Knowledge Based Engineering Approach Combination with Computer Aided Designing

Ravinder Kumar, Sunil Kumar and Dr. Gulshan Chauhan

***Abstract*— The widening, intensifying, speeding up, and growing impact of worldwide interconnectedness, better known as globalization is forcing most industries to put their efforts to implement newer strategies to get desired profit and to retain the market leadership. Globalization has changed the nature, organization, and location of engineering work in the automotive and aerospace industries. Today's manufacturing industry is experiencing an increased competitive environment due to the effects of market globalization. As product and manufacturing technologies become more common and widespread, the competitive advantage for many companies shifts to knowledge about using those technologies. Engineering knowledge thus is an asset that needs to be captured, stored and managed, which provides strategic long-term benefits. In parallel, IT tools for storing and executing different kinds of knowledge, such as expert systems for diagnosis or rule-based systems for mechanical design have been developed and are more usable and accessible today. In the field of engineering, rule-based applications are available in many IT tools for computer-aided design (CAD), computer-aided engineering (CAE) and so on. In this paper the focus is on how KBE, both as an IT application and as a method, is integrated with the product development process.**

***Keywords*— Knowledge based engineering, Computer Aided Design, Design Automation.**

I. Introduction

KBE represents a merging of object-oriented programming, artificial intelligence, and computer aided design. KBE systems aim to capture product and process information to allow businesses to model engineering processes, and then use the model to automate all or part of the process. Many CAD systems provide "design automation" capabilities. These systems typically allow parts, assemblies, and drawings to be parametrically varied. However, capabilities for extensive changes to the product configuration are often restricted, and the ability to embed rules is limited to simple logical statements. KBE systems provide far more power and flexibility in the development of design automation systems. These systems are designed to allow complex rules, heuristics, artificial intelligence, and agents to be embedded in the system. In addition, some KBE systems provide more direct control over geometry and topology as well as more advanced geometry introspection capabilities. KBE systems leverage reuse of corporate design knowledge to the maximum extent possible, eliminating mundane tasks within the complex process of transforming a product concept into production-ready details. The ultimate goal of a KBE system should be to capture the best design practices and engineering expertise into a corporate knowledge base. The application of knowledge based engineering includes design (CAD), analysis (FEA), simulation (CAS), optimization, manufacturing, and support (CAPP) where CAD is the foundation for the rest of the cycle. *Using KBE as a method for automated engineering design reduces design and drafting time from weeks to hours.*

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II. Research Methodology

The engineering design process is a formulation of a plan or scheme to assist an engineer in creating a product. The engineering design is defined as component, or process to meet desired needs. It is a decision making process (often iterative) in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation. The engineering design process is a multi-step process including the research, conceptualization, feasibility assessment, establishing design requirements, preliminary design, detailed design, production planning and tool design, and finally production. Design methodologies accomplish that task. While many models have been proposed for the design process, the one used attempts to incorporate current technology and tools available for design, Fig.1. The process shown consists of six steps starting with `Problem Definition' and ending with `Prototyping.

Traditional design departmentalized as the engineers would develop the product design and any working and detail drawings associated within the conceptual design [2]. The design is then passed to other departments within the organization (manufacturing for process and material selection, marketing, purchasing, etc.). The design may then be sent back to the design team for rework and revision. The traditional design process tends to be exceedingly tedious and resource inefficient. This tedious and inefficient nature can lead to increased lead time and loss of profit. The following figure shows the product life cycle of a typical product.

As you can see from Figure 3, design and develop account for most of a production life cycle. This wastes time and resources, which calls for a more efficient way of designing a production. Knowledge based engineering is an alternative. In short, the objective of knowledge based engineering is to maximize the resource utilization.

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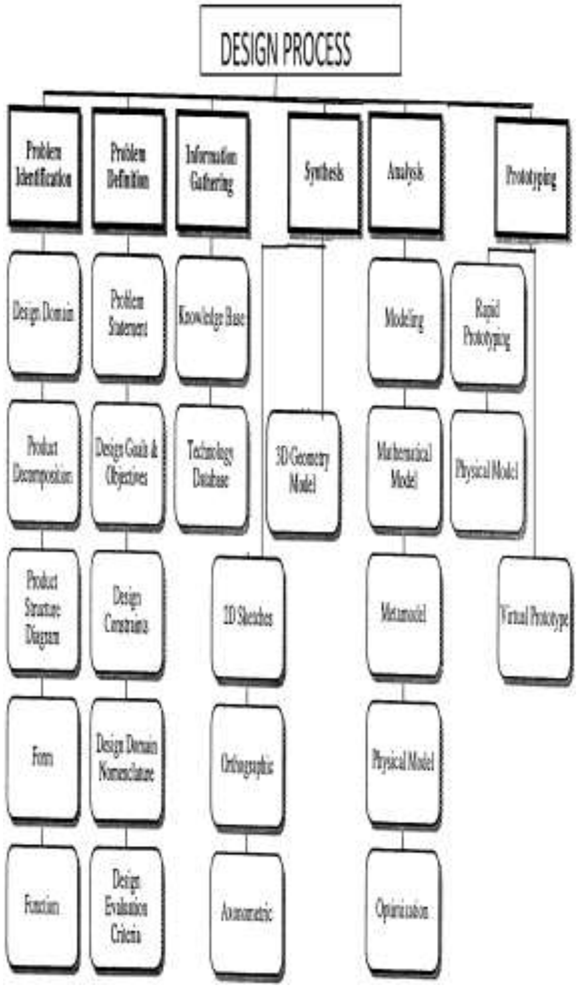

Fig.1: Design process

III. Knowledge Based Engineering

KBE can be defined as: The use of advanced software techniques to capture and re-use product and process knowledge in an integrated way [17]. KBE system has shown by fig. 2. An emerging design technology known as knowledge-based engineering (KBE) is the next step beyond CAD for product representation. KBE allows a true generative virtual prototype to be developed that represents both the geometric and the non-geometric characteristics of a product. KBE is the methodology for capturing and structuring knowledge about a design and its design process. KBE may be used to define engineering methods and procedures [10]. In KBE, the product structure tree (topology) is dynamic, so that KBE offers true engineering automation including application development, geometric modeling, application deployment and tools integration. Knowledge- based engineering is a programming tool used to develop a virtual prototype or a design advisor for the design of an established product in a given design domain. Dym, et al. [15] and Gonzalez, et al. [16] provide valuable overviews of KBE.

KBE is defined as "the process of combining engineering knowledge, methodologies, rules and best practices with process knowledge and best practice to create product models that describes how product designs are created or engineering analyses are undertaken" [3]. KBE combines past design knowledge and practices with rules of design. KBE has origins in CAD. However, CAD differs from KBE because CAD personifies the "what" of a product design [4]. The "what" of a design includes product dimensions, geometric and surface contour, product materials, etc. KBE, on the other hand, personifies the "how" and "why" of a design [4]. The "how" of a design consists of manufacturing systems and processes involved with product conception and production. The "why" of a production model captures the engineering rules, governmental/corporation regulations, etc. of a design. KBE has roots in the aerospace engineering and automotive design industries. Engineers can input their past design experiences, engineering rules, rules of thumb, and corporate and governmental regulations in the form of logical constraints. These inputs are normally referred to as domain knowledge [7]. KBE helps to maintain the reuse of corporate knowledge and design experience [5]. Any reused design knowledge can lead to adaptive or variant design depending on the context [6]. This knowledge recycling leads to similar designs that can perform related functions. Similar designs can be created by applying new ideas and constraints to a single base model [1]. Applying knowledge and reasoning to design can eliminate rework and repetitive tasks [4].

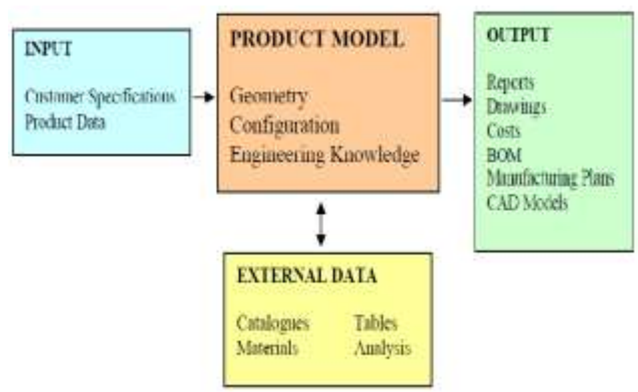

Fig. 2: KBE SYSTEM

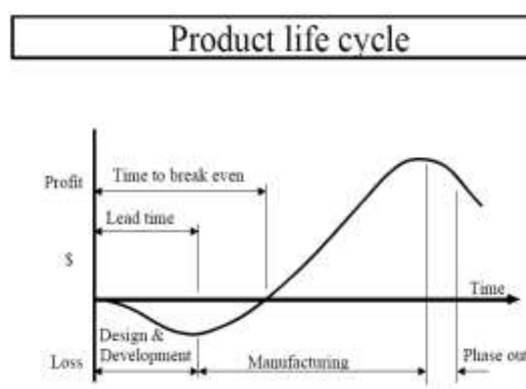

Fig. 3: The Traditional Product Life Cycle

A knowledge-based system (KBS) is the one that captures the expertise of individuals within a particular field (the “domain"), and incorporates it and makes it available within a computerized application. The level of complexity of the tasks performed by such a system can vary greatly. However, it can generally be said that while a domain expert would find them routine, they would be outside the capabilities of a person unfamiliar with the domain.

The following example of a typical KBE application demonstrates some of the considerable benefits to be gained from its use: a “black box" application for the design of a class of products can be built, which as well as having CAD capabilities, can incorporate engineering knowledge, such as that relating to material properties, permitted stress levels, manufacturing feasibility, manufacturing and material costs, and so on. The designer is then able to exercise his creativity in designing the product, within the constraints imposed by the embedded knowledge. This will prevent his design from being rejected on the grounds that the product cannot be manufactured, or because it is too expensive to manufacture, or because it does not have the required physical properties. The main advantage of the KBE approach, however, is the compression of lead times through the automation of repetitive procedures. Key employees are then freed to concentrate on more creative and cost-effective activities. Moreover, KBE applications are not limited to the design area, and include product configurators for use as sales aids, and costing software to provide estimates and quotations based on company-wide knowledge.

Major companies already realising significant benefits from the use of KBE include the following:

A. *Lotus engineering*

This used the integrated car engineer (ICE) system in the design of the Lotus Elise. ICE consists of a vehicle layout system, and modules to support the design of suspension, engines, power train, wheel envelope and wipers.

B. *The Boeing Commercial Airplane Group*

This uses KBE as a tool to capture airplane knowledge to reduce the resources required for producing a design.

C. *Jaguar cars*

The Company’s KBE group devised a system that reduced the time taken to design an inner bonnet from 8 weeks to 20 min.

Many points of views on KBE can be found in the literature. Infosys views KBE as an engineering product development technology wherein the knowledge of the engineering product and its design process is captured and embedded into a software system and is used in the design and development of similar new products.

KBE helps in realizing substantial tangible and intangible benefits. The product development effort can be reduced by 20-30% in the first iteration and 40-50% in the subsequent iterations. KBE helps in automating the routine activities and increases the bandwidth available for creative activities.

Some of the tangible benefits of KBE include:

• Reduced product development cycle time
• Improved productivity
• Improved quality of the product
• Improved product performance with optimum weight.

Some of the intangible benefits of KBE include:

• Helps in realizing consistent products
• Ensures engineering knowledge capture and reuse
• Makes available more time for creative activities
• Helps in training the new team members and improves competency development
• Helps in implementation of concurrent engineering concepts

KBE has been implemented by many airframe and engine manufacturers realizing rich dividends. Infosys has successfully implemented KBE in all stages of aircraft product development. Many KBE applications have been developed. Some of these are large applications deployed for design and development of major components like floor beams. KBE has been successfully utilized to realize similar benefits in automotive and heavy engineering industries. Infosys believes that Retail and CPG industries can realize similar benefits through KBE as discussed in the subsequent sections.

IV. Advantages And Disadvantages Of A Typical Knowledge Based System

A. *Advantages*

1. Reduces time to market and lead time
2. Cuts production costs
3. Automates repetitive tasks
4. Allows for the reuse of critical knowledge and designs
5. Allows real-time design sharing using WWW, html, and hyperlinking protocols [1]
6. Suitable for analysis and simulation processes [9]
7. Reduces overhead costs [4]
8. Costs and time use can be reduced by 90% [6]
9. Compliments traditional CAx systems

B. *Disadvantages*

1. Costly to implement
2. Initially requires large quantities of time to compile design knowledge
3. May only be justified if a problem is faced many times [10]

V. KBE Tools

There are a variety of software tools available for KBE tool development. Included are ICADTM, TKSolverTM, Design LinkTM, ProEngineerTM, STONEruleTM and Smart ElementsTM. All of these are integrated with at least one of the contemporary CAD systems to provide a contemporary integrated design system. Unigraphics, CATIATM, Pro-EngineerTM, IDEASTM and Auto-CADTM are some of the options. These software tools are used to develop domain-specific design tools of the two KBE approaches, design advisor and the virtual prototype. [4].

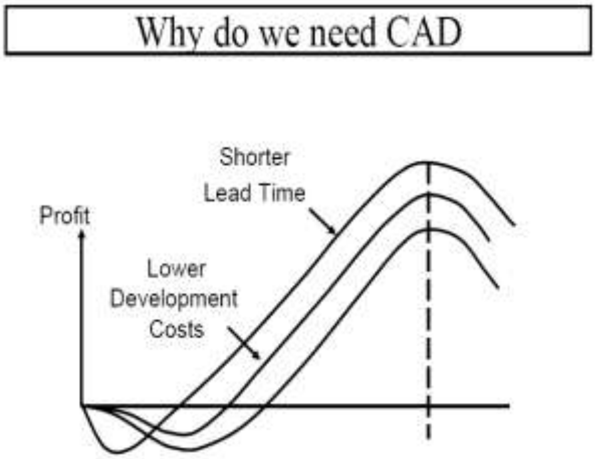

Fig.4: Product Life Cycle When CAD Is In Use

VI. Computer Aided Design

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD) is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software provides the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. CADD software uses either vector based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. CAD is an acronym for Computer Aided Design and uses something known as TTUA. IT is the use of a broad range of tools that are intended to assist architects, engineers as well as design professionals in their professional activities. CAD is the fundamental geometry authoring tool in the PLM process also known as Product Lifecycle Management [5]. It involves software as well as in some case, special hardware. A CAD model is generally the first geometry based input into a KBE system.

CAD can be combined with a knowledge based approach by utilizing a database of standardized parts. These standardized parts can be ANSI, ISO, DIN, or Parker fasteners and bearing. Accepted standard corporate designs may also be utilized in a part database. These accepted standard parts and designs can serve as class operators in an object- oriented environment. Changes made to the class object inside a CAD environment would result in an instance of the class. This process helps to cut down time to redesign or redraw any standardized designs.

CAD is used for the accurate creation of photo simulations that are often required in the preparation of Environmental Impact Reports, in which computer-aided designs of intended buildings are superimposed into photographs of existing environments to represent what that locale will be like were the proposed facilities allowed to be built. CAD is an extremely robust and accurate tool for designers although it is also used as a drafting tool. CAD provides a simple time-saving tool along with clean methods for the study of the design process and consequently come up with a near perfect design.

VII. Uses Of CAD

Computer-aided design is one of the many tools used by engineers and designers and is used in many ways depending on the profession of the user and the type of software in question.

CAD is one part of the whole Digital Product Development (DPD) activity within the Product Lifecycle Management (PLM) processes, and as such is used together with other tools, which are either integrated modules or stand-alone products, such as: Computer-aided engineering (CAE) and Finite element analysis (FEA), Computer-aided manufacturing (CAM) including instructions to Computer Numerical Control (CNC) machines, Photo realistic rendering, Document management and revision control using Product Data Management (PDM).

CAD is also used for the accurate creation of photo simulations that are often required in the preparation of Environmental Impact Reports, in which computer-aided designs of intended buildings are superimposed into photographs of existing environments to represent what that locale will be like were the proposed facilities allowed to be built. Potential blockage of view corridors and shadow studies are also frequently analyzed through the use of CAD.

CAD has also been proven to be useful to engineers as well. Using four properties which are history, features, parameterization, and high level constraints (Zhang). The construction history can be used to look back into the model's personal features and work on the single area rather than the whole model (zhang). Parameters and constraints can be used to determine the size, shape, and the different modeling elements. The features in the CAD system can be used for the variety of tools for measurement such as tensile strength, yield strength, also its stress and strain and how the element gets affected in certain temperatures.

CAD is used in the design of tools and machinery and in the drafting and design of all types of buildings, from small residential types (houses) to the largest commercial and industrial structures (hospitals and factories) [12]. CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products. It can also be used to design objects.

VIII. Types Of CAD

There are several different types of CAD, [14] each requiring the operator to think differently about how to use them and design their virtual components in a different manner for each.

3D wireframe is basically an extension of 2D drafting (not often used today). Each line has to be manually inserted into the drawing.. The operator approaches these in a similar fashion to the 2D systems, although many 3D systems allow using the wireframe model to make the final engineering drawing views.

3D "dumb" solids are created in a way analogous to manipulations of real world objects (not often used today). Basic three-dimensional geometric forms (prisms, cylinders, spheres, and so on) have solid volumes added or subtracted from them, as if assembling or cutting real-world objects.. Basic 3D solids don't usually include tools to easily allow motion of components, set limits to their motion, or identify interference between components.

3D parametric solid modeling requires the operator to use what is referred to as "design intent". The objects and features created are adjustable. Any future modifications will be simple, difficult, or nearly impossible, depending on how the original part was created. One must think of this as being a "perfect world" representation of the component. If a feature was intended to be located from the center of the part, the operator needs to locate it from the center of the model, not, perhaps, from a more convenient edge or an arbitrary point, as he could when using "dumb" solids.

IX. CAD Plus KBE Implementation Approach

One of the most powerful and useful combinations of a CAD-KBE approach is the ability to export a CAD geometry to other CAx packages including CAS, CAPP, and FEA applications. A KBE system can be used to automate the repetitive simplifications of CAD geometry. The simplification makes the geometry suitable for other CAx systems [10]. Creating a mesh suitable for an FEA and CAS system can make up 80% of design analysis cost [10]. A contemporary knowledge based CAD system can perform automated mesh generation by supporting level 2 automation [4]. CAD packages can automatically convert geometry from its native format to formats suitable for FEA, CAS, CIM, and CAPP. Once converted, the CAD model can be used in the other CAx packages to obtain critical engineering and manufacturing knowledge. As discussed earlier, engineering knowledge can be obtained from the FEA and CAS packages.

Manufacturing knowledge can be directly obtained from CAPP. There are two types of CAPP: retrieval CAPP and generative CAPP [10]. Retrieval CAPP stores past data into families. When new data is entered, retrieval CAPP searches its family database to find similar data [10]. The related data is then output to the user. The other type of CAPP is generative CAPP. Generative CAPP searches its database to find similar instances and then uses manufacturing knowledge and rules to develop new manufacturing plans.

When CAD and KBE tools are utilized together, an effective design can be produced. The steps to utilizing both KBE and CAD effectively are stated in Figure 5.

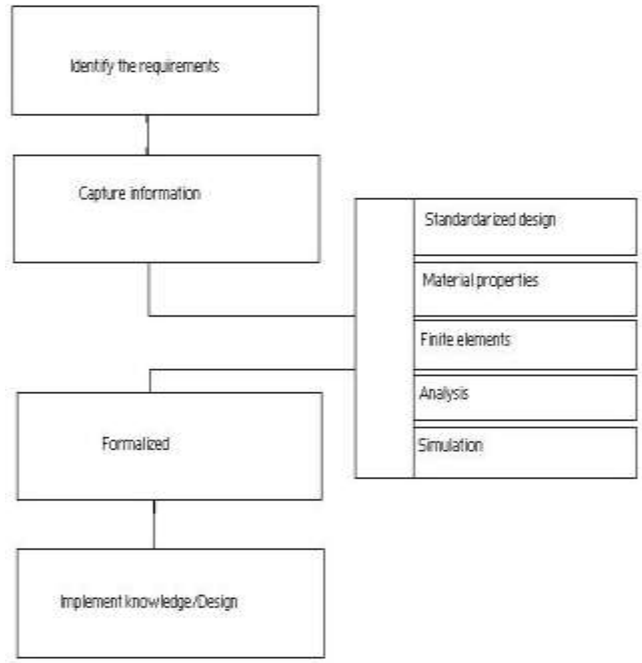

Fig.5 KBE and CAD Relation

X. Conclusion

In today's competitive and global market, new manufacturing and engineering techniques are being developed. One such technique is KBE. KBE allows firms to retain valuable engineering and design knowledge. This knowledge can then be used to automate the design process, leaving time for creative design thinking. Using the combination of KBE and automated CAD, compared to the traditional design process, cuts down on design time. The time that was saved was used to market the product and to get the product to market faster. The time saved was also used for developing new products KBE can then be used along with CAD to create a generative design environment, creating a foundation for other engineering processes. KBE techniques are especially useful in plastic design where molding techniques can be applied to the design. This technique allows for more time to be used in other aspects of production such as manufacturing. The time to market for the product is also greatly reduced.

XI. Abbreviations

KBE - Knowledge Based Engineering
CAD - Computer Aided Designing
CAE - Computer Aided Engineering
CAx - Computer Aided Technologies
FEA - Finite Element Analysis
CAS - Computer Aided Simulation
CIM - Computer Integrated Manufacturing
PLM - Product Lifecycle Management
CNC - Computer Numerical Control
DPD – Digital Product Development

XII. ACKNOWLEDGMENT

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