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STEPS OF GENERATIVE DESIGN IN INTEGRATED CAD SYSTEMS

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Abstract: Due to the continuous development of various areas of the industry, such as modern production equipment, material technology, computer and software development, it is possible to expand the range of conventional production technologies. These include additive manufacturing technology, which provides a new opportunity to produce everyday products, thereby satisfying market needs. Integrated CAD systems have occupied a place in the product design and development process for decades, which has partially reformed classical design methods and its steps.

Keywords: *product design methodology, topology optimisation, generative design*

1. INTRODUCTION

A successful product meets the level of technical development of a given period and fulfils the needs expressed by society. The aim of engineering design is to create a suitable solution for a given problem, both from a technical and economic point of view. Product design and development is an outstanding and special profession, as it requires extensive experience, a unique vision and additional specific skills. Earlier it has been accepted that the knowledge required for successful product design is a talent that cannot be fully learnt, described, is not an exact science, and cannot be mechanized. It was recognized in a short time that the quality of a product is greatly influenced by the concept defined and selected in the design phase. Furthermore, a series of decisions that arise during the design procedure play a key role in the product manufacturing process, which can result in beneficial or disadvantageous changes. Based on this philosophy, it can be said that in terms of the life cycle of a product, innovation activities consume huge resources. Assuming that this type of activity can only be properly performed by a competent person, design and development work proves to be an expensive and long procedure. The increasing expectations dictated by the market can be met as much as possible if a given product can be sold as soon as possible and with the lowest financial cost. Accordingly, the design and construction tasks must be transformed into tasks that can be performed by many, in which the individual stages and steps can be well followed and performed [1].

2. Milestones of development of design methodology

The development of various design methodological processes could be observed in the last hundred years. Literature related to the field can be found mainly in Europe, but there are researchers from all over the world whose work is related to this field of science. The aim of the research is unchanged: the design process must be divided into different stages, which can be clearly interpreted and followed in order to be applicable for others. Kesselring published on evaluation procedures as early as 1937 and then presented the basics of his convergent approximation procedure. Wögerbauer proposed in 1943 that the entire design process should be divided into subtasks. The founders of the Ilmenau school were Bischoff and Hansen. Hansen has been working on the basics of design methodology since the 1950s, and, in 1965 he summarized the theoretical aspects of his system. The founder of the Berlin school is Beitz, whose work is closely linked to the founder of the Darmstadt School of Design, Pahl. In 1974, Roth was among the firsts to realize that methodical design could be successfully automated using graphics computers and then developed an algorithmic design model. In Hungary, the Budapest School of Design is worth mentioning, which deals with the development and research of product design methodology and tools. The Hungarian founder of this topic is Bercsey, who developed the Autogenetic Algorithm. It is important to mention the design school in Miskolc, which was founded by Terplán and Tajnafői, and computer structure generation methods were created by Lipóth and Takács [2], [3].

3. Generative design and integrated CAD systems

The generative design model is able to generate concepts using predefined requirements and constraints. The procedure, including shape and topological optimization, was developed around the 1990s, but at that time could not lead to breakthrough success.

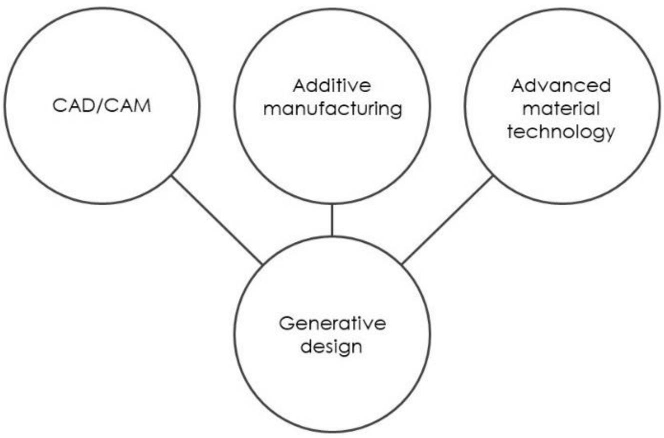

Figure 1. *The technological need of generative design*

The use of the programs was cumbersome, the capacity of the computers proved to be insufficient, but the main drawback was that the result obtained could not be produced with the help of the traditional manufacturing technologies of the given era. Over the next 20 years, the production of additives provided an opportunity to implement 3D printing, and in the early 2000s it became clear that there was an opportunity for additive production of high-performance metallic components, which attracted interest among integrated software manufacturers. Software supporting generative design appeared in the first half of the 2010s. Among the firsts TrueSOLIDTM from Frustum can be mentioned, developed by Jesse Coors-Blankenship. The other big developer is AutoDesk, but recognizing the need for generative design, more and more software development products have become available, which are summarized in *Table 1*.

Table 1

Generative design softwares

	Software developer	**Product**
Generative design software	Frustum	Generate
	nTopology	Element
	Paramatters	CogniCAD
CAE software supporting generative design	Altair	OptiStruct
	ANSYS	ANSYS Mechanical
	Dassault Systèmes	Tosca Structure, Tosca Fluid
	ESI Group	PAM-STAMP, ProCAST, SYSTUS
	MSC Software	MSC Nastran Optimization
Integrated systems with generative design module	Autodesk	Fusion 360, Inventor
	Dassault Systèmes	TOSCA suite
	Robert McNeel & Associates	Rhino
	PTC	Creo Simulate
	Siemens	NX, Solid Edge
	Altair	solidThinking Inspire

4. Steps of generative design in integrated CAD systems

Generative design is a design process in which an algorithm is used to optimize the shape of a part for a given boundary condition. Designing the shape itself is not a manual design task. The designer determines the functional boundary conditions of the part, adds it into the software, which calculates the shape of the optimized part according to the defined aspects during iteration processes [4], [8]. Limit states can usually be divided into two groups, the calculation requires an initial geometry, which must be constructed by traditional 3D modelling. This is quite similar to the solution used in traditional FEM systems: it is necessary to determine which area of the piece is subjected to which forces and which constraints [5–7]. Another possibility is to determine the volumes in which there can be no material because, for example, some other component is moving there. If there is no starting workpiece, it should be specified as a "volume part" that will be part of the finished part. The steps in the generative design process that are valid and show similarity using all the integrated CAD systems listed in *Table 1* are detailed below.

After opening the given program, our first step is to define the design volume, for which we have three options. The first way to do this is to define the geometries to be retained, which remain an integral part of the yellow geometry. Specifying them is a mandatory operation, and later these bodies and surfaces allow defining functions, such as placing mortises. The second method of design space is to define so-called interfering geometries, which can be used to specify those parts of space where there can be no material. The geometry produced by the program can only be located outside this space, but it can be applied in a similar way when the part is limited in size. These volumes are optional during design. The third method is to import a solid-state model whose shape features can be used to specify functions. In this case, the outer surface of the original model does not limit the enclosing size of the geometry produced during generative design by default.

After the precise definition of the design space, the second stage of the process can follow, during which the fixing points and further constraints of our model can be defined. It is possible to specify fixed points, but it is possible to unlock individual planes and axes of rotation within it. We have the option of creating a hinge or pivot point where radial, axial and tangential movement can be allowed. Furthermore, it is allowed to define slip planes and friction surface pairs.

In the third stage of design, we get to defining the location and magnitude of the loads. We have the ability to accommodate force, pressure, torque and distributed load, the direction and magnitude of which can be changed indefinitely.

The fourth step is to decide on the design criteria and objectives. This can be minimizing mass, maximizing stiffness, or developing minimal stress and its optimal distribution. In this phase, a so-called safety factor can be set.

In the fifth step, it is possible to choose the production method, where the production volume and the appropriate production technology can be selected. Optional technologies include additive manufacturing, cutting processes such as milling, cutting and casting. For each option, the minimum material thickness for the model and the tools used in the particular technology, such as the geometric size of the milling tool and the machining direction can be chosen. There is also the possibility that this step will remain unselected, in which case the generation of models will be more widely allowed.

In the sixth step of the process, the material has to be chosen from which the product can be made. The selection can be made from the material catalogues of the programs, but a new material with unique properties can also be defined. The material properties of the items in the catalogue can be modified without any problem.

Care must be taken to ensure that each manufacturing technology has a set of compatible materials.

After making these settings, a verification step becomes available that runs through the data we enter and alerts the user in case of lack of data or poorly entered conditions.

Once the check is done, the planning, i.e. the final calculation and generation process, can be started. We have the opportunity to filter the obtained solutions by categories and access the iteration results of the individual components.

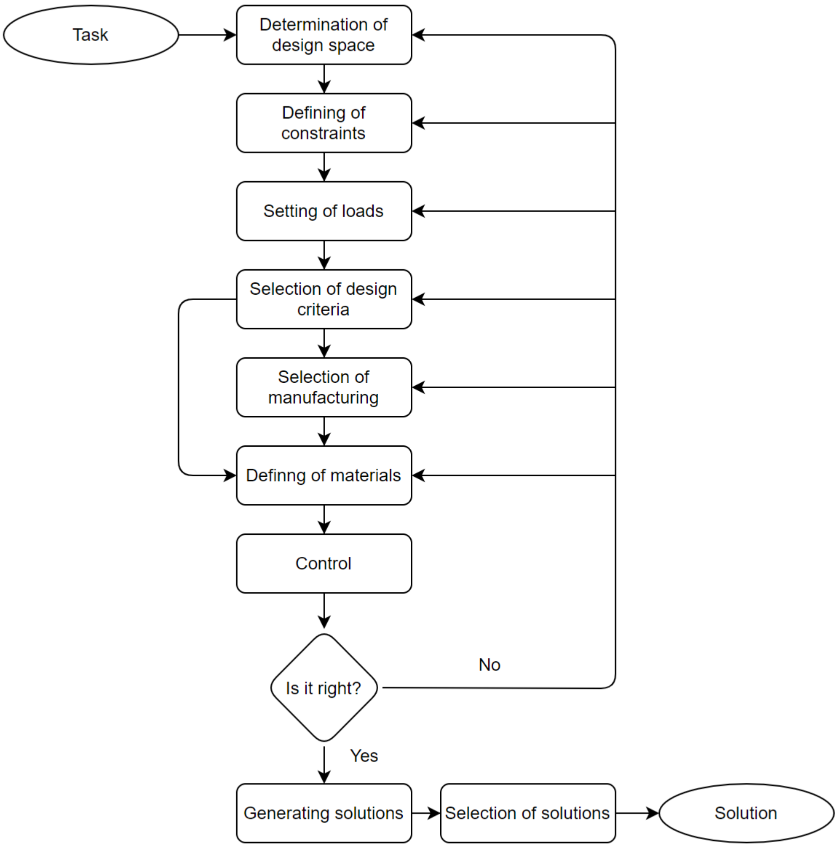

Figure 2. *Steps of generative design process*

5. Summary

The article reviews the development of the product design- and development field that forms the basis of generative design, as well as its defining stages. Factors influencing the spread of the generative design process and the development of the necessary technological processes are presented, and the article provides a short historical overview of the topic of software supporting. Based on the software listed, the article describes the steps required to use the method, which show a match for different programs. For quick understanding and illustration, a flowchart for the operation of the method was created, supplementing the possible iterations. By observing and following the steps properly, we get successful solutions to the formulated task.

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