CREATIVITY IN THE ENGINEERING DESIGN PROCESS

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Essay

Summary

Creativity is one of the basic human skills and abilities, it enables creative thinking and generation of new and innovative ideas. As such it has great influence on the engineering design process and consequently on business related to design and development. Because the purpose of the design process is development of new and innovative products a creative approach is necessary in the engineering design process. To achieve creativity in the design, creative methods are used. This paper describes how the creativity influence the design process and what are the creative methods used in the design process. The brief descriptions of two methods, brainstorming and TRIZ, are given as an example of one intuitive and simple method and one direct and more advanced creative method. In the end the influence of new technology, the additive manufacturing, on the creativity and creative approach in the design process is described.

Key words: engineering design process; creativity; creative methods; brainstorming; TRIZ; additive manufacturing

1. Introduction

When it comes to designing a new product, a creative approach is necessary. Only through creativity designers can create new and innovative products that can fulfil the needs of users. To create such innovative products designers must be creative. But what is creativity and who are the creative people or designers? In literature we can find various definitions of creativity such as “the ability to come up with ideas or artefacts that are new, surprising, and valuable” [1] or “the ability to imagine or invent something new of value” [2]. In essences, creativity is the ability to generate new ideas by combining, modifying or reusing of existing ideas. On the other hand creative designers are individuals that use some source of inspiration in order to stimulate generation of ideas [3]. The source of inspiration can be found all around us, it can be some visual or audio stimulant, analogy to some natural process, association with existing products and technologies, or some other unlimited source of inspiration. To improve creativity in engineering design process different methods were developed over the years to help designers in generating new ideas and finding innovative solutions. It is important to distinguish the creativity from innovation. While the creativity is the ability to create and invent some new idea, innovation on the other hand can be defined as an idea, device or process that is introduced to market or society to meet new requirements or customer needs [4]. In essence creativity is intellectual process of creating the new ideas, while innovation is physical implementation of this idea into a product or a process. It can be argued that creativity can exist without innovation, but innovation cannot exist without creativity. The aim of this paper is to describe the creativity in engineering design, give the overview of
creative methods that are used in design process and describe how they influence creative approach in engineering design process. Additionally, advantages of additive manufacturing on creating creative products will be examined.

2. Creativity in engineering design

The aim of engineering design is to create and design new products and systems that will bring something new and original compared to the existing products. The purpose of design is not just to produce competitive products, but more importantly improvement of user experience through innovation and new functionalities of a product. For these reasons creativity is a crucial element in design [5] and a creative approach is a dominant factor in engineering design process [6]. Creative approach in design is best seen through process of generating ideas and as such it is considered as crucial factor to innovative design concept development and driver of competitive business [7]. The importance of embracing creativity in design process can be seen on success and collapse of many products and companies, for example we will use IT industry. In the 90’s Finnish company Nokia was a world leading company for mobile phones. Their products were innovative, and considered as the best in the world. Although the company had well established business they entered the 2000’s unprepared and with lack of creativity in their design teams and processes. Their products were the same as the previous generations, without any new, creative and innovative functionalities. In the same time companies, such as Samsung and Apple, used the creative approach in their design, and they introduced new kind of mobile phones – the smartphones with new functionalities based on internet user experience. As the years passed by, they became the world leading companies in the IT sector, and Nokia has lost the market share because of lack of creativity in their design. To avoid the same fate companies all around the globe, from small businesses to multinational companies, must embrace creative approach in their design and development processes.

As stated before, idea generation is a crucial stage in design process, especially in conceptualization phase, but creation of new and creative ideas is a very challenging task. Some of the factors that constrain the generating of ideas according to Han et al. [8] are lack of creative people, time pressure, numerous existing ideas, and limited core information. To stimulate the creativity and development of new ideas a variety of different methods for creativity are used, such as brainstorming, 6-3-5 method, mind maps etc. The reason why creative methods are used in the design process can be seen in Yamamoto et al. [9] argument that creative activity is a repeat of imagination and externalization. If this process can be followed smoothly through creative method the designers could create their product more effectively [10]. These structured creative methods can be used throughout the design process, but they are mostly used in two phases of design process, at the beginning in the fuzzy front-end phase and in concept generation phase. The main purpose for using creative methods in design process is to support the designer’s creativity, and enable development of innovative ideas and products to fulfil the customer needs.

3. Creative methods

A variety of different creative methods were developed over the years as a tool for helping the designers to invent new ideas. The principle behind most of these methods is removing of mental blocks that inhibit creativity [6]. The methods do not actually produce ideas but merely stimulate the designer’s creativity in their process of finding new ideas and solutions. Some creative methods, such as brainstorming, are rather simple and user friendly, so the user does not need to have a lot of experience or technical knowledge to use them. On the other hand, other methods like TRIZ, are relatively difficult to use as they depend on
user’s experience and knowledge. The diversity of creative methods gives the designers opportunity to choose the method whose characteristics are suitable for different personality attributes and different applications [11]. Although there are numerous different methods, such as 6-3-5 method, brain-ball, mind maps, Synectics, SCAMPER (Substitute, Combine, Adapt, Modify, Purpose, Eliminate, Reverse/ Rearrange), brainstorming or TRIZ, only the latter two will be reviewed in this paper. The brainstorming will be reviewed because this simple creative method is the most commonly used method for deriving creativity, and TRIZ as an example of creative method designed for engineers and because of its usefulness in the engineering design process.

3.1 Brainstorming

When it comes to creative methods there is no better known and spread method then brainstorming. Brainstorming is an intuitive method for generating large number of ideas for the given problem. From numerous ideas that are generated with this method most of them will be discarded but few will emerge as the ones that are worthy for further development [12]. In concept generation phase this method is focused on product function and architecture [13]. The process of brainstorming starts with small team usually with between 6 and 10 participants. There are no differences in roles between the participants, they are all equal, but one person should have additional role of moderator. The purpose of moderator is to ensure that one or more individuals do not enforce their ideas on others and that everyone feels free to express any idea they have in mind. This is crucial in brainstorming, as there is no bad idea, all given ideas in session are valuable and the categorization and selection of best ideas is happening after the session. The aim of the session, which shouldn’t last more than 20-30 minutes, is to generate as many ideas as possible. Any idea is a good idea, furthermore seemingly-crazy ideas are welcomed and encouraged as they can be the generator for some other novel ideas. To ensure the success of the method one crucial rule is that no criticism is allowed during the session, for this reason comments such as “that will never work” or “that is ridiculous” are forbidden since criticism kills the spontaneity and creativity. To boost the creativity participants should combine and improve ideas of others and try to build new ideas. The typical brainstorming session can be seen on the Figure 1. It shows the small team that is generating different ideas that are written on colourful cards to encourage creativity and additionally to categorize the ideas. When the time of session is over or no more new ideas emerge, all ideas are collected and process of evaluation of ideas can begin. Ideas than can be classified in groups, this can even help the development of some knew ideas or indicate the solution area. If from dozens of ideas that emerged in a session only one or two prove to be worthy the session can be considered successful.

![Fig. 1 Typical brainstorming session [14]](image-url)
3.2 TRIZ

Besides brainstorming and other more basic and intuitive creative methods, we also have more advanced and direct methods such as TRIZ. TRIZ or Theory of Inventive Problem Solving, is a problem-solving method developed in the late 1940s in former U.S.S.R. The principle of this method is to direct the user in process of solving a problem or in development of a new concept. It stimulates the creativity and innovation, gives different principles as a solution for the considered problem, gives a structure to brainstorm and widens the thinking process [15]. The TRIZ method is based on discovery of patterns in patent claims. According to the same patterns, engineering systems and products are being developed. This can then be used to predict the development of a product and to direct the search for new concepts and solutions. The key initiator of inventive solutions in this method are conflicts or contradistinctions between elements of a product and principles for eliminating those conflicts. This principals are universal across different product domains and the systematic application of principles for eliminating conflicts helps the designers in finding new and innovative solutions [13]. From these observations, a contradiction matrix was developed as a main tool of TRIZ method. In the contradiction matrix, we have 39 different factors which could have an impact on each other. The factors are represented in rows and columns of the matrix, and in the cell where two different factors in conflict are connected we can find principles for solving the conflict between those factors. There are 40 different principles of solution that are applicable across different domains of a product, and each cell of conflict in the contradiction matrix contains subset of two to four principles. The application of this general solutions than lead to new and innovative application of basic scientific principles on a given problem in different product domains. The steps of TRIZ method can be seen on Figure 2. The basic flow of action is studying the specific problem, transform it into a general problem for which the general solution already exists, and then transform it back into a specific solution for the given problem. Creativity is best seen in the transformation from general solution to specific solution, because only with creative approach can the designer apply the general solution on given problem, especially when the solution is from different product domain.

![Fig. 2 Steps of TRIZ method](image)

4. Creativity and additive manufacturing

Creative methods in their essence do not have any limitations. However, when it comes to manufacturing of a product some creative solutions that were found and developed during design process must be abandoned because of manufacturing restrictions of conventional manufacturing techniques. The development of additive manufacturing removed some of the restrictions and enabled application and manufacturing of some creative solutions that were not possible with conventional manufacturing techniques. While conventional manufacturing techniques are based on process of removing or deforming material, additive manufacturing is
based on adding material layer by layer or even point to point. This approach opens new possibilities in the design and product manufacturing because designers have access to the inside of a part, they can change the material structure or the material itself in different regions of a part. Additionally entire assemblies can be manufactured in a single process, and with it removing additional step of assembling the parts. All possibilities enabled with additive manufacturing will change the designers approach to design process and with it also the creative approach in it. The possibilities in creativity that are enabled with additive manufacturing are best seen through shape and functional complexity that can be achieved with this new technology. As the additive manufacturing enables production of very complex shapes with almost no restriction on a design and enables incorporation of multiple functionalities in a single part [16] designers can use those possibilities to produce even more creative and innovative products. The recognition of new possibilities and removed restrictions can influence the design process and its creative approach. This fact will not influence the performance and methodology of existing creative methods, but will simple give different view on evaluating their outcome. Never the less, it is possible that in the future some new creative method, specialized for design of additive manufactured products, will be invented and bring new and innovative creative approach to the design process. For now some authors argue that in Design for Additive Manufacturing a creative approach must be implemented in early stages of design process [3] to take the advantage of additive manufacturing and creativity it enables.

5. Conclusion

It is concluded that creativity is one of primal human skills and abilities, and as such it was always a part of a design process. As the consumer market dictates that only creative and innovative products will ensure the economic success of a company, a creative approach in the form of structured creative methods must be applied in the engineering design process. Over the years many different creative methods were developed, each one with different characteristics how to stimulate the creativity in the designers and in which situations can it be applied. The creative methods became the integral parts of design process and can be found in all design stages, however they are still mostly expressed in conceptualization phase. The development of the creative methods will be continued as they will must support new manufacturing technologies such as additive manufacturing that will bring some new possibilities for expressing the creativity of the designers through new creative and innovative products.

REFERENCES


