-sided hollow beam, length L = 3000 mm, which is loaded in the centre by a lone force F = 15 kN (Figure 4).

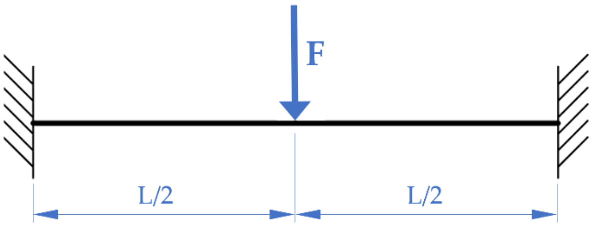


Fig. 4 *Schematic representation of the beam*
Source: (authors)

In terms of classical structural elements, such a use case could be represented, for example, by the hot-rolled sections IPE 180 or PSH IPE 180 shown in Figure 5.

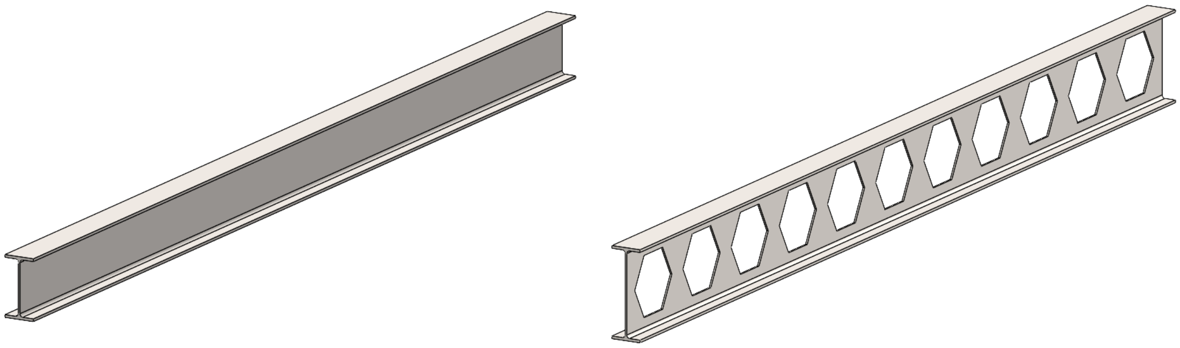


Fig. 5 *Profiles (left side IPE 180, right side PSH IPE 180)*
Source: (authors)

The above-mentioned beams have their characteristic geometrical, cross-sectional and mass characteristics. These data were used as input data to generate new optimal shapes that will satisfy the boundary conditions as shown in Figure 4.

As a first case, topological optimization was used. A block (with a cross section of 92 x 180 mm) of length 3000 mm was used as input geometric shape. These dimensions represent the contour of the IPE 180 profile. Siemens NX software was used for the optimization. The principle of this method is to progressively remove material from the initial geometric shape until the specified boundary conditions are satisfied. The result of the optimization is shown in Figure 6.

Fig. 6 *Topology optimization from Siemens NX software*
Source: (authors)

The second case was the use of generative design. In this case, the methodology for generating the resulting shape is the opposite of that used in topological optimization. The algorithm of the program tries to gradually add material to the bounded space until it produces the optimal shape. For this case, Autodesk's Fusion 360 software was used. This results in the generation of multiple shapes that the system provides for selection. One of the offered shapes is shown in Figure 7.

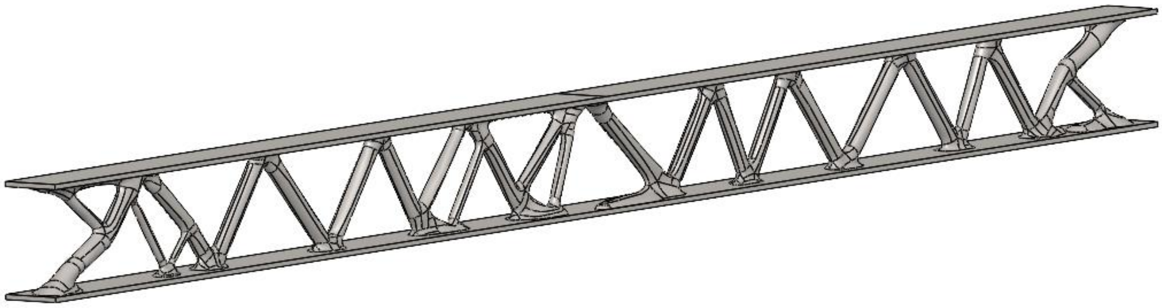


Fig. 7. *Generative design from Fusion 360 software*
Source: (authors)

In the context of shape generation, the system also takes into account the possibilities of subsequent product production such as milling, de-moulding or free form without specifying a manufacturing process.

One of the conditions for the generation of the above shapes was the weight, which was set to about 55 kg. Table 1 shows the weights of the individual products.

Tab 1. *Comparison of beam weights*

Product	**Weight (kg/m)**
IPE 180	18,7
PSH IPE 180	18,1
Topological optimization	16,1
Generative Design	18,5

Source: (authors)

4 CONCLUSIONS

The advantage of these technologies is the effort to maximize material utilization while maintaining the required structural rigidity. However, the shapes created are usually not possible to produce by conventional manufacturing technologies and are more suitable for additive manufacturing. However, it is possible to retrofit the structure according to the generated shape to a form where classical manufacturing processes can also be used.

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