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Design agility through computer aided design

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Abstract

Purpose – The purpose of this paper is to report a research which is conducted to examine the power of computer aided design (CAD) in achieving agility in traditional organizations.

Design/methodology/approach – The CAD model of the knob of an electronic switch was developed. This model was shown to the team of executives. The theoretical and practical knowledge provided by them were utilized to design new ten CAD models of the knob. The reactions of the executives about these new models were gathered and analyzed.

Findings – The creation of a CAD model of an existing product is found to be a useful input for evolving new models in an agile manner. It is found to be an easy task to gather the theoretical and practical knowledge for achieving design agility through the visualisation of CAD models.

Research limitations/implications – This paper is conducted on only one component manufactured by an electronic switches manufacturing organization. Although it appears to be a limitation of this paper, the nature of the design process carried out in this traditional organization mimics that of any other design practices carried out in the world. Hence, the contributions of this paper are applicable in traditional manufacturing environment.

Practical implications – Throughout the conduct of this research, the practitioners' views are gathered. Their views are favorable towards the successful usage of CAD model in achieving design agility.

Originality/value – For many years, CAD has been used for carrying out complex design projects. However, it appears that it has not been used in its simplest form to visualise and bring out new models electronically for achieving design agility. This simple approach is presented in this paper which may be used by both theorists and practitioners.

Keywords Agile production, Computer aided design, Electronic switching systems, Product design

Paper type Research paper

Introduction

The increasing pace at which globalisation has been happening has which paved the way for entry of numerous competitors in markets (Cater, 2005). This situation necessitates the customers to occupy a dominant position in the societies. As a result, modern customers not only demand high quality products and services but also varieties (Vin *et al.*, 2006). Many times, varieties of products and services are demanded by modern customers in different volumes. This situation triggers the modern

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organizations to spontaneously become adaptive to the dynamic demands of the customers (Gunasekaran *et al.*, 2008). Hence, modern organizations are in pursuit of producing products and providing services of different varieties and volumes within a quick span of time. The organizations which are capable of accomplishing this goal economically and without compromising quality are able to thrive in today's globally competitive market. This kind of capability of an organization is known as "agile manufacturing" (AM) (Brown and Bessant, 2003).

The formation of AM forum at Iacocca Institute, Lehigh University, USA in the year 1991 marks the beginning of researches on AM. Thereafter, a significant number of researches on AM have been carried out. Many of them have resulted in the evolution of models to achieve agility. However, these AM models are seldom applied in practical scenario. The absence of AM models contributed by the researchers in practical arena does not mean that practitioners have failed to incorporate agility in their operations. In fact, the agility principles are inculcated in certain industrial sectors at a fast pace. For example, in the case of mobile phone manufacturing, all the leading companies bring out different models with many innovative features within short period of time (Sigala, 2006). Those models are developed quickly using advanced technologies and anticipating the tastes of the customers. However, agility is not still taking the root in many of the traditional industrial sectors like those manufacturing pumps, compressors, and machine tools (Devadasan *et al.*, 2005). Presumably due to this state, these industrial sectors have been failing to face the competition in the global market. This kind of situation leads to an impression that the AM models developed by the researchers are not practically compatible (Yusuf and Adeleye, 2002). In other words, there exists a considerable gap between AM researchers and practitioners.

In order to develop a bridge between researchers and practitioners, many researchers developed practically compatible AM criteria. However, those criteria are highly biased towards management aspects. A very little emphasis has been given on the agility through design of products. During the past several years, the design field has been witnessing tremendous developments (Nandkeolyar *et al.*, 1996). Particularly, "computer aided design" (CAD) technology has been extensively used by the product designers (Holst and Bolmsjo, 2001). However, there is very little evidence that the practicing community has been adopting CAD technology for improving agility in organizational arena. In this context, this paper reports a research project which has been carried out from the perspective of improving agility of traditional organization through CAD.

Literature survey

During the research being reported here, the literature was searched to trace the researches and practices carried out to achieve agility using design principles and CAD technology. This search made in leading databases like Emeraldinsight, Sciencedirect and Ebsco resulted in the identification of 13 relevant papers. The contributions of these papers are briefly reported here. Kusiak and He (1997) have proposed three rules for the design of products for agile assembly. Three rules for the design of products for agile assembly from an operational perspective. Accomplishment of design for agile assembly by considering the operational issues at the early product design stage. Kusiak and He (1998) have proposed four rules for designing from agility perspective. These rules allow product and system design for easy scheduling. Lee (1998) has considered AM in the early design of components and manufacturing systems. Design for short manufacturing lead time has been studied in the form of the design rules. Design for agility rule has been formulated, proved, and substantiated by numerical results. Vernadat (1999) has discussed organizational, technological and human aspects of agility with respect to product design, manufacturing system design and innovation management.

Toussaint and Cheng (2002) have proposed enabling techniques with an example based on tolerancing application and two java-based machining simulators for e-manufacturing purposes. Investigation on a web-based engineering approach to enable engineers for sharing design and manufacturing data through the world wide web. Helander and Jiao (2002) report a model which enables the participation of customers while designing products to achieve mass customisation. For this purpose, they have proposed an electronic product development enabled mass customisation model. On implementation, this model will facilitate the customers to express their requirements through electronic media which would be processed again through electronic devices. They have also suggested the usage of techniques like analytic hierarchy process and quality function deployment during this process. An important emphasis of this paper is the need for integration of all functions, particularly design, manufacturing and logistics while designing products and thereby achieving mass customisation.

Zhan *et al.* (2003) have contributed a model which facilitates the collaborative product development with the aid of internet. This model entails the participation of a number of designers while designing agile products. Mervyn *et al.* (2003) have developed an internet enabled interactive fixture design system. They have suggested that an effective fixture design system should be portable on different operating platforms. Pan *et al.* (2003) have proposed a novel approach to implement a design support system using world wide web to achieve agility in rolling bearing design. The web-based distributed system will be globally accessible on the internet to the users and can be automatically sized according to the demand or application requirements. Su and Chen (2003) have presented a framework of network support for the integrated design. This integrated agile design system integrates stages within the design process including product design specification, conceptual design, detailed design and manufacture. This has been achieved with the aid of integrating various software packages into a single environment.

Devadasan *et al.* (2005) have proposed the concepts of design for product as well as system agility. They have adopted a modified orthogonal array-based model exploiting the technique "design of experiments" in an AM environment. Borissova *et al.* (2006) have used the concept of combinatorial process, equipment and plant design for achieving agility in manufacturing. The proposed approach has been particularly appropriate for the design of agile plants for families of products. Onuh *et al.* (2006) have evolved a model for agile product design involving CAD, computer aided manufacturing (CAM), rapid prototyping, and rapid tooling.

Though many concepts of design engineering have been proposed in linkage with AM, only scant researches have taken place in utilizing the concept of design engineering with AM. Also, it has been observed that one of the underutilized technology in enabling AM is CAD. This is despite the fact that features like time composition, increased product variety, achieving lead time increased customer domain are complementary to both CAD and AM. Moreover, the products manufactured by traditional manufacturing organizations are not compatible for attaining agility. This is due to the underutilization of the CAD technology for enhancing agility. In this context, the research reported in this paper was carried out. This research was focused towards examining the practicality of achieving agility through the exploitation of CAD technology. Hence, this research was dominated by a case study which was conducted in a traditional electronic switch manufacturing organization.

Research methodology

The research being reported here was carried out by adopting the methodology shown in Figure 1.

As shown, first the literature on AM and design for agility was studied. Then a traditional manufacturing organization was selected and the product (electronic switch) manufactured by this organization was studied. This was followed by the CAD modeling of a component by this electronic switch. Then the CAD model of new components were developed by applying creative thinking. This was followed by the validation of results to check the performance improvement of new models of the components. Then the inferences were derived.

Case study

The case study has been carried out at Salzer electronics limited (hereafter referred to as Salzer). Salzer is an electronics switches manufacturing company located in Coimbatore City of India. Salzer was started in the year 1986 with the collaboration of Saelzer Scaltgeratefabrik, Germany. Salzer's main product is CAM operated rotary electronic switches. Other products are direct current switches, relays, starters and modular switches. Currently 350 employees are working in Salzer. At the time of inception, Salzer's turnover was <10 lakhs Indian National Rupees (INR) (equivalent to US$20,000). The current turnover of Salzer is 18 crores INR (equivalent to US$3,600,000). Salzer is a company rising towards world class horizons by implementing total productive maintenance, ISO 9001 and total quality management. Despite adopting these competitive

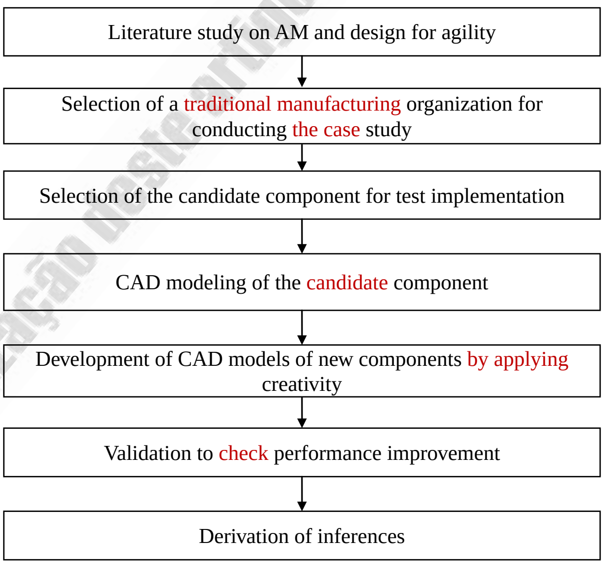

Figure 1.
Research methodology

strategies, Salzer has been slow in evolving new models of switches to suit the customers' dynamic demands. Particularly, the adoption of CAD technologies has been rarely used in Salzer. In this context, Salzer was considered as a traditional manufacturing organization and hence, was chosen during this research to examine the practicality applying CAD technology for achieving agility. To begin with, one of the Salzer's switches by name "CAM operated rotary switch" (here after referred to as switch) as the candidate product of this case study. The operational features of this switch are briefly described in the next sub-section.

Operational features of the switch. The switch shown in Figure 2 operates with the help of a CAM to allow different and desired sequence of operations. The operations carried out by the switch are making and breaking the power circuits and diverting the power line to auxiliary circuits. The design of the switch is so flexible that according to the customers' varied requirements of operating sequence, the CAM can be positioned and the required operations pertaining to each switch can be made. The materials used are of superior quality which ensures complete safety when switches are connected to either alternating current or direct current line. The plastics such as nylon, acetal copolymer, and glass filled polyamide used for manufacturing certain components of the switch ensure higher mechanical strength. The aesthetics of the switch is so good that it is appealing to the international customers. As marked in Figure 2, during the conduct of this case study, the knob of the switch was chosen as the candidate product. Subsequently, the CAD model of the knob being used was created using Pro/E Wildfire 3.0 software package. This CAD model is shown in Figure 3.

Keeping this CAD model as reference, ten new CAD models of knob were created using the same software package. These CAD models are shown in Figure 4. The new models of knobs have been designed using the ideas generated during the brainstorming session conducted with the executives of Salzer. During these brain storming sessions, four design criteria namely aesthetic, ergonomics, functional improvement, and gripness facilitation were considered.

Validation

Being a traditional organization, there has been no history of evolving any new switch within a short period of time at Salzer. The new switches whose models were created within one month using Pro/E were presented to five executives of Salzer. After a brief presentation about exploiting CAD for evolving new models of the knobs, they were given a questionnaire to respond.

The questionnaire contained four questions. Three questions enabled the respondents to indicate their views in a Likert's scale of range 0-10. Another question enabling the respondents to write their overall opinion about the digitalization

Figure 2.
CAM operated rotary switch

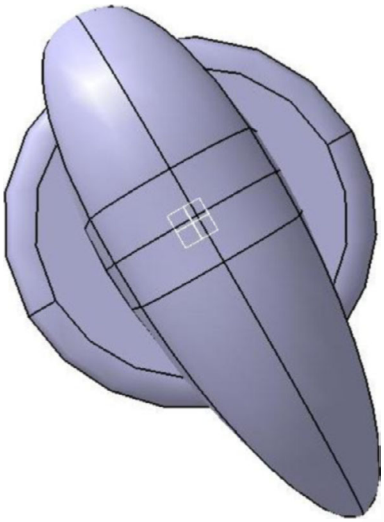

Figure 3.
CAD model of existing knob

of switches using CAD was also included in the questionnaire. The summary of their responses against the first three questions is presented in Table I. As shown, the minimum average value is "6.3" against the first four questions. This indicates the practical feasibility of bringing out design agility in Salzer through CAD.

In Table II, the opinions written by the competent personnel are presented.

The opinions written by the five executives also further established the practical feasibility of acquiring design agility using CAD. The results of this case study indicated that a variety of knobs can be generated using the creative thinking as well as the proactive anticipation of the customers' dynamic requirements. This state of creativity enhancement among workforce is a vital requirement for achieving agility. The new models created in electronic virtual environment during this case study possess features such as improved aesthetics, improved ergonomics, functional improvement, and gripness facilitation. This kind of exercise would promote the culture of new product development which would be a stepping stone for achieving higher degrees of agility.

Performance improvement in agility measures. After gathering and analyzing the reactions of executives about the new CAD models of knobs, a comparative table for estimating the performance improvement of achieving design agility through CAD was developed. The consolidated data gathered are shown in Table III. As shown, the performance of deploying CAD for enhancing agility is expected to increase from the value of 6.8-9.7 (in a Likert's scale of range 0-10).

Statistical validation. In order to further statistically analyze the feedback of the five executives, the quantified values were entered into Software Package for Social Sciences (SPSS). The SPSS package was used to conduct *t*-tests and examine the acceptance of "Agility through CAD modeling." In the first case, the test value was given as nine which meant that "90 percent of the opinions are in favor of successful achievement of agility in design through CAD in practice at 95 percent confidence interval." As the significant (two-tailed) values for some cases are <0.05, this null hypothesis is rejected.

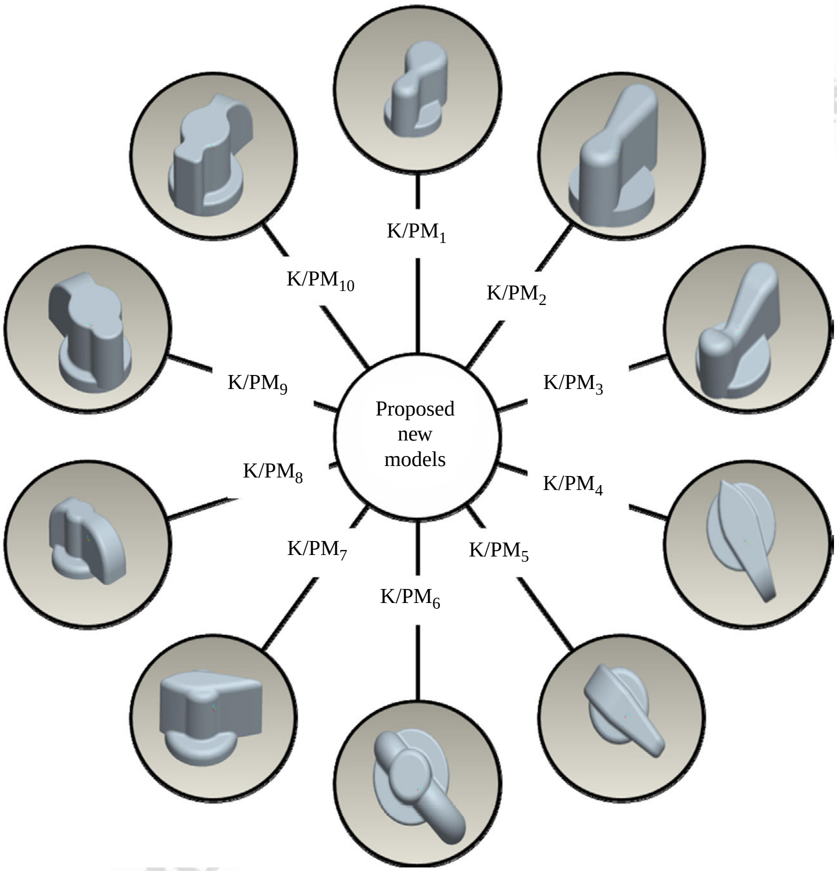

Figure 4.
CAD models of new ten knobs

In the second case, the null hypothesis was set as "80 percent of the opinions are in favor of successful achievement of agility in design through CAD in practice at 95 percent confidence interval." In this case, the significant (two-tailed) values are > 0.05. Hence, this null hypothesis is accepted. The screens displayed by SPSS package pertaining to this null hypothesis are shown in Figure 5.

On the whole, this validation study indicated the feasibility of deploying CAD for acquiring agility in practice with the success rate of 80 percent.

Testing the reliability of the questionnaire. In order to check that reliability of the questionnaire, SPSS package was used to determine the value of α. The purpose of this study was to check whether the questions truly reflected the intention for which they were designed. The data displayed by SPSS in this regard are shown in Table IV.

If the correlation value is more than 0.5 for all questions and also the α value is more than 0.7 for the entire questionnaire, then it should be construed that the questionnaire truly reflects the intention for which it was designed and thereby it indicates its reliability in drawing inference. As shown in Table IV, correlation value is more than 0.5 against all questions and the α value is also more than 0.7. Hence, it revealed that

Table I. Feedback from Salzer on achieving design agility through CAD

Question number	Question	Average response in Likert's scale of range 0-10 K/ PM_1	K/ PM_2	K/ PM_3	K/ PM_4	K/ PM_5	K/ PM_6	K/ PM_7	K/ PM_8	K/ PM_9	K/ PM_{10}
I	To what extent do you think that the development of this switch is technically feasible at Salzer?	9.2	8.6	8.6	8.8	8.2	9.2	9.4	8.6	8.8	8.2
II	To what extent do you believe that this switch is ergonomically feasible?	9.8	8.4	8.2	8.3	7.8	9.2	8.4	8.2	7.2	6.8
III	To what extent do you believe that this switch can be manufactured within a quick span of time?	7.6	7	7	7	6.3	7.4	7	7.1	7.3	6.6

Note: K/PM, proposed model of knob

Table II.
Opinions from Salzer on achieving design agility through CAD

Designation of personnel	Opinion
Question IV	*What is your overall opinion about achieving design agility through CAD?*
Manager – standards and systems	Using CAD reduces the development period to a great extent and it enables the easy production as CAD to CAM transfer is fast and accurate
Deputy manager (works)	Agility plays an important role in product design
Senior engineer – machine shop	CAD is very useful for making design changes and quick developments
Senior engineer – quality control	Design process has been made rapid
Engineer – design	Improvement in design has been achieved

Table III.
Data on performance measures of agility

Serial number	Agility performance measures	Current level (before deploying CAD) (please use Likert's scale of range 0-10)	Future level (after deploying CAD) (please use Likert's scale of range 0-10)
1	Responsiveness	7.2	8.3
2	Competency	7.2	8.7
3	Flexibility	6.8	9.2
4	Quickness	7.3	9.0
5	Re-configurability	7.5	8.7
6	Manufacturing speed	7.2	9.7
7	Information management	7.1	8.3
8	Innovativeness	7.4	9.2
9	Proactivity	7.7	9.1
10	Market competitiveness	7.2	9.2

the questionnaire was reliable enough to gather the feedback data and draw inferences with regard to applying CAD for propelling an organization towards achieving agility.

Managerial implications and roadmap for achieving design agility through CAD

The experiences of conducting the research led to an impression that the practising managers and engineers are yet to prepare themselves to infuse agility in their organizations and professional practices. Hence, more than technological challenges, managerial challenges would dominate the journey of acquiring agility through the deployment of CAD. In this context, the roadmap shown in Figure 6 is suggested for successfully implementing AM through CAD. The steps involved in implementing this roadmap are briefly described here.

As shown in Figure 6, the first step starts by forming a team comprising the representatives from all functions. Then the two dimension drawings under use need to be gathered from the organization. This is followed by the selection of a CAD software based on the management's perspectives and technical requirements. Then, CAD models of the existing components/products are created. Subsequently, brainstorming sessions are conducted by exposing the CAD models of the existing components/models

	N	Mean	Std. deviation	Std. error mean
A	6	8.00	0.894	0.365
B	6	8.17	0.753	0.307
C	6	8.33	0.516	0.211
D	6	7.83	0.753	0.307
E	6	8.17	1.169	0.477
F	6	8.33	0.516	0.211
G	6	7.83	0.983	0.401
H	6	8.00	0.894	0.365
I	6	8.17	0.408	0.167
J	6	7.83	0.753	0.307
K	6	8.50	0.548	0.224

One-sample test

	Test value = 8					
					95% confidence interval of the difference	
	t	df	Sig. (two-tailed)	Mean difference	Lower	Upper
A	0.000	5	1.000	0.00	–0.94	0.94
B	0.542	5	0.611	0.17	–0.62	0.96
C	1.581	5	0.175	0.33	–0.21	0.88
D	–0.542	5	0.611	–0.17	–0.96	0.62
E	0.349	5	0.741	0.17	–1.06	1.39
F	1.581	5	0.175	0.33	–0.21	0.88
G	–0.415	5	0.695	–0.17	–1.20	0.87
H	0.000	5	1.000	0.00	–0.94	0.94
I	1.000	5	0.363	0.17	–0.26	0.60
J	–0.542	5	0.611	–0.17	–0.96	0.62
K	2.236	5	0.076	0.50	–0.07	1.07

Figure 5.
Roadmap for achieving design agility through CAD

to the managers. This is followed by the application of creative ideas for generating the CAD models of the new components/products. Then the management's approval needs to be obtained to select the new components/products for manufacturing.

Instead of attempting for full fledged implementation, one or few AM cells may be created for achieving agility through CAD. Since, a good amount of knowledge is created in research institutes on achieving agility through CAD, such AM cells should be linked to those types of research institutes. After a specified period, the competitive strengths achieved by each AM cell by imbibing CAD practices to acquire agile characteristics shall be assessed. Depending upon those strengths, the future programme on achieving agility through CAD shall be refined and expanded. This will be an unending practice by which the enhancement of competitive strengths is continuously checked.

Conclusion

This paper points out that many of the AM researchers concentrate on the managerial aspects of agility. Hence, in future, the researchers in AM will have to orient their work

Table IV.
Output of the SPSS package pertaining to the α values

	Reliability analysis – scale (α)			
Item-total statistics	Scale mean if item deleted	Scale variance if item deleted	Corrected item total correlation	α if item deleted
A	81.1667	28.5667	0.8786	0.8842
B	81.0000	32.4000	0.5601	0.9031
C	80.8333	33.7667	0.6221	0.9016
D	81.3333	31.0667	0.7309	0.8941
E	81.0000	27.2000	0.7545	0.8960
F	80.8333	32.9667	0.7645	0.8965
G	81.3333	28.2667	0.8162	0.8884
H	81.1667	29.7667	0.7377	0.8934
I	81.0000	35.2000	0.4954	0.9070
J	81.3333	35.8667	0.6435	0.9232
K	80.6667	31.4667	0.9764	0.8875

Notes: Reliability coefficients: n of cases = 6.0; n of items = 11; α = 0.9068

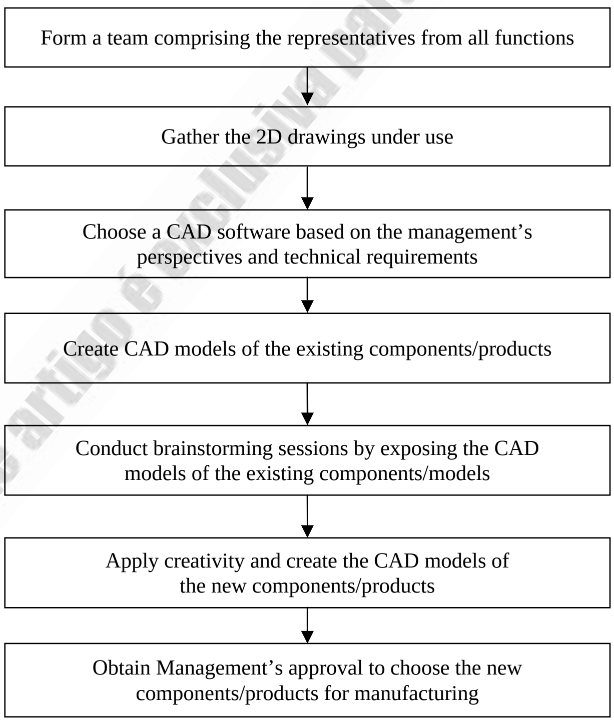

Figure 6.
Roadmap for achieving design agility through CAD

towards the technological aspects of agility. However, this kind of research should be carried out in conjunction with the developments occurring in practical environments. Hence, achieving design agility through CAD will be promising provided close linkage is established among AM researchers and practitioners. This process will enable the major size global companies to enhance their competitive capabilities. By adopting design agility strategies, traditional manufacturing organizations would also be able to compete in the global markets. During the research reported in this paper, this aspect was examined by designing new CAD models of knob of an electronic switch at Salzer. These new CAD models were validated systematically using a questionnaire-based feedback. The response of the executives indicated the practical feasibility of these new knob models. It was estimated that the agility level will improve in case the new ten knob models are manufactured. On the whole, the conduct of the case study at Salzer indicated that there exists avenues for enhancing the agility level of traditional organizations through the design of products and components using CAD technology. However, considering the lack of preparedness of mangers to proceed in the direction of achieving agility, this task has to be accomplished in a tactical manner. In order to accomplish this process, a roadmap for successfully achieving agility through the application of CAD technology has been proposed in this paper.

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