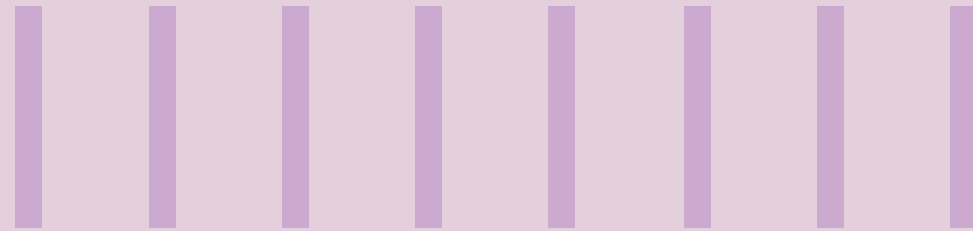




KNOWLEDGE BASED ENGINEERING (KBE)

Key product development technology to enhance competitiveness
– Devaraja Holla V.



Abstract

In today's competitive environment, it becomes imperative to look for innovative ideas to bring high quality product to market in a short time, especially in the context of engineering products which is highly knowledge and experience driven. Knowledge based engineering (KBE) will help engineering organizations to efficiently utilize their existing product knowledge base to launch innovative products much faster, better, and cheaper.

This paper presents a point of view on KBE technology, its benefits, levels of use and maturity in the industry and shares some of the critical success factors.

Introduction

Most of the engineering products especially in aerospace and automotive industry are highly knowledge and experience driven. Even today, a significant portion of this knowledge base is still in the form of tacit knowledge within the heads of experienced engineers who are specialized in specific disciplines. Any typical engineering product development involves multiple disciplines such as stress, aerodynamics, optimization, loads, weights, design, tooling, manufacturing, etc., working concurrently. Obviously, it requires a significant amount of time and effort of all concerned engineers and subject matter experts (SMEs) to develop any new product; even though they have prior experience of developing similar products. Typically, an engineering organization is specialized in a specific type of product (like business jets, transport aircraft, or a passenger car, etc.) and many times the newer products that they develop will be in line with their existing product series but with some additional features, values, or performance. Hence, significant portion of the knowledge required for developing the new but similar product is already established and available within the organization. The idea behind Knowledge-based Engineering (KBE) is to capture this generic knowledge of the product family and reuse it efficiently in the development of a new product of similar product family; so that experienced engineers and SMEs can focus more on inventive designs and newer products instead of again focusing on routine design activities of a similar product.

Any product development comprises of several stages such as conceptual design, preliminary design, detailed



design, tooling, manufacturing, assembly, testing, etc. In a conventional engineering product development scenario, most of the activities are planned to be carried out manually using in-house or commercial third party CAD / CAE / PLM systems. There have been significant advancements in the area of software and CAD technology in the last few decades. There is significant scope for leveraging these technologies and software tools in product development beyond the traditional use of CAD, CAE, and PLM applications by engineering organizations. KBE leverages these advanced software/CAD techniques to model the engineering knowledge and apply them to product development more efficiently, consistently, and in a more automated way than the conventional approach.

Though the term “Knowledge-based engineering” has been in use in the industry for many years, there appears to be significant confusion about its definition and scope; not only across various organizations, but also within various departments in an organization; especially owing to various similar knowledge-based initiatives that exist in the industry such as knowledge management, and knowledge engineering. This paper presents a closer look at the definition of KBE and its relation with respect to other related terms and technologies in the industry. This paper also outlines how KBE benefits engineering organizations. Also, this paper discusses a few of the factors that influence the maturity of an organization in the use of this technology and finally shares some of the critical success factors.

What is Knowledge-Based Engineering?

Knowledge-based engineering (KBE) is an engineering in product development technology wherein the knowledge of the engineered product and its design process is captured and embedded into a software system (known as KBE system) and the use of this system in

the design and development of similar new products. It is the product-specific generic engineering knowledge that is captured and represented as the product model within the KBE system (suite of KBE applications). These KBE applications are then used by the designers to generate a

new but similar product design for a new set of input specifications. In fact, these KBE applications can be re-used again and again to generate many new but similar product designs.

Differentiating between Knowledge and Data

The essence of KBE technology is that it differentiates between engineering knowledge and engineering data. Engineering knowledge comprises of the product knowledge as well as the knowledge of the process of designing the product. Irrespective of the input specification, the knowledge portion, to a large extent, remains the same, and

this knowledge is applied to generate specific product design data for a given input specification. The input for any product development comprises of specific values of product specifications such as size, performance, cost, appearance, etc. The output typically comprises of 3D part models, 3D assembly models, part drawings, assembly drawings, installation

drawings, bills of material, etc; and these outputs depend on the values of the input specification. The knowledge component comprises of the rules, constraints, heuristics, guidelines, standards, design methodologies, etc. Broadly, the knowledge can be classified into two types – Explicit knowledge and tacit knowledge; as detailed in Figure 1.

Explicit Knowledge	Tacit Knowledge
Formalized and well-documented knowledge	Embodied within the experienced engineers and not documented
Design Manuals	Rules of Thumb
Engineering Methods	Heuristics
Material Specifications	Observations
Engineering Standards	Best Practice
	Experiences
	Plausible Reasoning

Figure 1: Knowledge types

Explicit knowledge is the formalized knowledge found in handbooks, material specifications, engineering data books, design standards, etc. Tacit knowledge comprises of rules of thumb, best practice, heuristics, observations, experience, and

plausible reasoning. Tacit knowledge normally is hard to acquire and normally lies in the heads of experienced engineers and is most valuable knowledge. KBE technology involves capturing both types of knowledge and embedding that into the

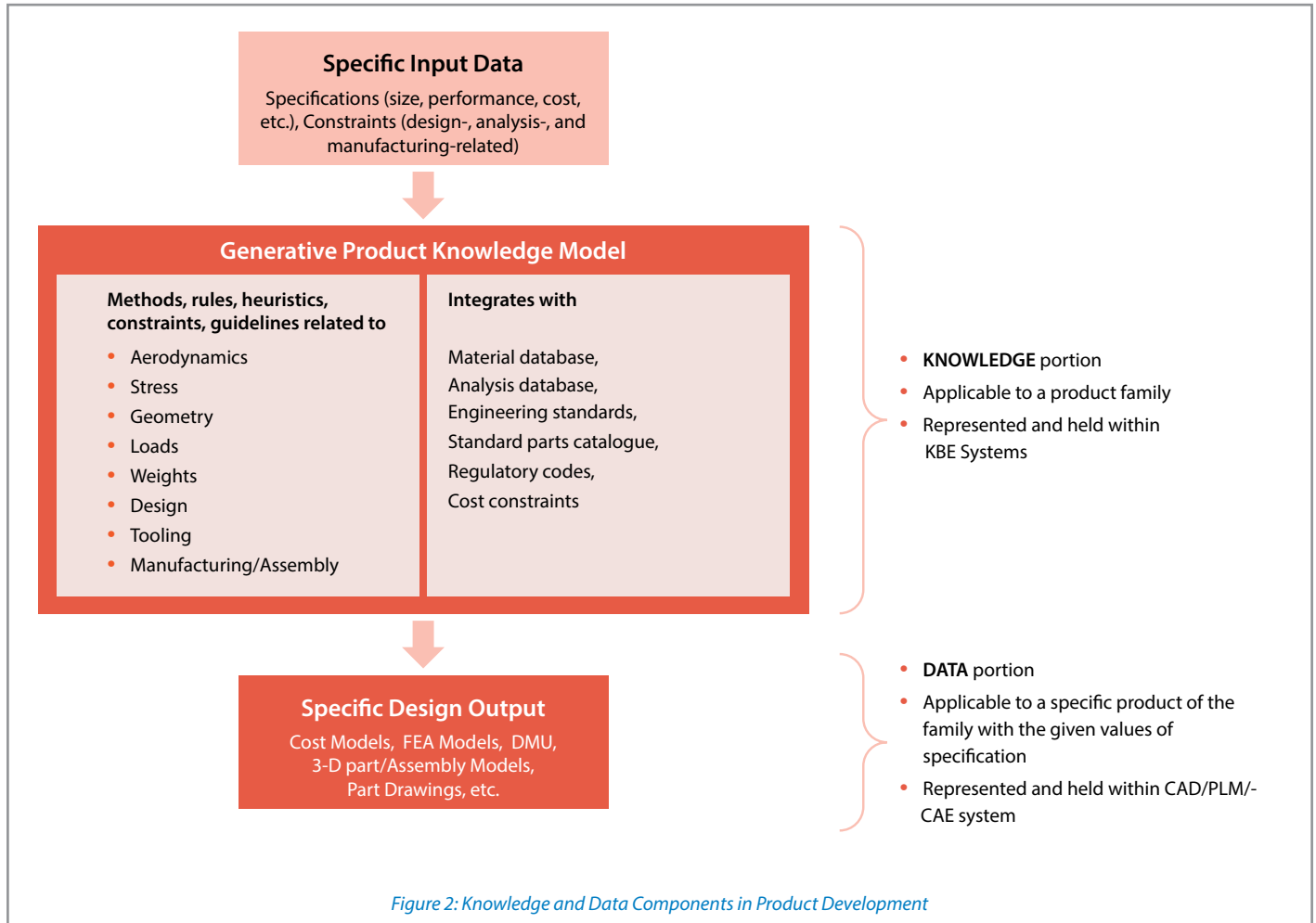
KBE system (suite of KBE applications) and then using this KBE system to generate the specific product instance for given values of product specification. Figure 2 shows a pictorial representation of differentiation of knowledge from data.

In Figure 2, the middle portion is the KBE system and encompasses product-specific knowledge in the form of product model. KBE system is used to generate specific product design given the input specification. Output typically comprises of 3D Models, FEA models, BOM, etc., which are generated as per the design processes and rules coded within the KBE application. To the designers, KBE applications

provide a structured approach to do the design; and the geometry generation is automated based on these rules within the KBE applications. For every change in the input specification, the output can be regenerated consistently and quickly.

In KBE product development technology, the main objectives of KBE system is to hold the knowledge of the product family and generate the design; whereas the

primary objective of CAD system is the representation of product-specific design data. However, there exists an overlap and dependency between KBE system and CAD system. While geometry and CAD are essential parts of any KBE system; many commercial CAD systems offer good features that enable encapsulation of engineering knowledge within a CAD system.



Key characteristics of KBE System

As outlined in the above section, a KBE system holds the knowledge of the product family for which it has been developed. Hence a KBE system is very specific to a particular product family for which it is intended to be used. Since the design rules, the specifications, heuristics and standards are all specific in nature, obviously KBE systems are built for a very specific purpose and product. Invariably the product-specific design knowledge are all proprietary to an organization that produces them, hence typically a KBE system developed for a specific product of a specific company cannot be used for a similar product by a different company. The reasons being:

- The product know-how, its technology, experiential knowledge, etc., are proprietary and very specific to the company that has built them over a period of time.

- The processes, standards, regulations, materials, and tools used for the development of a product will vary from company to company even though the product type remains the same.

There are some commercial “general KBE systems” available in the market (such as ICAD), but their scope is limited to providing features and frameworks that help companies build specific KBE systems efficiently and quickly.

One of the key characteristics of a KBE system is the generative nature of the product knowledge captured within the KBE system. As mentioned earlier, the product model is a generic representation of the product type for which the KBE application has been created. The generic product model holds the generic product knowledge that includes geometry, topology, product structure, and manufacturing processes such as design

rules, heuristics, etc. Generative modeling maps all functional specifications to a detailed representation of the product. The advantages of a generative model are that as the product requirements change, the design representation is immediately updated directly affecting all the outputs. Because of the generative nature of the product model, KBE applications can be re-used again and again to generate various product instances corresponding to various input specifications. Even the changes to an existing design because of change of input specification can be handled efficiently. This is illustrated in Figure 3; where a KBE system developed for a product family, say P, encapsulates all the generic knowledge of the product and its design process. Hence this system can be used for the design of all the variants (say P₁, P₂ etc.) of this family. Given the specifications of a product variant P₁, the KBE system of P can be reused to generate the design of P₁.

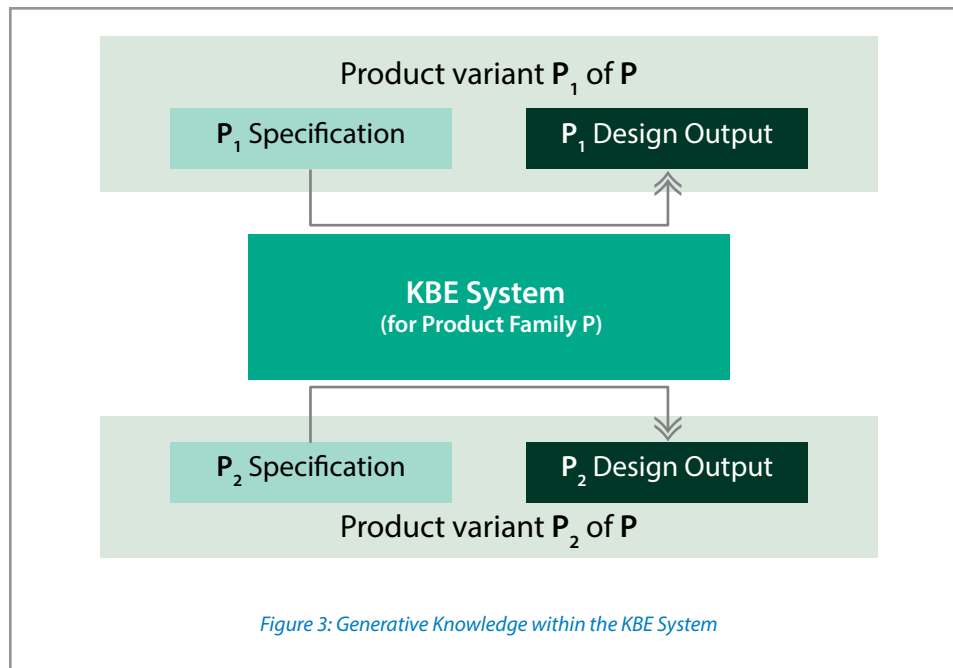


Figure 3: Generative Knowledge within the KBE System

Another key characteristic of a good KBE system is the integrative nature of knowledge encompassing multiple disciplines. Development of a product comprises of several stages such as conceptual design, preliminary design, detailed design, manufacturing, etc.

At every stage of the product development, the knowledge and intervention of multiple disciplines such as materials, standards, costing, analysis, tooling, regulations, and safety is essential. A product model encompasses the complete knowledge of the product from

the perspectives of all the disciplines in an integrated way. This ensures that various models (finite element model, cost model, DMU) of this product corresponding to each of the disciplines can be automatically created in a consistent way from this single product model. This helps to analyse quickly the effect of change of a parameter from the perspective of any one discipline on various other perspectives or disciplines. The impact of changes on various disciplines can be studied and analysed in an efficient way.

The use of advanced software and CAD techniques helps in building efficient and good KBE systems. Typically, KBE systems are characterized by their combination of object-oriented programming techniques with geometric modeling. These enable generative and integrative modeling of the product that allows the engineers to generate the new designs quickly and provide the ways to create product views for a range of product development disciplines.



How KBE is related to other similar practices / systems?

There has been significant divergence on the definition of KBE across the industry. In addition, various related practices and systems such as Knowledge engineering, Expert systems, etc., have been used sometimes synonymously with KBE by many people. This section attempts to bring out the relation and differentiation of KBE with respect to other similar practices and systems.

Knowledge Management (KM) and KBE

KM is the collection of processes and practices that govern the identification, creation, representation, distribution, dissemination, and utilization of knowledge of an organization; either embodied in individuals or in organizational processes or practices. It is more of a streamlined approach at improving knowledge-sharing across the organization for finding, selecting, organizing, distilling, and presenting information. KM does not insist upon or enable integration of knowledge into the engineering product development process. However, some of the KM processes and practices of knowledge capture can be utilized in KBE technology for the engineering knowledge capture to build the KBE system.

Knowledge Engineering (KE) and KBE

KE deals with formal techniques to extract, model, reason with, and share knowledge; and typically involves

knowledge representation (such as ontology) knowledge extraction techniques, knowledge elicitation techniques, reasoning / inference techniques, etc. While KBE is to improve engineering product development through use of engineering knowledge, knowledge engineering is more about engineering of the knowledge itself. This is not limited to product development or engineering. Some of the elements of knowledge engineering techniques such as categorization of various knowledge objects and their relationships, etc., can very well be used in KBE technology for the engineering knowledge capture, modeling, formalization, and representation within the KBE system.

Expert system and KBE system

An Expert system is a software system that attempts to emulate a human expert most commonly in a specific problem domain. Typically, such a system contains so called "knowledge base" that comprises accumulated experience and a set of rules that are applied on knowledge base to each particular situation. Knowledge engineering techniques are normally used to capture and codify the knowledge into knowledge base and building the rules to capture from the knowledge base. Expert systems typically capture knowledge in an automated decision-making format, generally a collection of "if-else" rules and are non-algorithmic-intensive; and these are not designed for mechanical

engineering. Expert systems do not have geometry and CAD primitives to describe mechanical engineering projects whereas geometry is an important element of any KBE system. Expert systems are used across domains outside engineering and product design as well; whereas KBE systems are very specific to engineering products.

Knowledge-based system (KBS)

A Knowledge-based system is again a software system that is intended to imitate human problem-solving and it is programmed using artificial intelligence methods and techniques. The core components of KBS are the knowledge base and inference mechanisms. KBS uses different techniques such as rule-based, case-based, etc. Expert system is one of the many types of KBS.

The key differentiating factor is that KBE is very specific to engineering product development; however, it takes elements from other practices for various aspects of KBE technology.

Within the context of engineering product development, many times "Design automation" has been used synonymously with KBE by many people. Design automation is more of an outcome of KBE technology; and it is one of the modes of reusing the knowledge. KBE system helps in execution of many of the mundane design tasks in an automated way. Hence Design Automation and KBE are not synonymous.

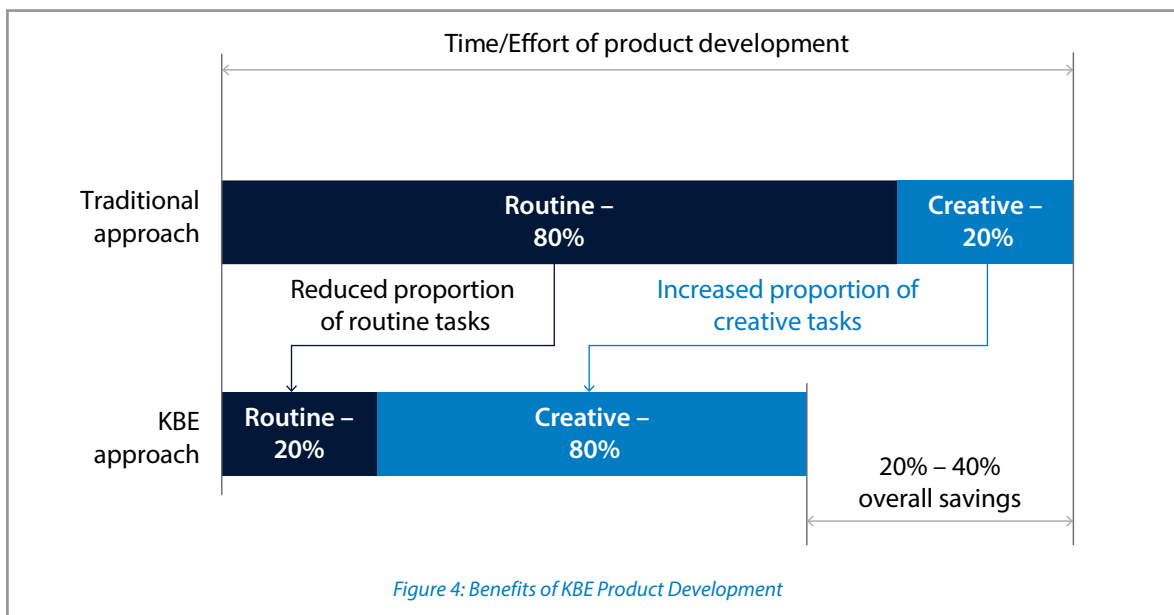
Benefits of KBE

As compared to traditional product development technology, KBE technology brings a lot of benefits, both tangible as well as intangible. There has been a significant reduction in costs and lead time for new products realized by many organizations besides improved quality of the products. In addition, this technology ensures that the knowledge is captured and continuously enhanced and reused for newer products. One of the major concerns of an engineering organization is the "Aging work force" where enormous amount of engineering

knowledge is permanently lost on retirement or on leaving of the highly experienced designers from the company. KBE technology helps in capture of all the knowledge and ensures that it is available for the future.

Figure 4 shows a comparison of traditional product development with KBE product development. Typically, the tasks in product development can be categorized into creative tasks and routine tasks. Creative tasks typically involve arriving at multiple design alternatives, design optimization, etc. Any traditional product

development involves only about 20% of creative tasks and the remaining 80% of the tasks are routine in nature. KBE helps in automating the routine tasks so that the designers spend less time on routine tasks (about 20%) and they can focus more on creative tasks. In addition, an organization can realize about 20% to 40% reduction in the cycle time as well as effort in the product development. The rest of this section elaborates on the benefits that can be realized with KBE.



Reducing product development cycle time by automating routine design activities:

Normally, most of the new products that a company launches are variations of existing products. However, in most cases, each new product design starts either with very less knowledge of the existing product or spending too much time of experienced people to leverage that knowledge. Similar products share many of the same routine engineering tasks; they

are designed from similar components using similar engineering techniques, and are analyzed and produced in similar ways. Engineers must repetitively do tedious (and sometimes inaccurate) calculations and look up numerous tables and catalogs. Much of the time is spent in repeating analyses that enhance product designs. A KBE system helps to automate these routine engineering tasks for similar products by representing the knowledge of how to accomplish them as rules in a

product model. This not only helps to reduce the cycle time but also free up engineers to spend more time for creative tasks.

Improving quality of the product:

Many times, under the pressure to launch a new product to market quickly, quality aspects for new products are given less priority. Since a KBE product model accelerates the optimization process, higher quality products can be designed in

the same amount of time or less than the time it takes to produce a design using the traditional product development process. A higher number of iterations is possible to enhance the product to a much greater level. Increasing the number of design iterations always improves the design quality, since the designer now has more time and opportunities to explore many options. Additionally, many potential design mistakes are eliminated because of the consistency of generating a design from the same set of rules. This helps to reduce the dependency of quality on the experiences of the designers who are performing the design activity. Since the knowledge is already part of KBE system, a less experienced designer can use this system to generate the design and still get consistent results.

Capturing engineering expertise and reuse:

One of the key benefits of KBE technology is the capture and reuse of engineering tacit knowledge. Significant experience can be lost permanently when the key design people leave the organization. A KBE system captures their design knowledge and makes it available for future use. In addition, an organization will have a lot of flexibility in terms of availability of experienced resources for high-end design activities while less experienced resources can be utilized for routine design activities using the already captured knowledge in the form of KBE system.

Enable concurrent engineering:

Normally, product development involves multiple disciplines such as stress analysis, aerodynamics, design, tooling, etc., and traditionally various engineering disciplines work separately and sequentially on the same product design.

Any change to the design requires each engineering discipline to re-evaluate their portion of the design. A product model within a KBE system synthesizes the constraints and engineering rules from all engineering disciplines in an integrated way. The KBE system automatically checks that a design change made by one engineering discipline does not contradict the engineering rules and constraints from the other disciplines. An "Integrative" nature of the KBE system enables concurrent engineering for the product development bringing multiple disciplines together.

There have been numerous instances of benefits realized by many aerospace and automotive industries by adopting KBE technology. A few examples are as below:

1. An Aerospace OEM was involved in evaluating the concept of a passenger aircraft of medium size. One of the sub-systems to be evaluated was the cock-pit and this required simultaneous evaluation from aerodynamic performance, manufacturability, and cost perspectives. One of the broader concepts was evaluated using the traditional approach and another broad concept was evaluated with the KBE approach. Within a specified time frame, using the traditional approach they just managed to complete one concept whereas using the KBE approach it was possible to evaluate more than 50 concepts to a consistent and higher level of detail.
2. For an Automotive OEM, it used to take about four weeks to do the feasibility assessment of every styling revision of headlamps. With the KBE system in place, the styling change assessment was possible within a few minutes. This also helped in rapid feasibility assessment to meet

various legislative requirements of different markets.

3. Design of the wing of an aircraft typically involves various disciplines such as geometry, aerodynamics, stress analysis, and this is very iterative in nature. For an aerospace OEM, for one design iteration using traditional approach it generally took about six months with 20 engineers. With the KBE approach, this was reduced to just 1.5 months with only four engineers.
4. For an aerospace OEM, translating the airlines options to engineering definitions in terms of pre-design parts usually took about 20 months with a lot of scope for errors and inconsistencies. With a KBE-based approach, there has been significant savings in effort to the extent of 500 hours for every airline option and the lead time expected to reduce from 20 months to 4 months.
5. For an aerospace OEM, KBE-based development of floor beams (both for stress as well as design) for a section of a passenger aircraft resulted in about 50% savings in effort and about 30% savings in flow time.

The benefits realized by an organization are proportional to its maturity of this technology. However, even in traditional product development, KBE concepts can be applied in specific pockets at various stages of the product development such as detail design. KBE applications that capture some of the routine design activities can help in reducing enormous amounts of time. KBE is exceptionally useful where the design process involves many different engineering groups of experts with conflicting views of the perfect design.

KBE in Industries

KBE has been in use in many aerospace and automotive industries for many years. However, there has been significant variation in the maturity and use of KBE technology in product development across the industry. While some organizations adapt KBE technology in a strategic way, many organizations still use this in a tactical manner whenever things go wrong such as skipped schedule, effort or cost overrun, etc. Typically, the maturity of an organization in KBE technology is characterized by a few factors. These are elaborated below.

KBE Driver (Strategic/Tactical)

This is one of the major factors for the success of KBE in an organization. Some organizations have considered KBE as a strategy to become more competitive and are driving this with a strong management commitment. In such organizations, KBE is being driven centrally down to all the departments and disciplines; with clear objectives and goals. The areas where KBE can bring in significant benefits are identified jointly with all stakeholders and then the KBE technology is driven through all of them. Since all the disciplines are involved in this, the integrative and generic knowledge is captured and embedded into the KBE system. There are many organizations where KBE concepts are being driven only at the local level by a few engineering groups or engineers who have seen benefit out of KBE concepts. In such organizations, the scope of KBE system is very much limited to that of the disciplines or engineering group where the development and use of KBE systems are being carried out. In many such organizations, KBE is considered

as a tactical solution to overcome the schedule slippage and effort overrun within product development. Many organizations generally start with more of traditional design automation rather than from a real KBE perspective. Traditional design automation approaches can be characterized as piecemeal automation or a tightly coupled application based on hard-coded procedural programming in an ad hoc manner. The focus here is only to automate certain time-consuming tasks in order to reduce the flow time and manual effort. The issue with this tactical approach is that one of the most important aspects of KBE technology i.e., reuse of KBE applications for future similar products is completely overlooked. Such automation solutions or applications are normally neither generic in nature nor do they encapsulate knowledge of at least one discipline in a usable form. While these automation solutions satisfy specific product development needs, they are often not part of a system solution; and such automation solutions cannot be called as true KBE applications. Many such customized solutions have shortcomings (such as maintenance issues) and many disadvantages compared to the new generation KBE technology having the key characteristics discussed earlier.

KBE Penetration

Some of the major aerospace OEMs have significant numbers of KBE applications used across various aircraft models. The scope and nature of KBE applications typically determine the maturity of an organization in KBE technology. Any product can be viewed as an assembly of various components and each component as an assembly of individual parts. For example, if we consider aircraft wing as

a product, then it has three components – wing box, fixed trailing edge and fixed leading edge. The wing box comprises of spars, ribs, stringers, and skins. The scope of the KBE system can be at the part level or at the component level or at the product level. The development of a product or a component or a part involves multiple disciplines such as aerodynamics, loads, design, tooling, etc. Again, the scope of a KBE system could be any one specific discipline or it could encapsulate the knowledge of all relevant disciplines. Accordingly, there are two dimensions to the scope of any KBE system, one in terms of disciplines covered and second in terms of level in the product structure. There are very few instances in the industry where KBE is applied for a complete product covering all the disciplines of the product development. A few organizations have KBE applications covering all disciplines for a specific part; for example generic rib or stringer application encapsulating loads, stress, material, geometry, and manufacturing disciplines. Another example is a KBE system to estimate the weight of a wing box comprising of skins, stringers, ribs, and spars; covering aerodynamics, loads, material, and stress disciplines. A few highly matured organizations have high-end KBE systems with wider scope both in terms of product structure as well as disciplines covered. There are some organizations having a large number of KBE applications targeted for specific disciplines for a part or for specific stages of the product development such as preliminary design or detailed design.

KBE Development Approach

Development of a KBE system involves capturing the engineering knowledge from various sources and then translating

them into a software code to build the KBE system. The KBE system thus built would be used by the engineers to design similar new products. If the knowledge captured and implemented within the KBE system is not well represented and traceable to the software code, the usability of the KBE system will be impacted significantly. Engineers will not be confident and comfortable in using this system unless it is very easy for them to understand the rules, heuristics, and constraints implemented within the KBE system. In many organizations, engineers involved in the development of KBE application directly start with coding of the application without structured representation of the knowledge that they intend to capture within the KBE application. It becomes extremely difficult at a later point of time for an engineer to understand what has been captured within the application code and to do any modifications on this. It also becomes very person-dependent, and this significantly affects the maintainability and reusability of applications for future products. Hence it is essential to have good and structured development and knowledge modeling methodology of translating the engineering knowledge to a software code. The development methodology should be arranged in such a way that the implementation of

a specific knowledge (such as a rule/constraint) is easily traceable from raw knowledge to the corresponding software code. Typically, any generic software development involves following life cycle stages – requirement specification, high level/architecture design, detailed design, coding, testing, deployment, enhancement, and maintenance. KBE system development would also involve similar high level life cycle stages and has to be adapted to handle engineering knowledge. Engineering knowledge tends to be complex and diverse. Many different aspects of the knowledge – from basic physical, geometrical, and technical laws to highly sophisticated expert heuristics, have to be taken into account. Though there are no standard KBE development methodologies available in the industry, there has been some research effort made towards developing a structured approach for KBE. MOKA (Methodologies and tools Oriented to Knowledge-based engineering Applications) is one such effort made by a European consortium to develop a structured development approach for KBE. Typically, a software development process uses Unified Modeling Language (UML) to create the abstract models of the software system. UML is a standardized general purpose modeling language in the area of software engineering. This includes a set

of graphical notation techniques to create abstract models of a software system. A similar technique can be adapted in the area of KBE also. Even MOKA methodology has considered UML as a representational basis to come out with MML (MOKA Modeling Language) to support additional expressiveness for engineering knowledge representation. MOKA methodology provides a structured approach of translating engineering raw knowledge (understandable by the engineers) into a formal model (understandable by the software developer) using MML.

Adapting a structured KBE development methodology (either UML-based or otherwise) that provides a consistent bidirectional traceability between engineering knowledge and software code is one of the key characteristics of KBE-matured organizations. Though there are no international standards specific to KBE, some organizations are adapting general software development methodologies and tools for KBE development. Some organizations are also working on adapting MOKA methodology for KBE developments. Figure 5 shows various stages of a structured approach for the development of a KBE system.

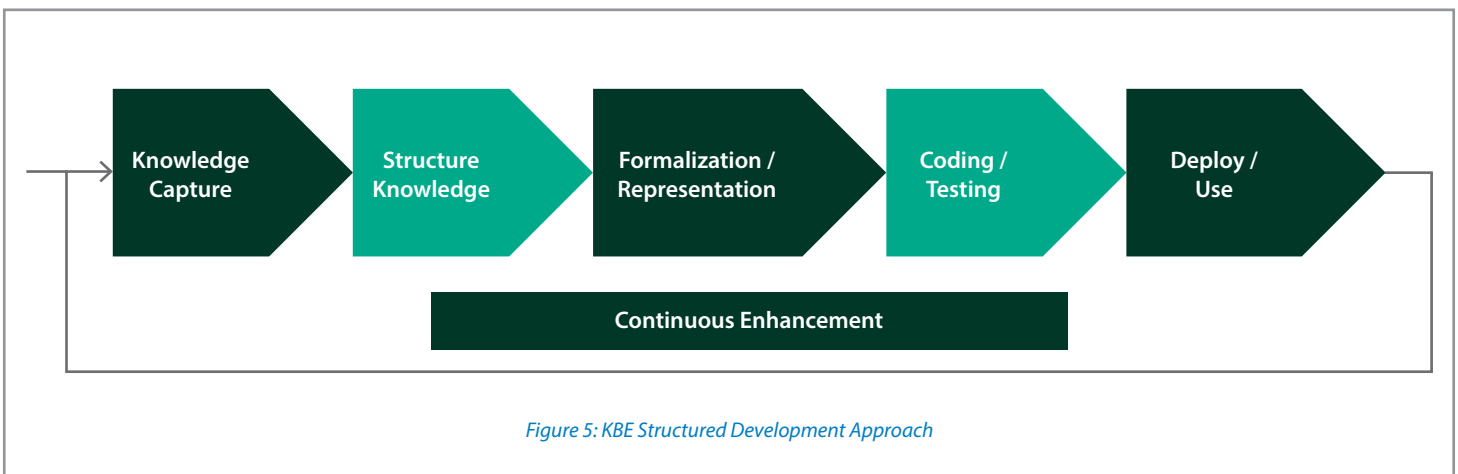


Figure 5: KBE Structured Development Approach

In the industry, there are very few organizations where KBE is considered strategic and are highly matured. Many automotive and aerospace organizations are at relatively lower maturity. KBE is a very promising area for an organization to improve its productivity in addition to leveraging its knowledge to become more competitive. Figure 6 pictorially shows the various factors that determine the maturity of KBE in an organization.

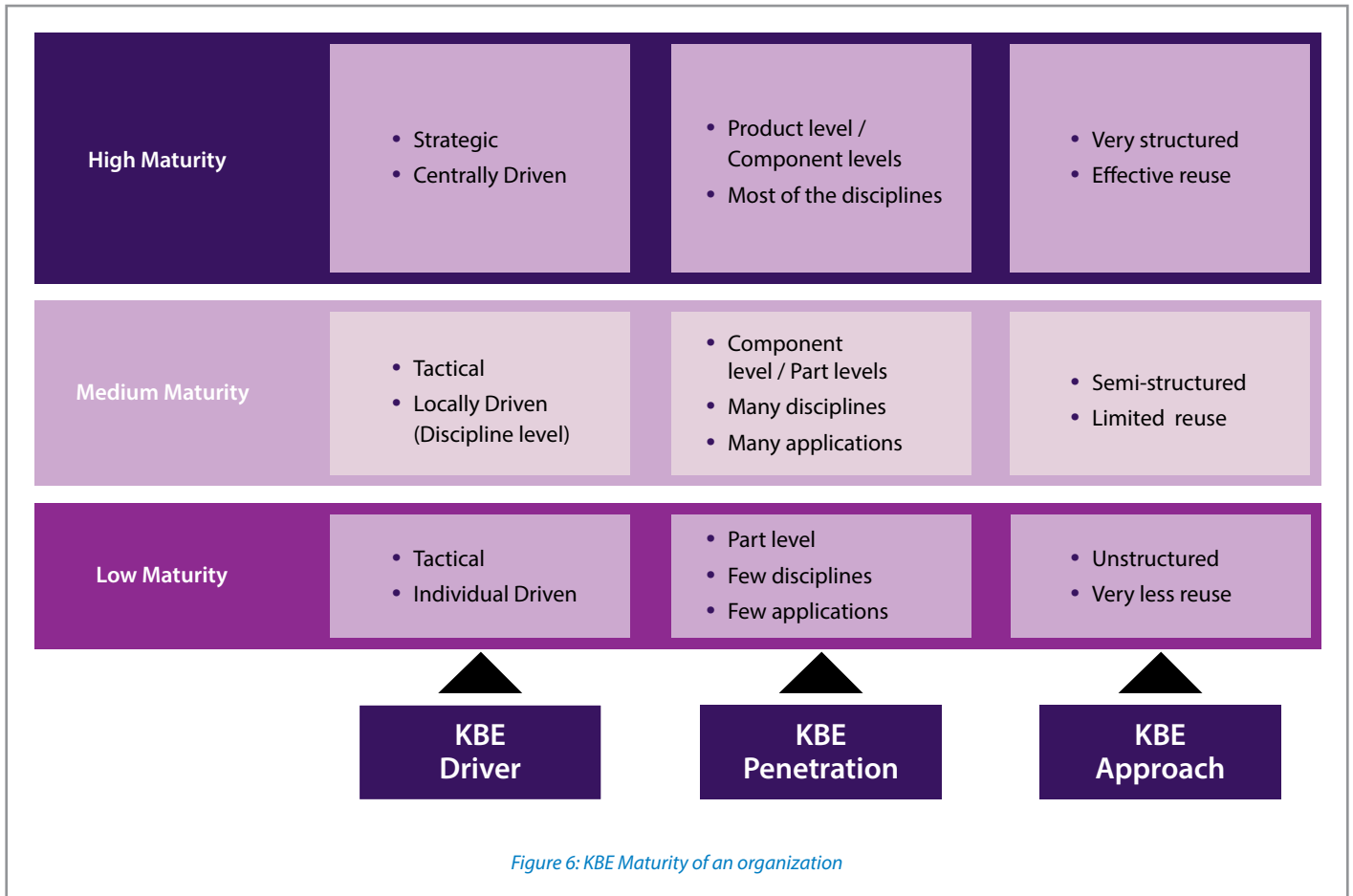


Figure 6: KBE Maturity of an organization

It is important for an organization to put key enablers in place in order for KBE to be most successful. Most of the organizations irrespective of their maturity level have realized productivity improvements, but in accordance with the level of maturity in KBE. The next section outlines some of the success factors to be considered for an organization to improve the maturity in KBE so that it can leverage the benefits to a greater extent.

Critical success factors for KBE

As discussed earlier, KBE technology involves both development as well as use of KBE systems for an engineering product development. For the development of KBE system, it is required to have an interdisciplinary team possessing software development expertise as well as domain expertise. Once the KBE system is in place, this has to be used by the designers for the actual product development. This involves a different kind of workflow, responsibility structure, as well as mind-set of the involved departments and engineers. Good management support and drive becomes a critical factor to make this happen. In addition, it is required to have a robust, scalable approach and technology for KBE system development from a perspective of long-term repetitive use, enhancement, and maintenance.

Management Buy-in

Having a strong management buy-in is a critical success factors. KBE involves

collaboration from multiple disciplines for both KBE system development as well as use of the KBE system. Unless there is good management buy-in, it becomes extremely difficult to bring all stakeholders together and keep the momentum. Management should have a long-term vision and goals that flow down to various departments or disciplines. In the absence of this, KBE concepts will be used only to a limited extent either at the local level or individual level within specific disciplines depending upon the interest and extent of support. It is also essential to capture the metrics of the benefits realized and investment done for KBE technology so that the management is convinced of the benefits of this technology. This helps to sustain the KBE momentum and reap the benefits over a long period of time.

Structured KBE Approach

As discussed in the previous section, having a structured development

methodology for translating raw engineering knowledge to the KBE system is another very critical success factor for KBE. Most of the traditional KBE approaches suffer from lack of the dynamic nature of product development formulation. Whenever anything about a product model changes, the application programmers are needed to update the software source code. By the time a design automation program is completed, it is often obsolete, providing little flexibility for change and evolution in product development. Hence it is important to have a structured application development approach wherein there is a systematic approach of translating the raw knowledge of the product and its process into KBE application code. This helps in maintaining the application over a long period of time and also to do the enhancements based on the evolution of the product.



Conclusion

Knowledge-based engineering is a product development technology wherein the knowledge of the engineering product and its design process is captured and embedded into the KBE system and then using this KBE system to design similar new products. KBE technology helps to reduce drastically the cost and time for the product development; besides having improved quality product with less time to market. Strategically, KBE enables retaining the proprietary knowledge and

valuable experiences gained over several decades and leveraging them to all future similar product development processes. Though many aerospace and automotive industries have realized significant benefits through KBE, there still exists enormous scope in tapping the benefits of KBE technology. The maturity and use of KBE across the industry is varied and typically characterized by several factors such as – KBE strategic drive, its penetration into various disciplines and levels of product

structure, and adapted methodology for KBE development. Adapting a structured KBE development approach combined with the involvement of all the engineering disciplines together in an integrated KBE product development environment with a strong management drive can bring in tremendous benefits to an organization. KBE is a key product development technology to become more competitive.

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