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KNOWLEDGE BASE TECHNOLOGIES AS A NEW PARADIGM IN DATA DRIVEN MANUFACTURING SYSTEM

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ABSTRACT

The maximization of prospects for substantial benefits and projecting the industry to fulfill the competitive needs in globally oriented business environment requires wide-ranging information based decision support system. The knowledge sharing framework requires an extensive research to improve inter-operatiability of cross-functional systems and subsequently provide the basis for diverse utilization of knowledge base technologies in manufacturing. The effective knowledge sharing framework in manufacturing industries is used to speed-up the New Product Development & Introduction (NPDI) process and improves the effectiveness of information flow in Product Lifecycle Management (PLM) environment. This paper describes the development of Knowledge Base System (KBS) to select process for making circular shapes and explores the manufacturability of the required designed product. The KBS is an expert system, used to select the suitable process and cutting tools by defining the constraint values into the system. The KBS is designed using E2KS, the state of the art software and knowledge capturing techniques. The machining examples are used to demonstrate the implementation of the system and how it will provide a basis for knowledge sharing in PLM environment. The Manufacturing knowledge is captured in order to provide manufacturing consequences.

Keywords: *PLM, NPDI, Knowledge Management, Knowledge Capturing, Knowledge Sharing.*

INTRODUCTION

Highly competitive environment and modern business requirements in the world of globalization always drive technological solutions to sustain the competitiveness of the company. In globalised economy, companies are always facing growing challenge to accelerate the new product development process to shorten time–to-market for early entry into the market and to decrease time - to - profit for quick revenue generation. In response to these challenges, companies are under high pressure to meet the demands of the market. These business requirements are[1]:

- To speed up product development
- To enhance manufacturing and supply capability and capacity
- To improve revenue from lifecycle efficiency

These new business dynamics has led the industry to a wide range of new concepts and totally forced the business gurus, industrialists, academia and scientists to develop the new strategies, which enable the industrial sector to come up with the ideas to fulfill the requirements of mass customization. Accordingly the traditional business model in manufacturing industry shifted from make-to-order (MTO), to engineer-to-order (ETO), to configure -to-order (CTO), to design-to-order(DTO) and in near future to innovate-to-order (ITO) illustrated in Figure 1. The new business model has dragged the manufacturing industry to the race of technological solutions to support these business models. These technologies also changed from traditional mass production (MP) to flexible manufacturing system (FMS), to manufacturing knowledge management (MKM), to the product customization (PC), to the product knowledge management (PKM), and to the product lifecycle management (PLM) as illustrated in Figure 2[1,2]. The integrative knowledge base approach will provide customer, developer, manufacturer, supplier the capability of knowledge sharing within PLM system and successful implementations will improve collaboration within the enterprise and will manage the product lifecycle activities more effectively to accelerate the decision making process by providing the right information at the right time. This approach will provide a basis for multifarious knowledge sharing in manufacturing industries lays strapping boundaries for further devel-

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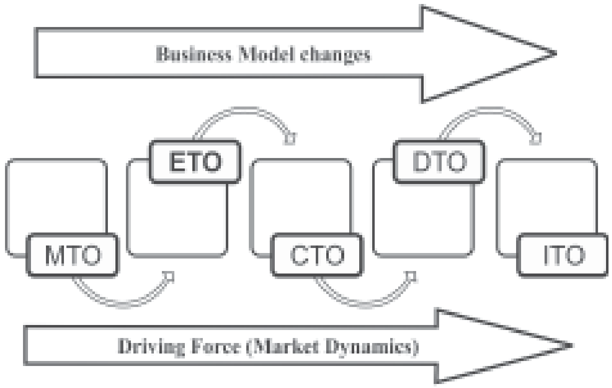

Figure 1: Development of New Business Models

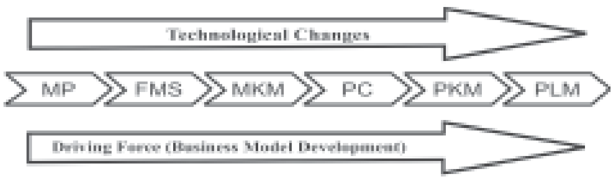

Figure 2: Technological Development

opment and applications of PLM strategy for the benefit of industries.

PRODUCT LIFECYCLE MANAGEMENT

Product Lifecycle Management (PLM) is simply, a product strategic approach based on product and stakeholder's interactions from inception to the end of life[3]. Different organizations have defined PLM in their own context. The National Institute of Standard Technology (NIST), USA has published the following definition of PLM A strategic business approach for the effective management and use of corporate intellectual capitals[12]. All manufacturers are faced with the challenge of making high quality products within a short product introduction time while reducing costs as low as possible. PLM is an emerging solution to address this challenge. PLM focuses on the creation, storage, and retrieval of data, information and, ideally, knowledge throughout the lifecycle of a product from its conceptualization or inception to its destruction or recovery/reuse/recycle or remanufacture. The aim of adopting PLM is to improve the efficiency of product development processes and the capacity of a company to use product related information[2]. PLM integrates the people, data, processes and business systems and provides product information at enterprise level[4]. With the implementation of PLM approach enhancement in productivity of new product development and innovation is achieved[5].

KNOWLEDGE MANAGEMENT

Knowledge Management is the means by which the company generates wealth from its knowledge or in other words from its intellectual capitals. The objective of Knowledge Management is the value creation. Knowledge management needs to be based both on organizational processes and on the creation of a favorable environment. Knowledge Management leads to structures and Management methods that are based on the idea of Knowledge sharing[6]. To improve product development decisions and to obtain a competitive advantage, an industry should effectively retain, transfer and improve its knowledge[7]. With this new and changed dynamics of the business scenario the knowledge capturing, representing and maintaining the knowledge have become an important aspect for companies. The competitive is powerful if it has the ability to take advantage of all its available knowledge and has the capability to apply that knowledge[8].

KNOWLEDGE BASE SYSTEM

Knowledge Base System (KBS) is considered to be an important tool for maximizing the utilisation of knaolwdge. KBS is a system that aim to follow the experience and knowledge of humans to be represented and used on a computer so as to enhance decision-making ability[13]. A special kind of database providing a base for knowledge management All KBS have the potential to accomplish the functions such as capturing, representing, sharing, reusing , transferring, and maintaining the knowledge handelled by a manufacturirng company. Due to these reason the KBS approach have been adopted in a variety of decision making processes manufacturing enterprise during last decades and continued to be a centre point for research intrest[8]. Generally the KBS is a sort of specific database which associated with knowledge management providing a way forward to digitizing collection, storage, organising and retrieval of knowledge. The KBS utilisation in PLM environment is a novel approach to accelerate the entire product design and development process and enhance innovation through;

1. Capture and re-use of design and manufacturing knowledge
2. Digitizing and automating the cyclic and same design tasks
3. Encapsulation of design rules using standards parts

4. Enhanced collaboration among design, simulation, manufacturing, and services and recycling.

This research is mainly focusing on the KBS design for manufacturing processes and suggests the ways how to share this knowledge in PLM environment and especially for design and manufacturing in PLM system with a meticulous eminence on the information and knowledge domain which is needed to support manufacturing decision making process quicker and effective. This not just only covers the process knowledge but also the resource knowledge as a prototype of knowledge base technologies in manufacturing industry and can be extended to capture all the related knowledge and information from upstream to downstream applications.

MANUFACTURING KNOWLEDGE SHARING SYSTEM DESIGN

There are different techniques to tackle the challenges faced by the manufacturing industry and applied very nicely. One of which is the PLM and interoperatiability of organizations for developing the new product. The successful implementation of PLM system requires a knowledge base support and richer information core accessible by all departments and organizations working in collaborative environment at every stage of PLM. This new Innovation in manufacturing knowledge utilization primarily the data driven manufacturing will put the manufacturing industry into the new paradigm of product design and development. Knowledge base technologies enable the manufacturing industry to exist in the era of knowledge, wisdom and information creation and sharing[9]. Manufacturing process in reality is a combination of tangible and intangible transformation to get the end product. Tangibly we get the materialistic form of the end product but intangibly the knowledge is created with the virtual transformation of data information and managing that knowledge for substantial utilization in the form of knowledge base technologies which have no boundaries and limits in manufacturing or PLM environment, which is the essence of this research. Figure 5 explains this theory in block diagram.

METHODS AND TOOLS

The KBS techniques and design are based on the knowledge transfer approach, from domain experts directly to systems. However, this approach is

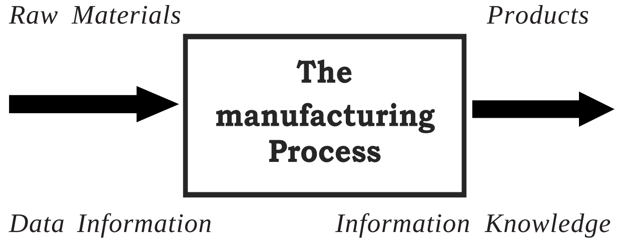

Figure 3: Real and Virtual Manufacturing Transformation

gradually replaced by the modeling approach that uses conceptual models for modeling the problem-solving skill of the domain expert[10]. Different tools and methods are applied to organise the data. Different logics and controlling factors rules are emphasiesd to manage the knowledge uses as a resource further downstream and reptitive environment. It is due to these features, knowledge base technologies have become a focus of attenton for many manufacturing organisations. Two different tools are used for designing the KBS in this research foucs.

- Unified Modelling Language (UML)
- Emergent System's Engineering Knowledge Management solution - E2Ks (Software)

In KBS the system functionality has significance. The UML is used to organise and arrange the random information as well as data into a specific order. The UML class diagrams are used to structure the process and resource knowledge in this research while the Use-case diagram is used for the graphical representations of systems behaviour and response in terms of system output when the input is provided. While the E2KS is emerging state-of-the art software (Technology) used for knowledge capturing in manufacturing environment introduced by Emergent Systems for manufacturing knowledge management solutions. E2KS provides higher maintenance and refinement of technical 'know-how and knowledge. Apart from this it also provides its systematic application to all points of 'Product' and 'Mfg Process' design, yielding compelling advancements in engineering capability. E2KS is highly-structured, web-deployed, repository and hub for technical know-how[11]. Generally E2KS is a unique 'Knowledge' base approach to managing technical know-how with a rigorous deployment of engineering standards. E2KS have different kind of features and entities like E2KS community of practice (CoP), Knowledge Pack (K-PAC) which offers a variety of options like basic K-PAC, Look-Up K-PAC, method K-PAC, Calculate K-PAC which provides a complete facilitation to capture the overall knowledge of manufacturing scenario. E2KS provides richer interface to capture and manipulate information and knowledge for human usage. Further, the captured information can be accessed and used by any other software tools. For example, E2KS information can be accessed within Computer-Aided Design (CAD) environment and the CAD information can be validated against the captured E2KS information. E2KS provides Software Development Kit (SDK) based on C^{++} and Java. The E2KS SDK can be used with CAD tools such as NX5, CATIA and PLM tools like Teamcenter.

MANUFACTURING KNOWLEDGE

A control convergence methodology was adopted to capture the information and knowledge for hole making process, required cutting tools and the materials which can be machined with that tool. The KBS will contain all this information as a source of manufacturing knowledge. Generally the knowledge base system will respond in two ways. Firstly the required process is identified and followed by required tool according to the selected process. Figure 4 explain the relation between the tolerance and the manufacturing process required under specific conditions. Generally the degree of accuracy expected reasonably from various manufacturing processes under average conditions was a basis for calculation in designing the manufacturing KBS. Figure 4 explains the rules of the process based on diameter vs. tolerances in manufacturing processes.

MANUFACTURING KNOWLEDGE

The KBS works in three steps. The first step is the process selection under specific requirements given to the system as an input and in second step the required tool will be selected and in third step the knowledge is shared in PLM environment.

Step 1 Process Selection: process selection procedure for simple hole making process is shown in Figure 8. The process selection based on three input values, upper tolerance (U.T), and lower tolerance (L.T) and diameter (D) of the hole. The E2KS knowledge base is responded with suitable process.

Step 2 Tool Selection: Once the process selected for required product then the E2KS KBS will select the required tool in available resource knowledge. Two input parameters are required the flute length (F.L) and diameter (D) of the hole. Generally the overall overview and structure of the KBS and its utilization is PLM system shown in Appendix A.

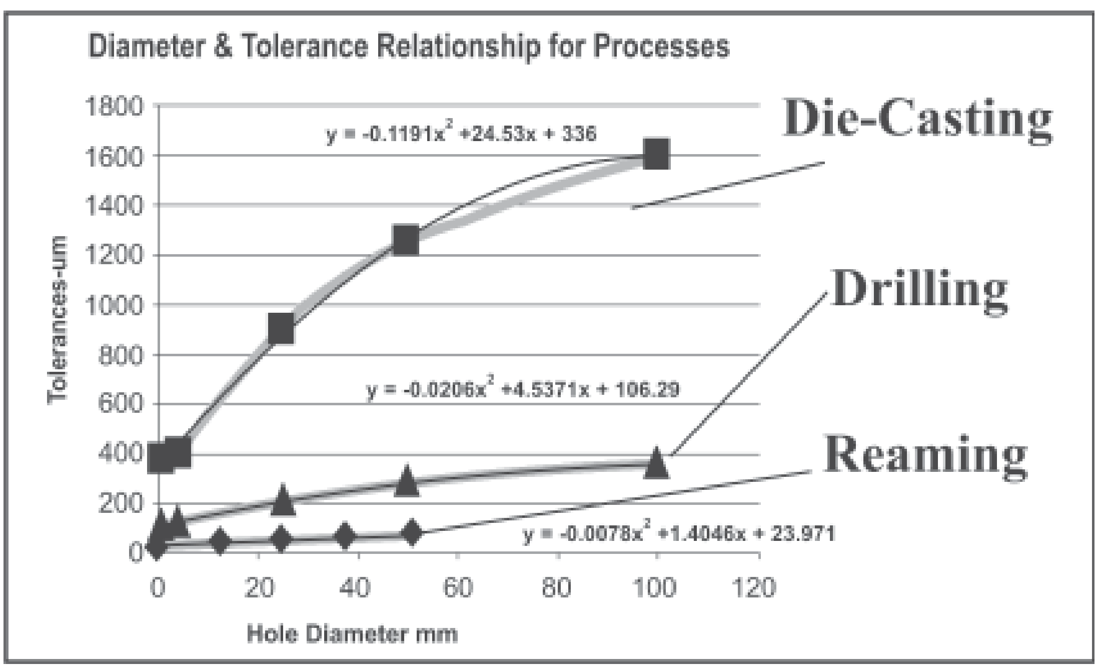

Figure 4: Description of Diameter vs. Tolerance

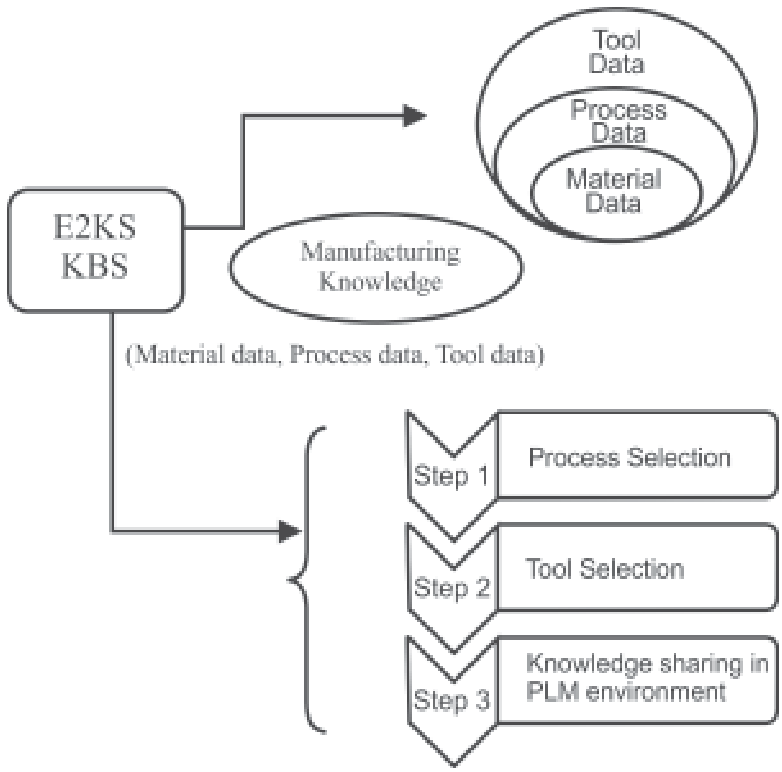

Figure 5: Manufacturing Knowledge Base (Sharing System) E2KS Process Overview

MANUFACTURING PROCESS SENARIO TO SHOW THE WORKING OF KBS

This scenario uses the simple hole illustrated in following case scenarios assumptions.

Scenario 1

- Diameter (D) of the hole: 15 mm
- Upper Tolerance (U.T): 50 (μm)
- Lower Tolerance (L.T): -50 (μm)
- Depth of hole (F.L): 55 mm

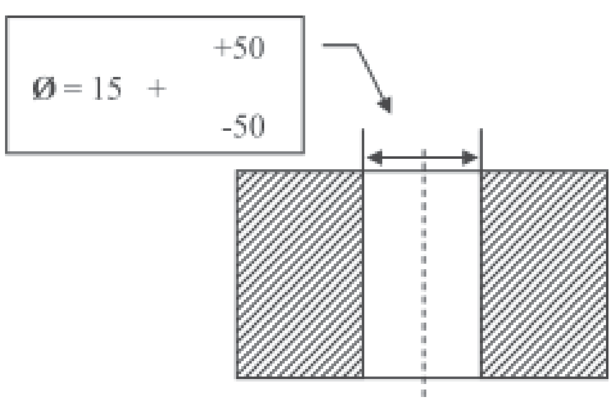

Figure 6: Hole making Scenario

The KBS resolves that what process is suitable for required size of hole as the simulation (E2KS Process Look-Up K-PAC) shown in Figure 7. Now according to the E2KS Knowledge base drilling is the required process to make the required size hole. Now the drilling tool K-PAC will resolves the required tool. The E2KS simulation is shown in Figure 8. The KBS system shows the two different tool series with required size which both can be used drilling the required hole size. Along with tool series the KBS also showing the surface finish that can be achieved with this tool and the materials which can be machined. Different types of materials can be processed with both series so now the tool selection depends on the material that supposed to be processed. This is shown is Figure 8 that how the KBS proceeds with tool selection for required dimensions.

Scenario 2

- Diameter (D) of the hole: 4 mm
- Upper Tolerance (U.T): 10 (μm)
- Lower Tolerance (L.T): -5 (μm)
- Depth of hole (F.L): 9 mm
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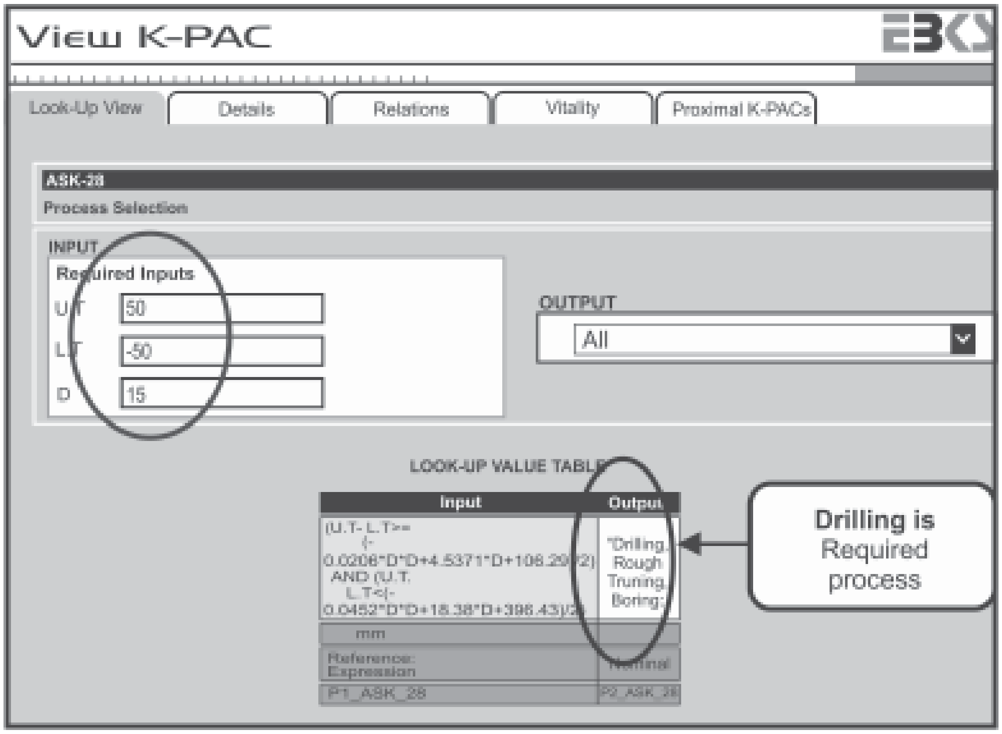


Figure 7: KBS Process Selection

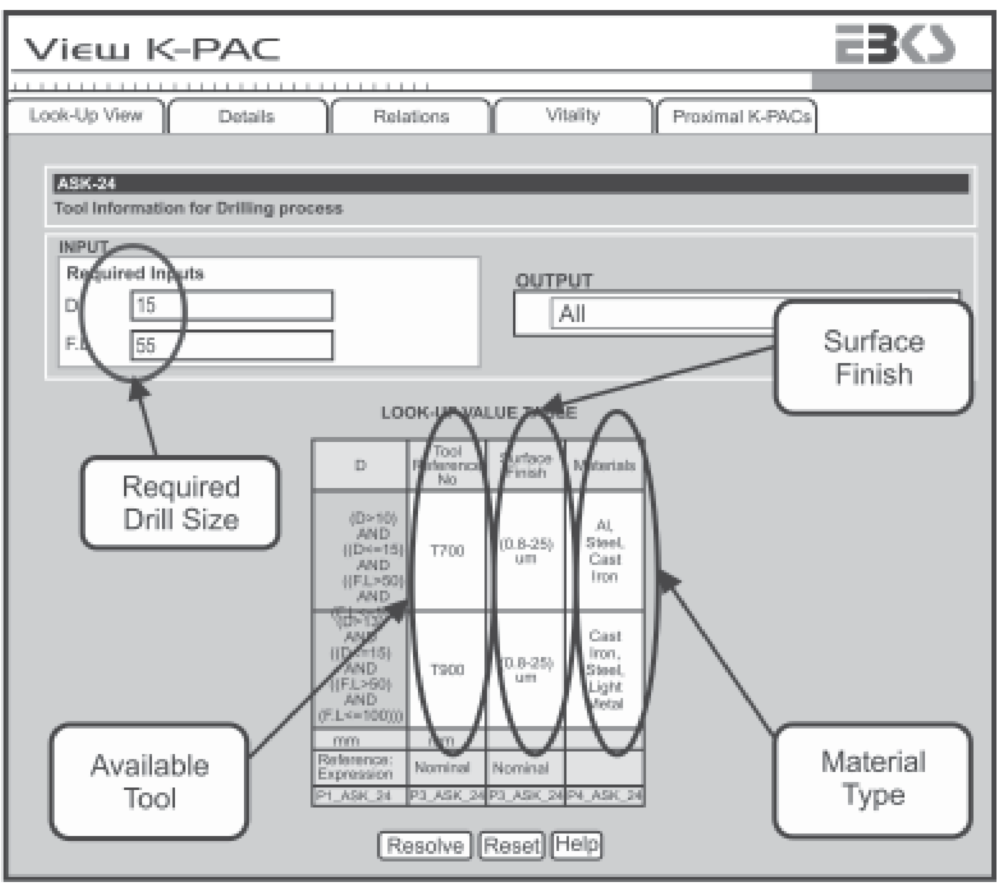


Figure 8: E2KS Tool Selection Process

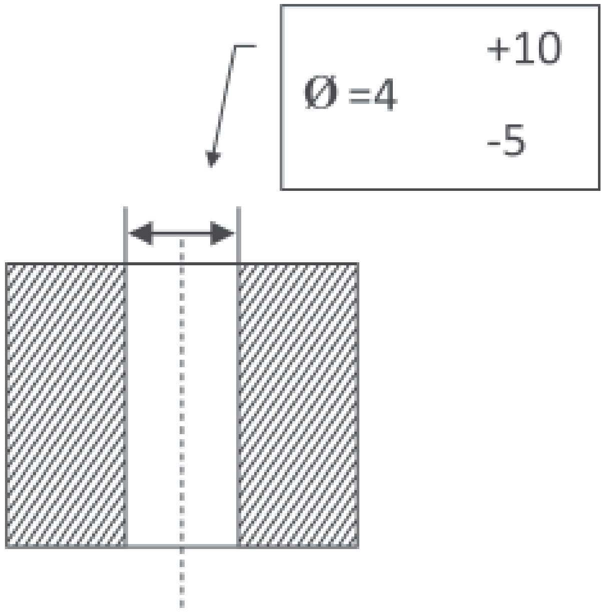


Figure 9: Hole making Scenario

The E2KS process and tool selection is shown in Figure 10 & 11. The required process is reaming and the available tools have to be looked into the reaming tool K-PAC.

Now as for reaming operation the tool is available but we cannot make the required hole size directly with reaming so first we have to drill the hole smaller than the required size. For this first we have to consult KBS to see if the required drill size is available or not. Let us say that for a 4mm (D) size and 9 mm (F.L) reamer the required drill is 3.5 mm (D) and 9mm (F.L). Figure 11 shows the available drill size to prepare the hole for reaming operation. Sometimes a problem occurs if both the tools, reamer and drill, are of different functionalities. For example if the materials are processed differently or if there is difference in the surface finish requirements.

DISCUSSION AND CONCLUSION

The future benefits for the manufacturing industry to remain competitive in the age of highly dynamic digital manufacturing are significant for manufacturing industry if the manufacturing knowledge can be shared within the company and across the whole supply chain. It is very important to explore the meaning of sharing to achieve any level of success in knowledge sharing. Different approaches and tech-

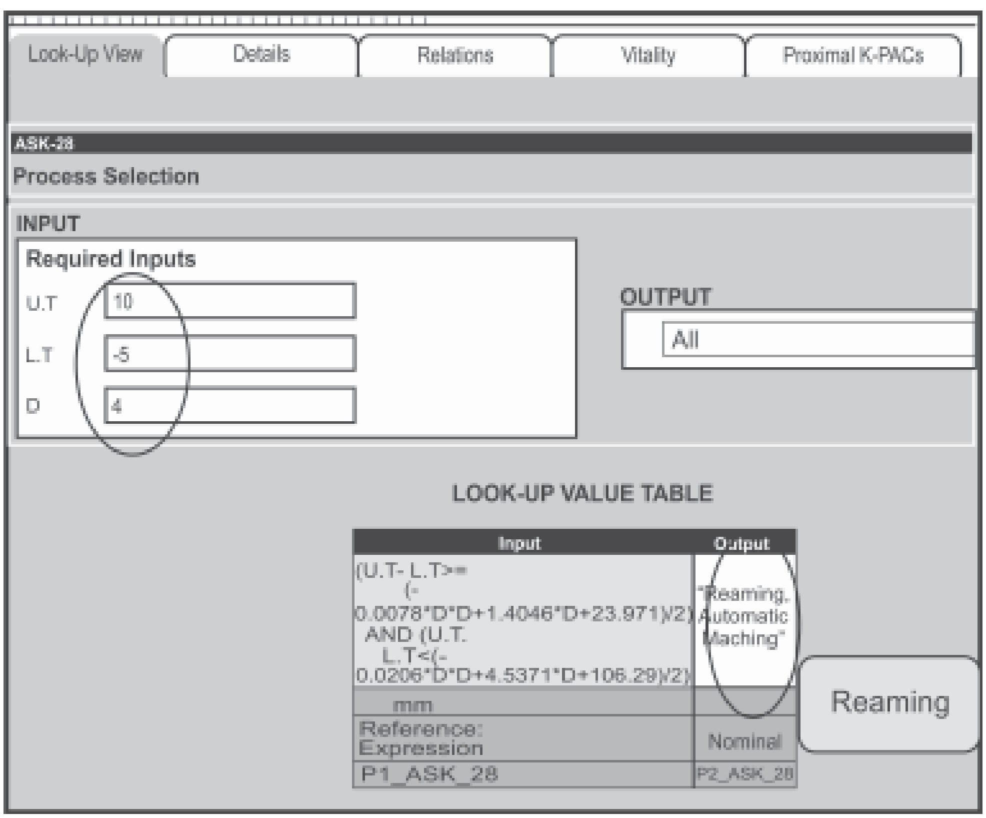


Figure 10: Process Selection for case 2

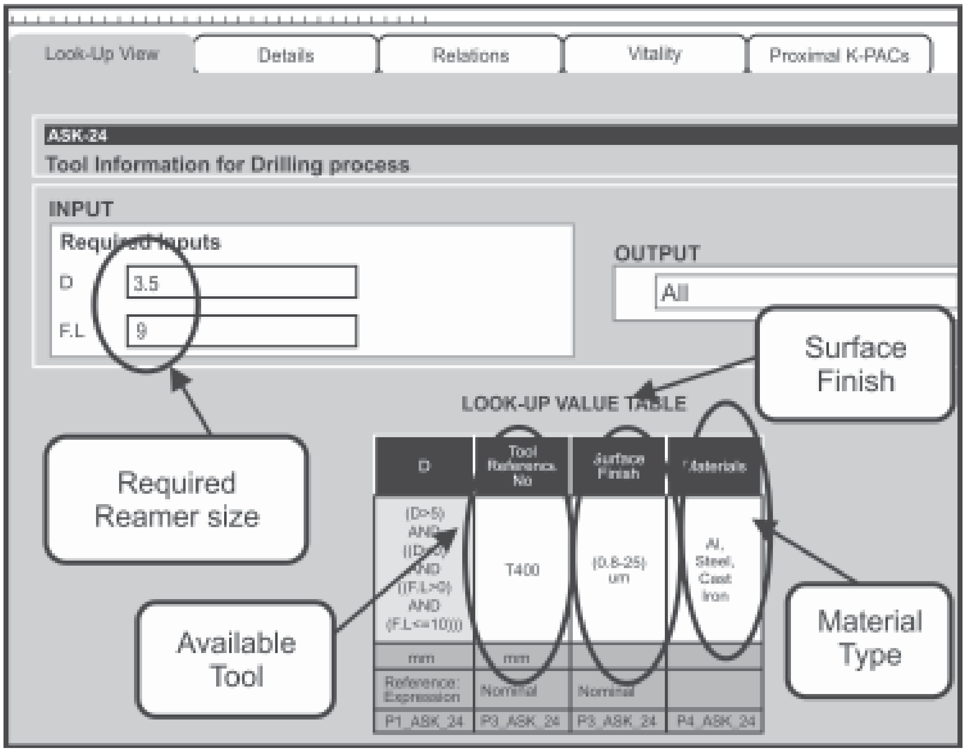


Figure 11: Reaming Tool Selection for case 2

niques are used in manufacturing industry to share the manufacturing knowledge effectively and improve the manufacturability of the system. We have developed the KBS for manufacturing industry and used the knowledge capturing tool (E2KS) for knowledge capturing. We have demonstrated the effectiveness of knowledge base (KB) technology and approach for capturing and managing the manufacturing knowledge superficially for manufacturing process and required cutting tools and argued for its value in providing an effective foundation to capture manufacturing concepts and knowledge. The system was kept related only to capture the manufacturing knowledge about the processes for making the circular shape designs and to check the capability of the tools to capture and share the same knowledge to accelerate decision making process. It is a tentative implementation of the proposed system where the Library Model is implemented in E2KS knowledge base to provide the manufacturing feedback during the product design and its manufacturing. Generally the knowledge and the approach developed and the implementations show the following:

a. E2KS has a variety of option to be used for manufacturing knowledge capturing.

b. The different K-PAC like methods K-PACs, look-up K-PACs, Calculation K-PACs etc provides different options to capture the knowledge.

c. The relationship between manufacturing and design part can be captured as rules

d. The rules can be very complex as multiple logical rules can be established.

e. The manufacturing best practice can be captured as method K-PACs

f. This E2kS knowledge base provides a foundation for manufacturing capturing and this knowledge can be shared in PLM environment.

The E2Ks knowledge base system partially implemented which can be further developed and integrated with some sophisticated functionalities like:

a. E2KS knowledge base can be shared in PLM environment tools like Teamcentre, etc

b. E2KS offers the integration facility with other CAD software tools like NX, CATIA, so the manufacturing and Design knowledge can be directly captured from CAD data.

c. E2Ks also perform the design realisation activities within the CAD environment by accessing the captured information with knowledge fusion functionality.

The integrative E2Ks Knowledge Base will provide customer, developer, manufacturer, supplier the capability of knowledge sharing within PLM system and successful implementations will improve the product lifecycle collaboration with the enterprise and will manage the product lifecycle activity effectively to accelerate the decision making process by providing the right information at the right time. Indeed the Knowledge Base will provide the foundation for developing a PLM system and the PLM concept and use of ICT in manufacturing sector will lays strong frontiers for further development and applications of PLM strategy for the benefit of industries. This research will provide a referring guide for professional research to conduct further research. An extensive research is currently underway to explore the inter-operation and knowledge sharing issues across the virtual manufacturing organization and improve the future inter-operatiability of the system and knowledge sharing procedures.

NOMENCLATURE

PLM: Product Lifecycle Management

KBS: Knowledge Base System

U.T: Upper Tolerances

L.T: Lower Tolerances

F.L: Flute length

D: Diameter

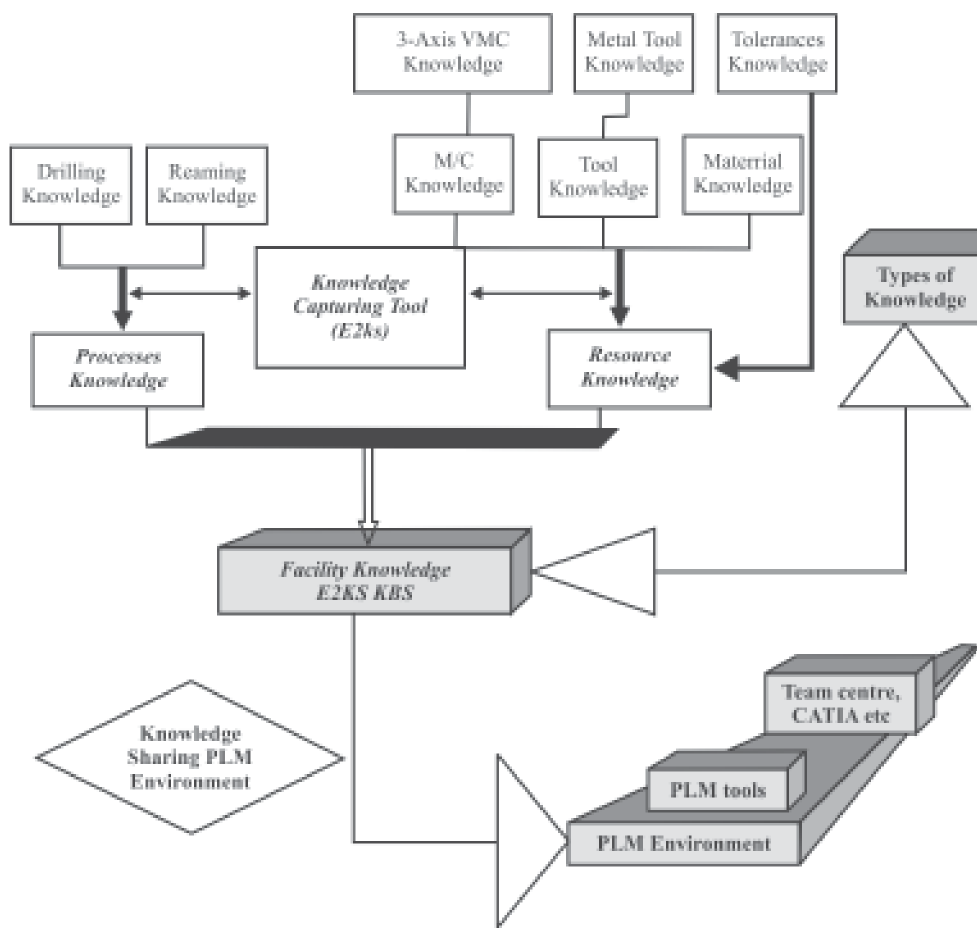
E2Ks: Software

CoP: Community of Practice

K-PAC: Knowledge Packets

Annex A

E2KS Knowledge base System overview & KB utilisation in PLM environment



REFERENCES

1. *Group, A. A., 2001. OLM Strategy, Key to Future Manufacturing Success*

2. *Guixiu Qiao, C. M., 2004. Manufacturing Information Integration in Product lifeCycle Management. New York: Wiley.*

3. *Ameri, F., & Dutta, D., 2005. Product Lifecycle Management: Closing the Knowledge Loops. Computer-Aided Design & Applications, 577-590.*

4. *Metafore. (Not available, Not available Not available). PLM Consulting and Services.*

5. *Stark, J., 1992. Engineering Information Management Systems. London: Springer*

6. *Bukowitz, W., & Williams, R., 2001. Knowledge Management-LearningBusiness.*

7. *Editorial, 2008. PLM Challenges. Advanced Engineering Informatics (22), 419–420.*

8. *Guerra-Zubiaga, D. A., 2004. A manufacturing Model to enable knowledge maintenance in decision Support Systems. Doctoral Thesis . Loughborough University.*

9. *S.Loub, Z., & Fang, X., 2001. KBS-aided Design of Tube bending processes. Engineering Applications of Artificial Intelligence (14), 599-606.*

10. *R.I.M Young, A. A.-D., 2007. Manufacturing Knowldge Sharing in PLM: a progression towards the use of heavy weigh ontologies. International Journal of Production Research , 45 (7), 1505-1519.*

11. *Emergent, S. (Not Available). Emergent Systems. Retrieved June 23, 2009, from Enterprise Engineering Knowledge System: availbe at [www.emergentks.com]*

12. *Grieves, M., 2006. Product Lifecycle Management: Driving the next Generation of Lean Thinking. New York: McGraw-hill.*

13. *Stark, J., 2004. Product Life Cycle Management-21st Century Paradigm for Product Realisation. London: Springer.*