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Role of CAD in Product Innovation:

A case study approach

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Abstract

In today's highly competitive and global market innovation is the most important strategy for any company to survive. With CAD tools becoming ubiquitous today it is affecting the designer's creativity in both positive and negative ways. This paper explores the role CAD plays in innovation through extensive literature review and mapping the findings on a case study of the design of a gasoline dispenser of a leading Indian manufacturing firm in which CAD had been extensively used.

Keywords

Product innovation, CAD, creativity, visualization, product design

1.0 Introduction

In today's highly competitive global market, companies need to innovate continuously in order to survive the pressure of competition. Innovation is recognized as one of the most successful strategies for profitable growth, capturing market share, and even the means for survival.

It is evident that the CAD tools are ubiquitous today and that they support the designer's creativity and everyday's work and curtail the innovation to an extend at times. The CAD tools are being used at all levels of product development by different people playing different roles like designers, draughtsmen, engineers and production personnel. It plays an important role in product life cycle management wherein CAD works as a connecting thread.

Creativity can be seen as first step in an innovation process. Creative ideas are novel and a successful implementation of these ideas results in innovation. Creative problem solving is essential at every stage of design process but it is of critical importance at the conceptual design stage. With the high pressure to meet deadlines and to reduce time to market, the designers sometimes struggle hard to come up with innovative ideas and this is where CAD tools come in and hamper as well as aid creativity. Hence, the approach of utilising the CAD tool in the initial phases of design is important and is illustrated through the case study.

This paper explores the way CAD tools affect a designer's work and the role it plays in the product innovation by using the case study for design of a new gasoline dispenser for a leading Indian manufacturing company. The use of CAD for the conceptual design as well as product development and manufacturing was studied in detail.

2.0 Objective

CAD play a very important role during the conceptualizing stage of product design and the different parameters of implications of CAD are identified through literature review and further qualified through the industrial case study.

Thus the objective of this paper is to analyse the identified parameters in the actual scenario using the case study method and come up with the ways to improve the effectiveness and contribution of CAD in the process of innovation.

3.0 Research Methodology:

The extensive use of various CAD tools has created a new culture and environment that requires to be studied using multiple perspectives. Literature survey combined with personal experience helped in identifying the key parameters for the role of CAD in product innovation. This was further validated using an industrial case study, which helped in getting deeper insights.

4.0 Literature Review

4.1 Understanding - innovation, creativity, CAD

Before exploring further, it is necessary to understand few terms used in this research. The common definition of Creativity from Webster's dictionary is- *Creativity is marked by the ability or power to create, to bring into existence, to invest with a new form, to produce through imaginative skill, to make or bring into existence something new.* Knowledge and thinking style are key attributes of creative problem solving. Knowledge and experience lay substantial foundation for creativity and creative thinking serves as the backbone of creativity. Another factor today affecting creativity is information technology. A designer can make use of knowledge-base technology, information searching technology, artificial intelligence and CAD tool to improve their creativity.

Innovation on the other hand, is a holistic process. Innovation requires multi-disciplinary teams and is a complete lifecycle process. Domain expertise is an essential component of innovation. Chakravarthy (2005) in his thesis describes a flower model of innovation where technology, user interface, cost, marketing, attributes, distribution, material, manufacturing, management all form the petals of the flower of innovation. To make it complete every petal has to be present.

In the paper titled as "world survey of computer-aided design" by Hatvany, Newman and Sabin (1993), CAD is defined as integration of appropriate computer hardware and software modules to create design systems for particular requirements. The authors classify the design activity in four phases; conceptual design, design analysis, detail design and design documentation. Today there

are various CAD tools available to assist the designer in each phase and help optimize the design decisions and processes.

4.2 Tools for innovation with respect to CAD

Due to increasing competition induced by globalization, innovation is seen as an essential factor for the future of manufacturing enterprises. Dougherty (1992) suggests that most innovative and creative ideas are generated by a team having members from diverse expertise, cultural backgrounds and globally distributed sites. When a mix of internal and external members combines their complementary skills and perspectives in new ways the creativity of the team enhances and results in more innovative ideas. The collaborative model for entrepreneurial innovation proposed by Chakravarthy (2004) suggests that innovation requires three different teams, (i) core team, (ii) expert team and (iii) external team. The roles of these three teams are clearly defined and it is very important for all the teams to constantly communicate with each other. CAD as a tool promotes communication among geographically dispersed team members via internet, intranet, etc. and enables richer "group creativity".

Promoting communication is one of the positive factors of CAD. But there are many more ways in which CAD tools influence the creative problem solving process. The supporting factors of CAD include better visualization, enhanced communication, freedom to play with the ideas and forms, increased efficiency, as it requires designers to spend less time on details and more on creative thinking, etc. While the positive aspects are generally accepted the negative ones are more nebulous. Robertson and Radcliffe (2009) define four categories of effects from their case study findings.

1. Enhanced visualization and communication: The use of CAD greatly enhances the visualization and communication of ideas within group, even across the globe. Still the authors suggest that people gathered around monitor, is not a good situation for brainstorming and idea evaluation. An illusion of completeness created by CAD model also tends to discourage further creative thought in a group scenario.
2. Circumscribed thinking: The functional capabilities of CAD tools tend to limit the solutions created by team. This also depends on the proficiency of the user. At the same time, a proficient user, who has too much of creative freedom, can introduce unnecessary complexity into the design and manufacturing.
3. Bounded ideation: Sometimes the process of drafting and constraining the model can become so mundane that it distracts the user from the actual process of designing. The excessive use of CAD might limit the number of ideas generated by the user.
4. Premature fixation: A CAD model sometimes gives an illusion of completeness, which in turn can lead to the fixation of idea. In addition, if the model is detailed, this might create a kind of inertia and a reluctance to make any changes and result in premature fixation of concept.

5.0 Research parameters

Bringing in the experience of the authors on various projects involving CAD and the

literature review helped in various factor identification. The summarised factors are as follows:

1. Visualization and communication
   It is impossible to look inside somebody's mind and scanned doodles or rough sketches sent across to different teams without the designer being present there, images do not communicate the ideas fully. CAD helps in communicating the ideas in a much better and easier ways, sometimes even without words.
   a. Enhanced visualization in 3D
   b. More realistic visualization
   c. Perception of size
   d. Enhanced communication
   e. Richer group activities – more collaborative efforts

   A CAD model undoubtedly gives a better 3D visualisation. The client or the other team can rotate the models, visualise from various angles and perspectives and render in realistic scenarios. This help in visualising the final product much better. At the same time, looking at monitor might not give the feeling of size. The perception of dimensions and sizes remain vague on the screen. Sharing of CAD models, 3D and 2D renderings among globally dispersed team members promote collaborative efforts and richer group activities.

2. Bounded ideation and premature fixation
   a. Effect of CAD on number of ideas developed
   b. Depth of exploration
   c. Premature fixation
   d. Reluctance to make changes in more detailed model
   e. Detailing done prematurely
   f. Effect of proficiency

   Sometimes developing a CAD model consume so much of time that it limits the number of ideas and hence depth of exploration. On the contrary, a very proficient user might end up generating too many ideas and hence more time in decision taking. A proficient user might end up introducing unnecessary complications to the design. The illusion of completeness also leads to premature fixation of ideas. Sometimes, to decide on the outer form, lot of internal detailing is done in the initial phases. This might lead to premature detailing and reluctance to make changes.

3. Better time management
   a. Reduced time in design finalization
   b. Reduced time for prototyping
   c. Reduced time for engineering
   d. Reduced time to market
   e. Avoiding reinvention of wheel, over design, failure detection
   f. Ease of documentation

   Faster communication and 3D visualisation reduces time required for taking the decisions. Sometimes, the faster decision is also caused by premature fixation. The better 3D visualisation cuts down the requirement of mock ups to certain extend. Rapid prototyping, CNC machining, bending, laser cutting and other modern techniques have cut down time required for making prototypes drastically. CAD modelling facilitates checking for interferences and clearances as well as material requirements for various thicknesses and mass calculation, etc. This reduced

the time for engineering and helps in faster and precise detailing of the design. This in turn reduces time to market. Automatic generation of design document, bill of material, design history, etc help in easier, accurate and efficient documentation.

4. Role of CAD in specific scenario
    a. Role in repeat order design
    b. Role in variant design

    CAD modelling encourages modular design. By picking up the standard parts in assembly from the previous models, not only save time in developing new designs with minor variations but also help avoid reinvention of wheel. It helps achieve variation in design in the same range of products faster.

6.0 Case study

The aim of this case study was to get the insights on the practice and impact of CAD tools in the design process. This project under consideration was taken up with the author as a consultant to design a new gasoline dispenser for a leading Indian manufacturer.

The brief was to design a modular, new shape, customizable, multiple hose, well-engineered and precise gasoline dispenser for the global market.

The client provided the abstract rendering with no dimensions of the product as illustrated in figure 1. The idea was to have an oval dispenser to match their oval brand identity.

Figure 1. The rendering of the oval pump

The Project brief started with the CAD rendering and helped the design team visualize the final product requirements very clearly in the beginning. However, it was helpful for the marketing and management team to convey the requirement to the design team, yet was constraining for the form exploration.

Using this first rendering the CAD team quickly developed the CAD model with all the new internal parts because of the earlier experience of designing the gasoline dispensers, as shown in figure 2. With the flexibility that CAD assembly provides, it was easier and faster to decide the location and orientation of the various internal components and the skeleton size. The detailing was done in the initial stages of the development but in this case, it was required to decide the skeleton size. This helped speed up the engineering later.

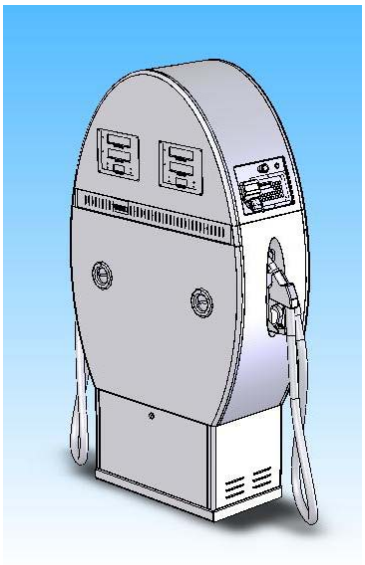

Figure 2. First CAD model of oval dispenser

The design team found it very difficult to perceive the actual size and the tolerances for the various parts looking at the computer screen. Hence, a full-scale AutoCAD drawing was used as a prop to understand all the functions as well as the organization of the components, as shown in figure 3.

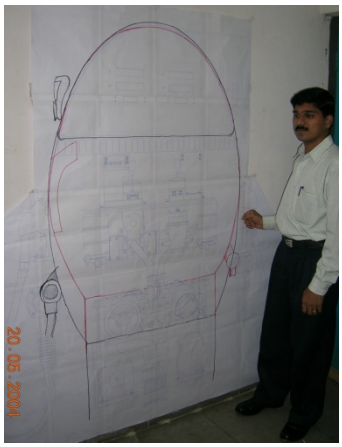

Figure 3. Full-scale drawing

All the improvements were fed into the cad model and a full scale mock up was prepared for volume and form perception using the rendered images. This was extremely important as even the top management could give constructive criticism that could not be provided on the CAD model. It also made the product look real and hence the suggestions and improvements were easy to come. The image of full scale mock up is shown in figure-4.

Figure 4. Full-scale mockup

CAD proved to be very effective in prototype building because of excellent support from CNC manufacturing. Innovative fixtures and welding techniques were used to create new shapes with sheet metal, which was not done earlier, as shown in the figure 5.

Figure 5. Gasoline dispenser prototype in process using CNC machining and bending

The full-scale working prototype was possible due to the excellent interface of cad tools with

the tooling and development department. Digital prototyping techniques, CNC machining of molds and vacuum forming made it possible to create precise working prototypes of excellent quality, as shown in figure 6, 7 and 8.

Figure 6. Working prototype of Oval Gasoline Dispenser

Figure 7. Vacuum formed panel

The final product prototype displayed an excellent interplay between physical and digital technologies using their strengths and negating their weaknesses.

The final form of the product did not change much from the first rendering received from client. The explorations were done more into technology, interface and features and the overall form of the product was not much explored. This shows bounded ideation and fixation which occur due to realistic renderings of the final concept.

Figure 8. Final working prototype

Learnings

1. Use of physical models in combination with CAD models helps in effective visualisation and overcome the limitations of perception.
2. CAD tools help in evolutionary design as it create links between various stages of product design and development.
3. Mock up models during different phases of CAD development helped in curtailing the illusion of size and detail perception.
4. Designers should ensure that the ideations are not bounded by ensuring a minimum of 3 to 5 concepts before evaluation.
5. It is important to ensure that detailing done at the initial stages does not result

in premature fixation by ensuring parametric modelling of only the key features.

6. The efficient use of CAD tools can reduce the time to market for any product drastically. Proper proficiency levels of the users are required to ensure this.
7. The designs should also be reviewed and evaluated by people who are not part of the design team to have unbiased opinions.

Conclusion

Though CAD tools are very over bearing and they have tremendous power for design, it is essential to understand its limitation and use the findings from the study to weed out the same so that there is a win-win situation for use of CAD. With these checks in place the CAD process can be a very effective tool for innovation.

References

[1] A CSC White Paper. What Innovation is – How companies develop operating systems for innovation. European Office of Technology and Innovation.

[2] Chakravarthy B K (2004). Collaborative network for innovation: A real case study. Proceeding of GLOGIFT March 13-15; 26-39.

[3] Dougherty D. (1992). Interpretive barriers to successful product innovation in large firms. Organization Science 3: 179-202.

[4] Hamel G (1998). Strategy Innovation and the quest for value. Sloan Manage Rev Winter: 7-14

[5] Hatvany J, Newman W M, Sabin M A. World survey of computer-aided design. Computer-Aided Design vol.25 no.12 December 1993.

[6] Jane Fedorowics, Isidro Laso-Ballesteros, Antonio Padilla Melendez (2008). Creativity, Innovation and E-Collaboration. International journal of e-collaboration, Vol.4, Issue 4.

[7] Marshall Catherine, Rossman Gretchen B. Designing Qualitative Research. SAGE Publications, Inc.; 1989.

[8] Noel Leon (2009). The future of computer-aided innovation. Computers in Industry 60: 539-550

[9] Paulus P.B., Nijstad B.A. (2003). Group creativity: Innovation through collaboration. Oxford University Press, New York.

[10] Piegl Les A. (2005). Ten challenges in computer-aided design. Computer-Aided Design 37: 461-470.

[11] Robertson B.F., Radcliffe D.F. (2009). Impact of CAD tools on creative problem solving in engineering design. Computer-Aided Design 41: 136-146.

[12] Yan Li, Jian Wang, Xianglong Li, Wu Zhao (2006). Design creativity in product innovation. International journal Advance Manufacturing Technologies (2007) 33: 213-222.

Biography

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