# Knowledge Based Engineering and It's Application in Engineering: A Review

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*Abstract*— Purpose: The use of Engineering tools and integrated systems prior to actual prototyping of end product is essential to reduce overall cost component. In democratic countries like India, a new kind of system will certainly help to directly enhance the abilities of fresher graduates. It is a dire need of today's India to come up with knowledge based Engineering system which will be a platform to have a systematic and convergent way to get a new design of product at hand. The intent of this paper to summarize & exhibit important aspects of Knowledge Based Engineering (KBE) in with respect to benefits, criteria and application in Engineering.

Design/Methodology/Approach: The review of Knowledge based Engineering is based on 64 papers selected based upon the methodologies adopted for modelling and implementation of interface in the field of engineering published from 1989 to till date in academic databases namely Science Direct, Emerald, Taylor & Francis Journals and articles published in international conference proceedings, and some of the paid journal articles, etc. with 'Knowledge Based Engineering' and 'Module Based Learning' as keywords.

Finding: Through the literature review, this paper brings up the analysis of aforementioned aspect of methodologies adopted in implementation of KBE system in engineering and benefits received by optimizing the work time, cost and improving the efficiency of change in engineering process.

Research Limitations/implications: The literature on practical difficulties for implementation of KBE system and tradeoff between benefits and risk associated with KBE are seldom available.

Originality/Value: This paper presents a literature review on three crucial aspects namely benefits, applications to various fields, methods of implementation in Knowledge Based Engineering. These are identified according to their level of importance. The main contribution of this paper is to draw together three above mentioned important aspects of Knowledge Based Engineering.

***Keywords:*** Knowledge Based Engineering, Module Based Learning, Web Based Design

## I. INTRODUCTION

In today's increasingly competitive and demanding market era, organizations believe on concept of mass customization i.e. the production of goods to meet individual customer's need with near mass production efficiency. Basically main focus is to curtail the production time and cost so as to survive in competing and demanding market. This has to be done keeping customer satisfaction in mind. According to [Reddy, E., J., et.al, 2015] manufacturing sector is transforming to mass customization to satisfy the needs of customer in turbulent markets by adopting web based design tools. To achieve this a defined methodology is very much essential which will help to design and develop product rapidly and produce a large number of product variants. The proposed article will summarizes the concept of Knowledge Based Engineering (KBE) applicable to engineering field facilitating mass customization which is based on storing data of past experience, geometry and data that related to assembly. According to [Verhagen, Wim J., C., et.al, 2012] Knowledge Based Engineering (KBE) is a research field that studies methodologies and technologies for capture and re-use of product and process engineering knowledge. Also according to [Rocca, G., 2012] Knowledge based engineering (KBE) stands at the cross point of diverse fundamental disciplines, such as artificial intelligence (AI), computer aided design (CAD) and computer programming.

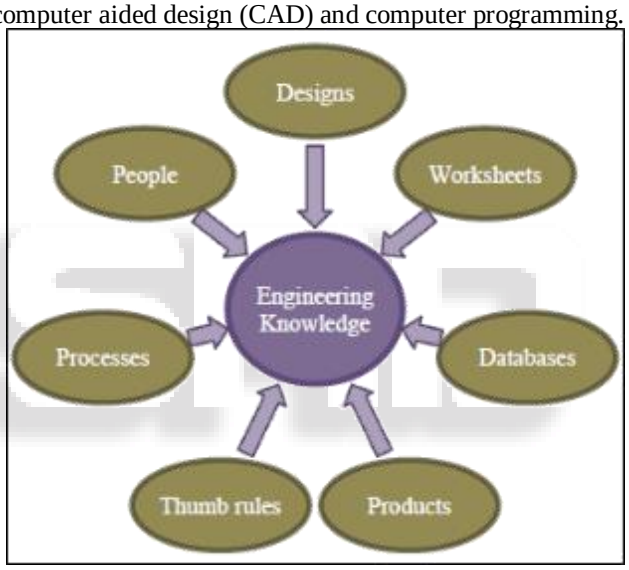


Fig. 1: Various forms of engineering Knowledge [Reddy, E., J., et.al, 2015]

After theoretical treatment given to design parameters, development of CAD model and manufacturing drawing require skilled hands and hours. Also, to overcome such uneconomical practices w.r.t 5 M's – men, money, machine, material and managerial, standardization by incorporating complete or partial automation of the processes is essential. Design automation is the process of automating conventional manual design process with the help of interactive interface or by extracting knowledge from knowledge pool. This knowledge can be worksheets, databases, thumb rules, standard design procedure, manuals, charts, etc. As per need knowledge can be extracted from the knowledge pool and can be reused. Thus, a systematic framework through knowledge management perspective will help to provide support and appropriate automation of repetitive and routine design tasks with integrating sources of expertise for performing multidisciplinary tasks. The primary aim of this article is to identify, justify and capture the various methodologies adopted in engineering problems, benefits received from the same. Thus, the use of such web

 

based Engineering tools and integrated systems prior to actual prototyping of end product is essential to reduce overall cost component.

According to [Gilmore, M.L., 1989] the knowledge base can be divided into two parts, one focusing on the factual knowledge and one in the form of heuristics gathered from the domain specialist.

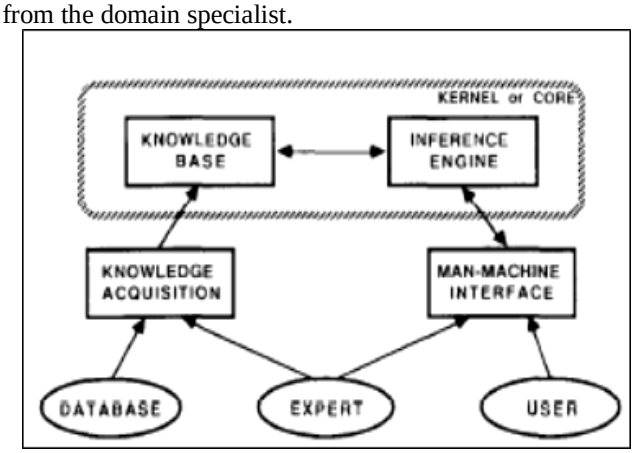


Fig. 2: Components and interactions of a typical knowledge-based system [Gilmore, M.L., 1989]

[Sandberg, M., et.al, 2017] says that consideration of multiple engineering disciplines and quantifications of trade off among confliction tradeoffs essential mandate for successful product development. Also concurrent design and analysis models helps for development of knowledge based approach. [Qin, H., et.al, 2017] emphasizes on reuse of designers knowledge subject to domain in enhancing efficacy for evolution of future project.

At present there is little consensus on what constitutes the theoretical foundations of the research field. Given this state of affairs, this article is an effort to collect and review existing literature on KBE, with the main objectives of identifying the benefits, adopted methodologies and application of KBE in Engineering field. A critical review of 64 suitable research papers has been performed in order to achieve these objectives. This detailed literature review will be discussed in more detail in subsequent sections which is divided in to 3 components namely benefits and applications and methodologies and discussed in the form of occurrence listing of KBE benefits and KBE methodologies. Conclusions are drawn at last form the observed findings.

## II. Methodology

The methodology for the review is depicted in Fig.3. The objective of this review is to exhibit and summarize methodologies adopted for modelling and implementation of interface in the field of engineering and benefits obtained from the same. The articles that had been published on KBE between time frame of 1989 to till date are selected because such articles are in accordance with the focus of this literature review. Selected articles are published in the academic databases namely Science Direct, Emerald, Taylor & Francis Journals and articles published in international conference proceedings, and some of the paid journal articles. The keywords used for this search are Knowledge Based Engineering' and 'Module Based Learning'.

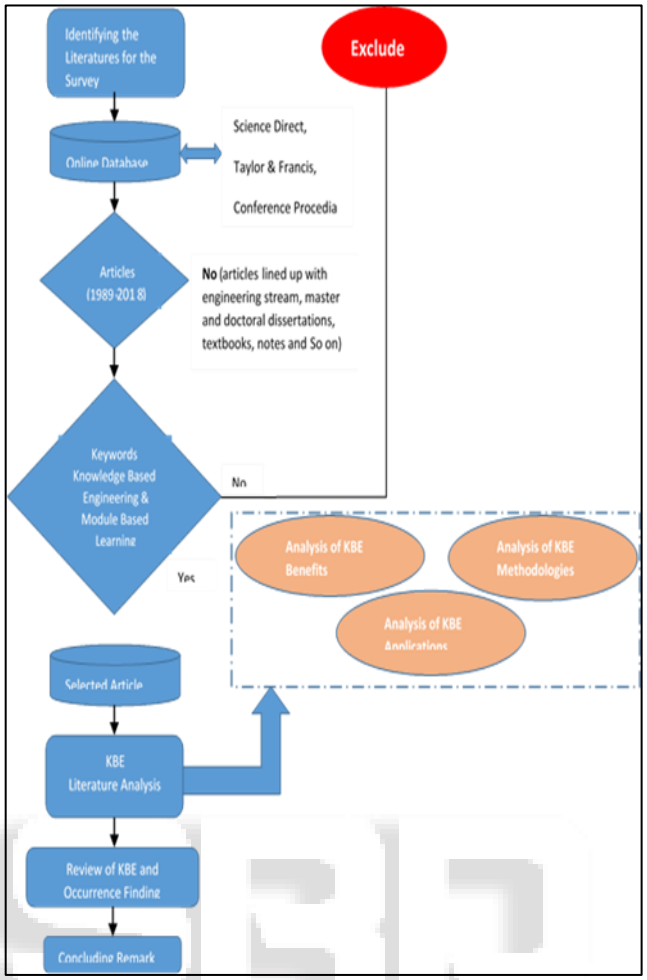


Fig. 3: Methodology adopted for Literature Review

Based on above mentioned conditions, 64 articles are collected from 1989 to till date (Table I) related to modelling and implementation of interface in the field of engineering. These articles are categorized into three categories namely: KBE benefits, KBE Methodologies and KBE Applications. Every article is reviewed and selected according to the predetermined design of analysis.

## III. Categorical Analysis

The review of KBE and its aspects in regards to application in the field of engineering, automation is based on 64 papers published from 1989 to till in academic databases namely Science Direct, Emerald, Taylor & Francis Journals and articles published in international conference proceedings, and some of the paid journal articles with "Knowledge Based Engineering" and "Module Based Learning" as keywords. The literature is based on integrating affective design, engineering, and marketing for defining design specifications of new products, survey of knowledge sourcing in the context of engineering design, etc. The categorical analysis shown in Table. I clarifies that organization started work on effective knowledge management. Basically the concept of knowledge management evolves from World War II, when it was observed that concept of knowledge management was beginning to appear as making of second airplane saved

 

time as well as reduced the percentage of defects as the process was well understood. Similarly Knowledge Management is about identifying, capturing and representing of experiences and insights gained by individuals and spreading it in to others in the organization to manage process better. With setting up some professional practices by knowledge management, we can see improvement in the capabilities of the organization's human resources and enhance their ability to share what they know.

*A. KBE Benefits*

Various literatures indicated that industry practitioners and academic experts agreed for excellence in KBE activities results excellence in optimizing the work time, reduction in operating cost and improving the efficiency of engineering change (EC) process. Gilmore, M.L. (1989) summarizes the use of KBE in construction and civil engineering leads to increase in the ability to interact directly with the software, Real-time response of the system to changes, ease of Documentation of changes to the plan, and optional documentation provided for each activity. The framework presented by Vosniakos, G.C. (1992) for interpretation of annotation-entity information in wireframe drawings enhanced to solid-like models which helped for relating annotation entities meaning to geometry primitives which is a piece of information that current CAD systems do not provide. Changchien, S. W., et.al (1996) applied KBE in the field of Concurrent Engineering which results in to better product design along with increase in product quality and reduce product development time and cost as well. Chapman, C.B., et.al (1999) applies KBE to reduce Costs, manufacturing and process time with increase in functionality and product life cycle by providing uniform solution through captured knowledge. Use of KBE facilitates to ensure the practicability of the finished product is proposed by Lovett. P.J., et.al (2000). Whereas Chung. Jack C.H., et.al (2000) proposes a design automation which helps in increasing performance and robustness of design along with constraint comprehension and manipulation towards development of downstream analyses.

The KBE is a very appropriate tool in material selection process by inclusion of material databases Sapuan, S.M. (2001). In the field of manufacturing researchers like Dwivedia, S.N., et.al (2003) found out that diagnosis and identification defects involved in component can easily be identified using KBE as it facilitates adaptability to new rules and situations without disturbing the entire system whereas Kong, L., et.al (2003) feels KBE is advantageous as it provides interactive computer-aided design environment, which can both speed up the mold design process and facilitate standardization. Chu, Chih-Hsing., et.al (2005) states that knowledge based system provides an effective approach to reducing the time yet improving the quality of tire mold development. Lin, Bor-Tsuen., et.al (2008) states that use of expert system saves a great deal of development time and cost and achieves high product quality and design flexibility. Yu, Y. (2010) states that expert system significantly improved the efficiency of product design and shorten the design cycle, reducing duplication of effort for lubrication recycling station. Freiberg, M., et.al (2012) clarifies that the use of system is adaptable and modifiable for switching between alternative designs and ideas could be evaluated in a straightforward, efficient manner which accelerates development while reducing implementation efforts. Also it further leads to robust operation, production systems have to be flexible enough to mitigate the effects of unanticipated disruptions mentioned by Legat, C. (2012). Rocca, G. (2012) states that KBE gives platform to generative design which increase the level of automation in the engineering design process, to capture and record the design intent, and to facilitate design tools integration.

In recent years researchers like Kwong,C.,K.,et.al (2015) justifies the increase in dynamic capabilities like attractiveness, quality, functionality, and user-friendliness of the design models which leads to reduction of operating cost in concern with demanding market. And Zhao,X., et.al (2015) comments that this comprehensive method automating the cost integration in the design process to improve the fidelity, repeatability and traceability of cost analysis. Chavalia,S.R., et.al (2015) concludes that this approach provides good platform for corporate support and sustainable development environment. Increase in the virtual product development efficiency through the use of real geometry and captured knowledge help was observed by Katonaa,S., et.al (2016) and system has a significant impact on manufacturing cost and product delivery improve the efficiency of change in engineering process stated by Yan, W., et.al (2016). Galasso,L.,M., et.al (2016) helps to improve man-machine interface by minimizing the complexity and reducing the stress level of user in tool industry.

 

| Sr. No | Publisher | Name of Journal | Span In Years | | | | | | | Tota |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1989 to 1993 | 1994 to 1998 | 1999 to 2003 | 2004 to 2008 | 2009 to 2013 | 2014 to 2017 | Jan-18 to Dec.2018 | |
| 1 | Elsevier | The 22nd CIRP conference on Life Cycle Engineering | | | | | | 1 | | 1 |
| 2 | | 26th CIRP Design Conference | | | | | | 1 | | 1 |
| 3 | | 9th International Conference on Digital Enterprise Technology - DET 2016 – "Intelligent Manufacturing in the Knowledge Economy Era | | | | | | 1 | | 1 |
| 4 | | IFAC (International Federation of Automatic Control) | | | | | | 2 | | 2 |
| 5 | | Measurement | | | | | | 1 | | 1 |
| 6 | | 5th CIRP Global Web Conference Research and Innovation for Future Production | | | | | | 1 | | 1 |
| 7 | | Computers in Industry | | 1 | | 1 | | | | 2 |
| 8 | | Knowledge-Based Systems | | | 2 | 1 | | 3 | 2 | 8 |
| 9 | | Advances in Engineering Software | | 1 | 1 | 2 | | 1 | 3 | 8 |
| 10 | | Expert Systems with Applications | | | 1 | 1 | 1 | 1 | 2 | 6 |
| 11 | | Journal of Materials Processing Technology | | | 3 | 1 | | | | 4 |
| 12 | | Advanced Engineering Informatics | | | | | 4 | 3 | | 7 |
| 13 | | 3rd CIRP Global Web Conference | | | | | | 1 | | 1 |
| 14 | | Engineering Applications of Artificial Intelligence | | | | | | 2 | | 2 |
| 15 | | Materials and Design | | | 1 | | | | | 1 |
| 16 | | International Journal of Project Management | | | | | | 1 | | 1 |
| 17 | | Computer-Aided Design | | | 1 | | | | | 1 |
| 18 | | Computer in Industry | | | | | | 1 | | 1 |
| 19 | | Robotics and Computer Integrated Manufacturing | | | | | | 1 | | 1 |
| 20 | | International Conference on Processing of Materials, Minerals and Energy | | | | | | 1 | | 1 |
| 21 | Taylor & Francis | Computer-Aided Design and Applications | | | | | | 1 | | 1 |
| 22 | | World Congress on Engineering | | | | | 1 | | | 1 |
| 23 | | 14th IFAC Symposium on Information Control Problems in Manufacturing | | | | | 1 | | | 1 |
| 24 | IEEE | 2nd International Conference on Computer Engineering and Technology | | | | | 1 | | | 1 |
| 25 | Butterworth (Publisher | Project Management | 1 | | | | | | | 1 |
| 26 | | Computer aided design | 1 | | | | | | | 1 |
| 27 | IJERA | International Journal of Engineering Research and Applications | | | | | 1 | | | 1 |
| 28 | ISER | EURASIA Journal of Mathematics Science and Technology Education | | | | | | 1 | | 1 |
| 29 | Scientific Publishing | American Journal of Intelligent Systems | | | | | | 1 | | 1 |
| 30 | Sryahwa | International Journal of Emerging Engineering Research and Technology | | | | | | 1 | | 1 |
| 31 | Emerald | Journal of Sustainability in Higher Education | | | | | | 1 | | 1 |
| 32 | | Assembly Automation | | | | | | 1 | | 1 |
| 33 | Cambridge Universit | Aeronautical Journal | | | | 1 | | | | 1 |
| 34 | Thesis | Linköping Studies in .Science and Technology Department of Mechanical Engineering | 1 | | | | | | | 1 |
| 35 | Prop-osal | Master of Science in Management, Economics and Industrial Engineering | | | | | 1 | | | 1 |
| TOTAL | | | 3 | 2 | 9 | 7 | 10 | 28 | 7 | 66 |

Table 1: Categorical Analysis of Literature

### *B. KBE Methodology*

Various literatures indicated that industry practitioners and academic experts are preferring mass customization over mass production by implementing concept of Knowledge based Engineering through various methodologies by expecting significant reduction in time required for overall design process hence reduction in cost, meeting the challenge of maintaining user interactivity and weaknesses in traditional solvers such as non-convergence, ill-conditioning, poor initial conditions, solution jumping and lastly increase mass production without adopting inappropriate procedures.

According to the typical methodological approach to practice KBE, before proceeding towards the development of any KBE application, it is required to perform task of knowledge acquisition that need to be

 

embedded in the KBE application itself. Once developed, the given KBE application will be deployed, typically as part of a broader and heterogeneous engineering design framework, where it will be integrated with other computer aided engineering tools by means of some workflow management system [Rocca, G.L., 2012]. The oversimplified description of the development and deployment process of a KBE application, it appears that the interest areas of KBE, Knowledge Engineering and knowledge management intersect, complement and specialize each other as shown in Fig No 4.

For new product development, according to [Gilmore, M.L., 1989] & [Chu, Chih-Hsing., et.al,2005] & [Belkadia, F., et.al,2015] initially one need to decide product specification based on closed loop system, consisting of requirement analysis followed by conceptual design, detailed design, modeling of component and system design and further followed by design analysis and manufacturing.

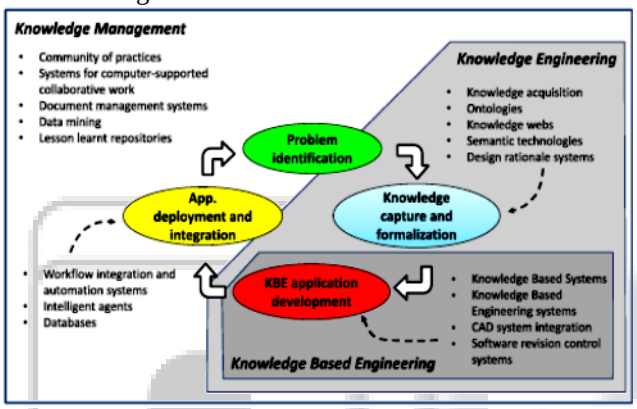


Fig. 4: Relative positioning of knowledge based engineering, knowledge engineering and knowledge management. [Rocca, G.L., 2012]

Once the initial design is done, with the help of KADS we can implement KBE which will reduce the time and human efforts in doing repetitive things [Lad,A.C., et.al, 2014]. Once the initial design is done, a company manager can see KBE as a technology asset to compress product development time and cut engineering costs. A developer might see KBE as a technology to augment the dynamic calculation capabilities of classical spreadsheets with generative geometry and report-writing capabilities [Kong, L., et.al 2003], or, vice versa, to augment the level of automation and ''intelligence'' of conventional CAD systems by embedding design rules and engineering knowledge [Myung, S., et.al,2001] & [Yu, Y.,2010]. Further the researcher used the concept of Knowledge Fusion (KF) [Tiwari,V., et.al 2013] in which design base contains the parametric relations of each dimension and formulae as to avoid redesign and remodeling of the part.

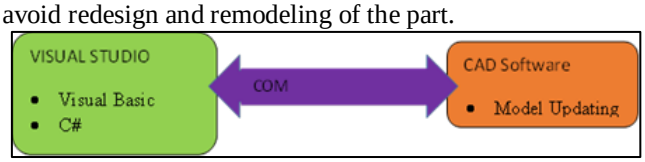


Fig. 5: Application of Programming Interface [Lad, A.C., 2014]

The most famous methodology which was adopted in recent years in Methodology and software tools Oriented to Knowledge based engineering Applications, commonly known as MOKA. It consists of six step namely - Identify, Justify, Capture, Formalize, Activate and Delivery and accompanying informal and formal models, is designed to take a project from beginning towards industrialization and actual use [Vadoudi, K., 2012]. The informal model basically works on Illustrations, Constraints, Activities, Rules and Entities whereas the formal model works on MML technique which is nothing but MOKA Modelling Language, an adaptation of UML. Basically MOKA focused on capturing and formalizing the knowledge of engineer so as to facilitate for minimization of extra workload, improve acceptation and use and maintenance of application from user's point of view.

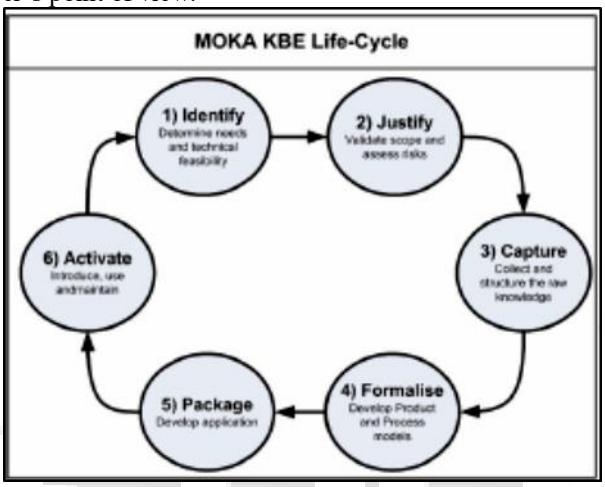


Fig. 6: a. Elements of MOKA Methodology [Verhagen, Wim J., C., et.al, 2012], [Reddy, E., J., et.al, 2015]

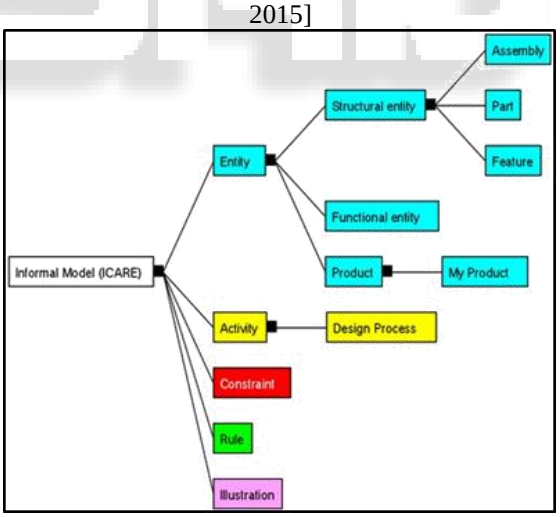


Fig. 6: b. Elements of MOKA Methodology [Verhagen, Wim J., C., et.al, 2012], [Reddy, E., J., et.al, 2015]

 

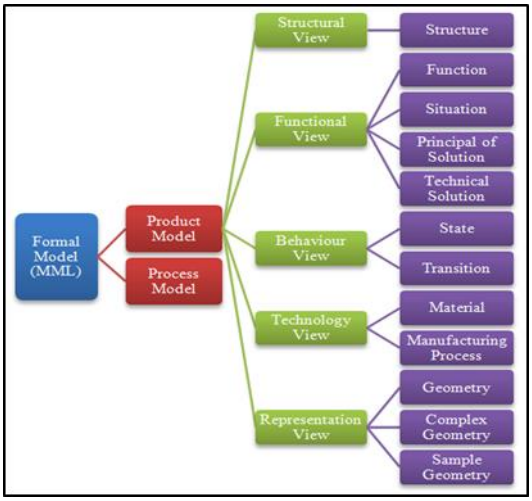


Fig. 6: c. Elements of MOKA Methodology [Verhagen, Wim J., C., et.al, 2012], [Reddy, E., J., et.al, 2015]

Knowledge- Oriented Methodology for the Planning and Rapid Engineering of Small-Scale Applications (KOMPRESSA) is a variant of MOKA used in small and medium scale industries which emphasizes on risk analysis and management. [Lovett, P.J., et.al, 2000].

Another methodology used for KBE is Design Engineering Engine (DEE), which deals with generation of product model by listing the requirements and making initial calculations as a first phase. The first phase is further linked with Multi-Model Generator (MMG) which is nothing but generation of framework for parametric model formation. Basically MMG generates the Report File which are further fed to the third major element i.e. detailed analysis modules which will work on design implications which will analyze the convergence of the mathematical design [Laan,V.D, et al., 2006]. The DEE is a superior over conventional MOKA approach as it includes detailed discipline analysis and subsequent multidisciplinary optimization in routine but having setback of inadequacy in capturing, formulation and delivery of knowledge [Vadoudi, K., 2012]. A hybrid approach is being adopted by various professionals which combines MOKA and DEE, commonly known as KNOMAD (Knowledge Nurture for Optimal Multidisciplinary Analysis and Design) methodology, includes step wise specific implementation through knowledge life cycle and knowledge management across that life cycle [Verhagen, Wim J., C., et.al, 2012]. The said methodology works in following steps-

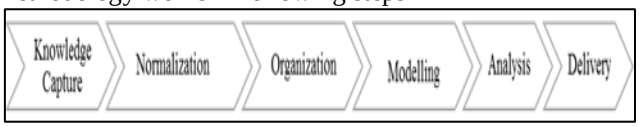


Fig. 7: Elements of KNOMAD

The first Step i.e. Knowledge capture includes identification of the scope, objectives and assumptions and factors depending for capturing the knowledge. In further phase the hard quality controlling and normalization will implement for captured knowledge. Basically verifying the applicability with respect to quality criteria and standardization of knowledge is done for inclusion in KNOMAD. In subsequent phases the organization of captured knowledge for utilizing in modelling and analysis by preparing structural framework through understanding of interrelationship of studied and expressed set of concepts and their definitions.

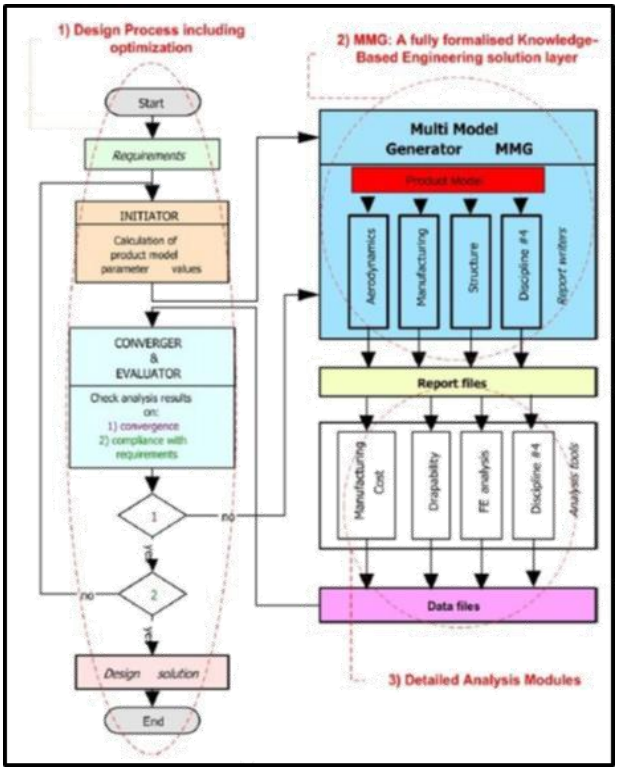


Fig. 8: Design Engineering Engine DDE methodology [Laan,V.D, et al., 2006].

*C. KBE Applications*

This category will study and analyses the different application of KBE system. Basically as discussed in earlier section, KBE represents a merging of object-oriented programming, artificial intelligence, and computer aided design. The main aim of KBE is to capture product and process information to allow business to model engineering processes, and then use the model to automate all or part of the process. A KBE product model can also use information outside its environment, such as physics-based analysis, databases, spreadsheets, legacy programs, and cost models. Also, 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. Direct control over geometry and topology as well as more advanced geometry introspection capabilities is also possible through KBE system. Thus, the ultimate goal of a KBE system should be to capture the best design practices and engineering expertise into a corporate knowledge base. This is the reason KBE system has got wider range of application in MNC's as well as SME's (Small & Medium Scale Industries) which is described in table II.

| Reference Literature | KBE Area |
|---|---|
| Gilmore, M.L. (1989) | Construction industry |
| Sapuan, S.M. (2001) | Appropriate selection of material in production industries |
| Myung, S., et.al. (2001) | Reduced time for modification in parametric design. |
| Chapman, C.B., | Rapid design and analysis of an |

 

| | |
|---|---|
| et.al. (2001) | automotive structure |
| Kong, L., et.al. (2003) | For plastics injection mold design process |
| Ratchev, S., et.al. (2003) | It uses in large project |
| Kulon, J., et.al. (2006), | It used in metal forging for better selection of material and their properties |
| Yu, Y. (2010), | Lubrication recycling station |
| Verhagen, Wim J.C., et.al. (2012), | It gives projects to move towards industries and in actual use |
| Rocca, G. (2012) | In the fields of aerospace and automotive |
| Nayak H., B., et.al. (2012), | Automation of nozzle |
| Kumar,S. (2014) | Managing processed food products. |
| Lad,A.C., et.al. (2014), | It is applied for designing of coil winding machine. |
| Ramnath,B.,V., et.al. (2015), | This method is used on two wheeler front fork. |
| Akhavei,F., et.al. (2016), | Used for welding applications |
| Górski,F., et.al. (2016), | Biomedical Engineering |
| Yan,W., et.al. (2016), | Used in Engineering Change process |
| Galasso,L.,M., et.al. (2016), | It is used for supervision purpose. |
| Esteban,S., et.al. (2015), | For designing the aircrafts. |
| Belkadia, F., et.al. (2015), | PLM is used for production and planning. |
| Neugebauer,R., et.al. (2015) | Application for sheet metal parts. |
| Chapman, C.B., et.al. (2001), | DART system for vehicle surface modelling and packaging |
| Dwivedia, S.N., et.al. (2003) | Magnetic method used for dye penetrant and ultrasonic test |
| Górski,F., et.al. (2016), | KOMVR solutions used for building interactive VR (Virtual Reality) applications. |
| Górski,F., et.al. (2016), | KOMVR used for heart transplantation application. Planning, visualization, programming, user interface and verification. |
| Molnár, V., et.al. (2017) | Online monitoring of pipe conveyors operation. |
| Farinhaa, F., et.al. (2005), | KBE applications are presented in the field of safety control of structures, like dams ad railways. |
| Chu, Chih-Hsing., et.al. (2005), | Demonstrating the practically of parametric design approach. |
| Verhagen, Wim J.C., et.al. (2012), | It develops KBE application for high level techniques to solve critical problems |

Table 2: KBE Applications

Gilmore, M.L. (1989) had given important guidelines for the application area for applying KBE, which briefly classified as Diagnostic problems, Configuration problems, Interpretation problems, Computer front end, Computer-based training. Also describes application of KBE in Construction and Civil engineering with respect to Transportation engineering, Geotechnical engineering, Environmental engineering, etc. Vosniakos, G.C. (1992) presented the framework for the interpretation of annotation-entity information in wireframe drawings enhanced to solid-like model and also concludes that knowledge-based approach makes catering for new cases straightforward by the addition of new patterns and rules, which will ideally be achieved through a suitable user interface. Chapman, C.B., et.al (2001) describes the use of KBE to increase the capabilities of BIW (body in white) engineers by responding dynamically to the changes within rapid time which leads to reduction in production cost and increase the sustainability of concept design through systematic implementation. Myung, S., et.al (2001) focuses on parametric modelling of process machine tools by developing commercial CAD system through API program.

Also researchers like Kong, L., et.al (2003) uses Application of Programming Interface method for designing of plastic injection mold. Kulon, J., et.al (2006) uses KBE in making hot forging dies from component profile taking into account machine, material and forging company specific data, and design considerations whereas Lin, Bor-Tsuen., et.al (2008) utilizes KBE for designing of drawing dies by taking advantage of pre-built design knowledge base and database, this system is able to output designs of the main components of a drawing die, such as upper dies, lower dies and blank holders, upon users' input of design information of blank lines, die faces, punch open lines, press data, and types of subcomponents such as hooks, guides, and stopper seats .Also Laan,V.D., et.al (2006) utilizes KBE for Integration of friction stir welding into a multidisciplinary aerospace design framework. Legat, C. (2012) highlights the efforts towards future factory automation systems which demands for automatic processable knowledge about the production system itself. Legat, C. (2012) also commented that use of KBE can be made for predictive diagnostics in order to detect failures of production facilities and reason about field-level control capabilities. Nayak H., B., et.al (2012) describes use of design automation of reactor nozzle by providing a parametric model for automatic generation of assembly and manufacturing drawings. Tiwari,V., et.al (2013) also facilitates design automation by knowledge fusion so as to avoid redesign and remodeling of the product. In recent era instead researchers like Lad,A.C., et.al (2014) applied KBE through API for design automation of entire assembly of winding machine which reduces the design time significantly along with 20-25 % reduction in cost. Girodon,J., et.al (2015) focuses on the organizational modelling of the future multi-agent system in order to specify its architecture through DOCK i.e. ((Design based on Organization, Competence and Knowledge). Whereas Neugebauer,R., et.al. (2015) applies KBE for extraction, recognition and interpretation of forming features. Zhang,Y., et.al (2015) extends his research in KBE domain to develop open, shared, and scalable knowledge framework for implementing domain-oriented and knowledge-based material selection through analyzing fundamental concepts

 

and relationships involved in all aspects of material selection. Similarly Zhao,X., et.al (2015) works on the financial aspects i.e. production cost of the aircraft components by automating the cost integration in the design process to improve the fidelity, repeatability and traceability of cost analysis. Ramnath,B.,V., et.al (2015) worked on the Concurrent Redesign process for the purpose of manufacturing of front fork of a leading 2 wheeler by integrating Redesign, Concurrent Engineering, Reverse Engineering & Group Technology through KBE. Recently Katonaa,S., et.al (2016) worked for the process to integrate real geometry data into product simulation through KBE and Górski,F., et al. (2016) implements KBE in the field of virtual reality in educational sector for integrating medical and biomedical engineering education. Verbert,K., et.al (2017) worked in the domain of fault diagnosis through KBE i.e. by investigating knowledge-based diagnosis task which is influenced by uncertainty, investigate which additional objectives are of relevance. Molnár, V., et.al (2017) understands the operational reliability by online monitoring of pipe conveyor system.

## IV. Conclusion and Remarks

This paper provides a systematic and categorical literature review on articles published from 1989 till date on the SD aspects. In total, 64 papers published in academic databases namely Science Direct, Emerald, Taylor & Francis Journals and articles published in international conference proceedings, and some of the paid journal articles, etc. with 'Knowledge Based Engineering' and 'Module Based Learning' as keywords was carefully selected as per the methodology prescribed. These papers analyzed to collect information regarding KBE benefits, KBE criteria and KBE applications. This paper summarizes more than 20 KBE benefits, 5 Significant KBE methodologies and 32 wide range of engineering applications working under KBE. The subsequent subsections present the identified gaps in the research, significant findings of the review and future directions for the research.

### *A. Gaps Identified*

Based on the literature review, a large benefits has been achieved by using KBE such as Time & Cost Reduction, Maintaining User Interactivity, Increase Mass Production, Increase in Efficiency of System, Adaptability & Flexibility, User Comfort & Reduction in Stress Level, Increase in Dynamic Capacities; there are certain drawbacks which has been identified and need to be addressed:

- Creation & Implementation of KBE System is Time Consuming, requires skill and great amount of funds along with hardware with higher specifications.
- Basically KBE is nothing but a GIGO (Garbage in Garbage out) if the inputs are not carefully inspected, because the processing is covert one, which can create problems in knowledge transfer for new entrant.
- Impact of KBE in local level implementation could not be registered to complete the product development process.
- Considering the recent advancement in implantation KBE for wide range of application, problem of Knowledge Management (KM) is not fully resolved as designers are not being able to make up to the requirements of customer.

### *B. Significant Finding*

This paper provides a categorical literature review on articles published from 1989 to till date on KBE benefits, KBE criteria and KBE applications. The significant findings of this categorical review are as follows: The excellence of KBE activities resulting in optimizing the work time, reduction in operating cost and improving the efficiency of engineering change (EC) process has been acknowledged by various researcher and academic professionals.

To summarize the benefits after implementation of KBE lead to increase in dynamic capabilities of the design process as well as to overcome the flows of mass production through the concept of mass customization. Also significant enhancement in man machine interactivity is observed by analyzing the applicability of KBE to wide range of applications and weaknesses in traditional solvers such as non-convergence, ill-conditioning, poor initial conditions, solution jumping, etc. can be easily avoided which will increase the transparency in design process.

### *C. Future Direction of Research*

This paper had reviewed in detail the current status of KBE aspects namely KBE benefits, KBE criteria and KBE applications. The following points offer some direction for future research:

- There is need of identifying the barriers or practical difficulties for implementation of KBE system in consultation with industry experts. The activities having a strong effect on the performance should be carefully identified and analyzed.
- The use of Engineering tools and integrated systems prior to actual prototyping of end product is essential to reduce overall cost component. In democratic countries like India, a new kind of system will certainly help to directly enhance the abilities of fresher graduates. It is a dire need of today's India to come up with knowledge based Engineering system which will be a platform to have a systematic and convergent way to get a new design of product at hand.
- The application area can be brought into the engineering education field, so that one can excel in bridging the gap between industry- academic relations

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