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Computer Aided Green Manufacturing: A Review

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***Abstract*: CAD/CAM technique shows high potential to reduce the cycle and cost of product development. Integrating CAD/CAM systems have been developed and employed to implement remote parts and manufacturing for rapid prototyping. Integrating CAD/CAM systems improve the capability of rapid product development .CAD/CAM technologies for superior product modelling become more and more pertinent in designing complete product variants in future. The evolution of product is one of the key weapons for a competitive advantage. The design and development of the product in small as well as in large-scale industries are managed with CAD/CAM/CAE systems. Also, integrations realized on CAD systems, like Computer Aided Manufacturing (CAM), Computer Aided Process Plan and Product Life Management are explored to products based on eco design. This paper presents a new CAD featured methodology for the selection of a green manufacturing process and CAD/CAM/CAPP/PLM integrations. The key issues for implementing the remote RP&M systems, involve (1) CAD/CAM (2) Modelling and Optimization, (3) Algorithms,(4) anisotropic measurement, (5) STEP/XML. Then the sustainability analysis is carried out for determining the environmental impact. This is followed by the optimization of the components by the use Computer Aided Engineering (CAE).This review paper provides a comprehensive review of previous research on CAD/CAM RP&M systems. It provides outlook on possible future development and research direction for CAD/CAM and R&P systems. Modern design engineers need approaches for creating eco-friendly products.**

***Keywords*: CAD/CAM; CAE, CAPP, Rapid prototyping, STEP/XML, Green manufacturing process / Algorithms**

1. Introduction

CAD/CAM (computer-aided design and computer-aided manufacturing) refers to computer software which is used to both design as well as for manufacture products. CAD uses computer technology for design and documentation. CAD/CAM software is mostly used for machining of prototypes and finished parts [1]. The footstep of the product development system should provide three essentials, viz. modelling of the high reliability products, CAD/CAM/CAE systems integration, and product information management throughout the product life cycle in order to improve the product development processes. The integration ensures that the CAD/CAM/CAE systems across the product development system, should communicate effectively to capture the creative input, identify and resolve the issues when changes are easy to make [2].

R&P is a new forming process which fabricates physical parts in layers under direct control of 3D CAD models in a very short time. The majority of rapid prototyping systems tend to fabricate parts using additive manufacturing process, rather than subtraction or removal of material. Therefore this type of fabrication is unconstrained by the drawbacks attributed to conventional machining approaches [3], [4]. R&P is newly evolving toward rapid tooling (RT). RT is a technique which transforms the RP patterns into functional parts, especially plastic or metal parts. It offers low cost method to produce moulds and functional parts very fast. The integration of RP and RT in product development strategy promotes the implementation of concurrent engineering [5].

2. Steps in product design, development and manufacturing

Product design has critical importance to the production system. It contributes more to the overall design and operation of the production system.

A. Product concept

It consists of basic sketches around our product idea. Such as, what is our product and how our product going to be used.

B. Product design development

Using the information we have gathered from our research we can now develop our product designs.

C. CAD/CAM

Using 3D modelling software (CAD – computer aided design) we will get a computerized 3D model of our final product design. These designs will often highlight problem areas where the theoretical stresses and strains on the product will be analyzed.

D. Prototype testing

This is the point where we may have to go back to the drawing board when we test our prototype. Be critical – will our product function properly.

Table 1
Literature review (Literature of different authors)

S. No.	Author	Title	Year	Methodology used/parameter analysed	Result and conclusion
1.	Gungor and Gupta	Environmentally Conscious Manufacturing and Product Recovery (ECMPRO)	1996	ECMPRO involved integrating environmental thinking into new product development and design, selection of material manufacturing processes and delivery of the product to the consumers	Manufacturing of eco-friendly products is necessary in order to minimize the use of new resources. Elaborate qualitative and quantitative decision tools is necessary For successful implementation of ECM.
2.	Dr. Bert Bras	Incorporating Environmental Issues in Product Design and Realization	1997	approaches to reduce the environmental impact of products	Recollection of current state and capabilities and target level for integrating environmental issues in product design and consciousness.
3.	Madu *et al*	hierarchical framework for environmentally conscious design	2002	used the analytic hierarchy process (AHP) to develop priority indices for customer requirements development of cost-effective design	It reduces the ecological impact of industrial activity without affecting quality, cost, performance and efficiency.
4.	Maxwel and Vorst	Sustainable Innovation in Product and Service Development (SPSD)	2003	used to identify, assess and implement the options for optimum sustainability in the design and development of a product and/or service	Reduced volume of raw materials reduced waste generation improved product Improved supplier relationships.
5.	Kaebernick *et al.*	sustainable product development	2003	presented the integration of environmental requirements into every single stage of product development from the very beginning, leading to a new paradigm for sustainable manufacturing	Decrease the environmental impact and avoid costs performance, cost and improve the quality.
6.	Masui *et al.*	Quality Function Deployment of Environment (QFDE	2003	incorporates the environmental aspects into QFD to handle both traditional and environmental quality requirements	Increases the efficiency and effectiveness of the application
7.	Yucheng Ding	An integrated manufacturing system for rapid tooling based on rapid prototyping	2004	Robotics and Computer-Integrated Manufacturing	Creates automated manufacturing processes, faster manufacturing
8.	Carlo H. Se´quin	CAD tools for aesthetic engineering	2005	Computer-Aided Design	Decrease in error percentage, save time, easy to edit
9.	Bevilacqua *et al*	Integration of Design for Environmental Concepts in Product Life Cycle	2007	LCA techniques for the successful implementation of a p product development in context of environmental sustainability	continuously reducing the overall environmental impact of products during their life cycle
10.	Bovea and Wang	novel redesign approach for integrating environmental requirements into product development	2007	identification of environmental improvement options and the study of the effect that the incorporation of these options has over other traditional product requirements	enhance customer satisfaction Designing environmentally friendly product.
11.	Rusinko	specific environmentally sustainable manufacturing practices	2007	the need to focus on environmentally sustainable practices and outcomes in other under-researched manufacturing and service industries	Lowers the manufacturing cost Increased product quality pollution prevention
12.	M. Oudjene	Finite Elements in Analysis and Design	2007	FE analysis of rapid prototyping tools for sheet metal stamping process	Virtual testing, analysis without any prototype
13.	Gehin *et al.*	End of Life (EoL) to assess product	2008	Profitable for an enterprise given the business model in place. design aids which permits designers to compare their products to ‘‘Remanufacturable Product Profiles’’	Enable the designers to evaluate the product’s environmental impact, prospective potential for reuse of product

E. Manufacturing

Once we are happy with your product prototype we can then manufacture our product. The cost of manufacturing depends on complexity of our product, like, multiple components, low batch product or high batch numbers. These factors should be considered to ensure we will make a healthy profit on our end product.

F. Assembly

The assembly of our product is vital – if we use a glue which will degenerate quickly we will not sell many products. It is recommended that our product should have minimum number of joins; this will reduce manufacturing costs.

G. Feedback and testing

Testing of our final product is very essential. It is very important to collect the feedback information we get back from other people.

H. Development of product

Whenever testing and feedback have highlight areas of improvement, thereafter we need to revisit the product development.

I. Final product

We have now our finished final product so we have to focus on marketing, campaign and how we should sell our products [6].

3. Product development & manufacture CAD/ CAM

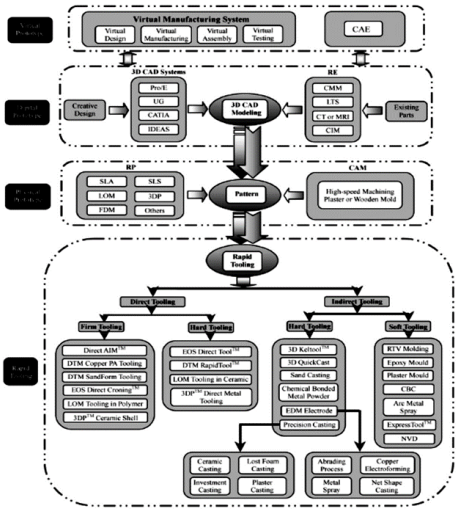

Fig. 1. Architecture of the RT integrated manufacturing system.

Developments in computers & the software relating to CAD/CAM has made it an indispensable enabling technology for time compression in product development. RP is newly evolving toward rapid tooling (RT). RT is a technique that transforms the RP patterns into functional parts. The RT methods are generally divided into two types; direct and indirect tooling, and also soft and hard tooling subgroups. Indirect RT requires a kind of master patterns, which can be made by conventional methods (e.g. High-speed Machining, HSM .Direct RT involves manufacturing a tool cavity directly on the RP system [7].Such as in plastic injection moulds we have to consider all needs with high difficulty as in case of die casting and sheet metal forming as well as forging dies. [8][9].Those applications increase the requirements on thermal, mechanical load & tool wear [10], [11]. Fig. 1 shows a flowchart for development and manufacturing process for an integrated based RT system [12].

4. Key issues in the development of product

In the development of various types of CAD, RPM systems, various issues have been discussed. The integration of the CAD/CAM means that the companies should be able to design anywhere, build and maintain anywhere at any time. Based on the result of current research for CAD and RP&M systems, the main key issues can be divided into following six categories:

A. CAD/CAM/CAE

STL, is most widely adopted data standard in the RPT industry. It is an approximation representation scheme for product models. It is based upon triangles or quadrilaterals. However, there can also be some intrinsic problems in STL files like, gaps, holes, overlapping facets, etc. during the conversion process from native CAD files [13]-[17].

B. Modelling and optimization

The modelling module allows the interaction of the designer with the VR model to manipulate the viewing perspective and geometry of part. This helps the designer to view the model by navigation around it and also changing the condition of lighting, shading and rendering [18]-[23].

C. Measurement of anisotropic compressive strength

In order to make the compression test specimens, for FDM the ABS material, azp102 material for the 3D printers, & an acrylic-hydroxyapatite composite for NCDS. Compression specimen's dimensions to be test are according to ASTM D695.hence in compression test, build direction was the only process parameter to be examined i.e. "axial" (horizontal) and "transverse"(vertical)[24], [25].

D. Algorithm

A slicing algorithm has been used for the representation of boundary contours of each layer which has to be sliced as a curve showing closed NURBS which maintains the original product's representation accuracy. A mixed tool-path algorithm can be used for generation of contours & zigzag tool-paths to fulfil both the geometrical as well as build efficiency requirements. The tool – paths of contour are used for fabrication area along the boundary of each layer to be sliced for improvement in geometrical quality of a product model.

E. Applying new technologies & concept of rapid prototyping systems

Rapid prototyping has variety of techniques which can be used for quick fabrication scale model of a physical part or assembly using 3-dimensional computer aided design (CAD) data. Construction of the part or assembly is usually done using 3D printing (3DP).Ballistic particle manufacturing (BPM), Fused deposition modelling (FDM),Laminated object manufacturing (LOM),Solid ground curing (SGC).Stereo lithography (STL),Selective laser sintering (SLS)etc. The Nano composite deposition system (NCDS) uses polymer resins as matrix and various nanoparticles, which will form composite materials, and consists of deposition mechanism and material removal process of "mechanical micromachining"

5. Conclusion

CAD/CAM and Rapid prototyping have the potential to further improvement of the traditional manufacturing system and service. Also they have become more and more important for current manufacturing industry. This paper presented the present methodologies which are being used and the future oriented methodologies which will be preferred. CAD/CAM and CIM users as well designers have been asked to rate several smart CAD/CAM technologies in respect to designing, developing & also manufacturing. The construction of a CAD / CAM integrated system provides a direct connection between the design & manufacturing processes. CAD services technique provides a solution for this issue. Some new technologies & concepts like, STEP, XML; provides effective enabling tools for software-based application systems.

6. Future scope

Future research and development on CAD-based RP&M systems are based on these new technologies and concepts, in particular 3Dprinting, NCDS. This technology is used, in generating scenarios in CAPP and for the choice of greenest ones in terms of environmental impacts. Our proposed approach, also, explores feature technology to evaluate possible manufacturing processes of an ecofriendly product from the geometric modelling phase by an LCA tool in real time. CAD-based RPM system has shown a promising prospect for manufacturing. However, there a long way for really commercial use of the CAD-based RP&M systems.

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