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Product Design Knowledge Reuse

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Abstract - **Engineering design is the most important activity of the product development process. In order to cope up with the frequently changing demands of the customers the companies are forced to modify or change the products. Development of any product consists of number of processes & these processes demand thorough knowledge of the particular process. Adapting the changes as per the customer demands is most challenging & requires strong knowledge base. For this, the reuse of the knowledge is the key. Knowledge storage & reuse is required throughout the product life cycle.**

Keywords* — *Product design, Knowledge based engineering, Design knowledge reuse

I. INTRODUCTION

There are a variety of proposals and analyses of design reuse methodologies and systems in the research literature. They come from a variety of domains including engineering design science, computer aided design / computer aided manufacture (CAD / CAM), artificial intelligence, and knowledge management [7].

The analysis show that still there is lack of support for early conceptual design problems which needs to look after. Effective design reuse is a whole system issue:

--Product design processes,

--Information management, and

--The products must be considered together.

Process (modeling) represents knowledge and can be applied to reusing design knowledge. Process models can be integrated with other aspects of design. A variety of approaches have been developed, however the integration is often not applicable to the whole design process [8].

Knowledge Based Engineering (KBE) issues in conceptual design are centered on information gathering, and the capture and reuse of design knowledge. Design knowledge, once embedded in KBE systems, is not reusable to the non-programmers. These demands for a common approach for knowledge reuse through the entire product development cycle [6].

II. KNOWLEDGE BASED ENGINEERING

Knowledge Based Engineering (KBE) is a term describing the application of knowledge to provide some level of automation in the engineering task. The term could be argued as being interchangeable with 'intelligent design' and 'design automation'. KBE can be applied to a wide range of design tasks. KBE as a general technology type can be applied to a range of problems. It can not be considered as a stand-alone design reuse solution; it requires a supporting methodology [9].

Knowledge-based engineering (KBE) provides a way of formalizing and automating product development. Design knowledge is utilized to expedite the cycle time from product design to manufacturing, at the time it assures the artifacts meet standards across design and manufacturing disciplines [10].

In terms of shared understanding and knowledge representation, the development of ontology and its application to engineering design is providing a means to represent domain knowledge: understanding product (or manufacturing, service, or any domain) concepts, data elements, and relationships between concepts [11]. Figure 1 shows an overview flow of knowledge based system

III. DESIGN KNOWLEDGE

Design knowledge in product development integration system is a generalized concept. It includes the product design information and the information derived from design information. Design information includes the form information such as engineering document, calculation expressions, CAD data, and other informal information such as measurement and tolerance of design, scheme selection, market information, market forecast, gist of decision-making, and so on. The result includes the knowledge re-created by product design, such as experience and rules [12].

Design knowledge in product development integration system can be categorized as follows: Market information, design parameters, Engineering material, system scheme, function design, structure, process, relation knowledge,

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process planning information, experience, and rules. Market information knowledge includes consumer advices, individualization demand, market direction, and so on; design parameters include applied standard, technique parameters and technical requirements, etc; engineering material knowledge includes handbook, catalog, standard, etc; rules include all what is created by field experts and knowledge engineers during their cooperation [13]. Various categories of design knowledge are shown in the figure 2 below.

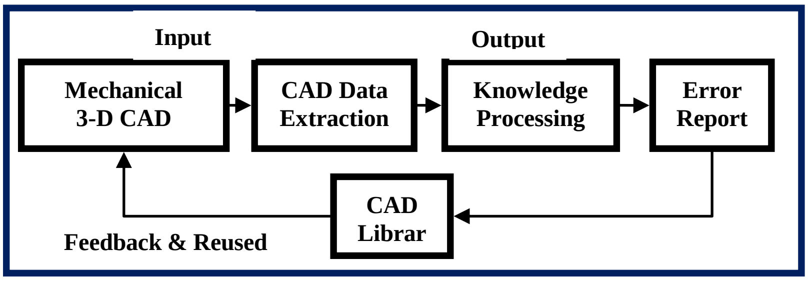

Fig.1 An overview flow of knowledge based system [5].

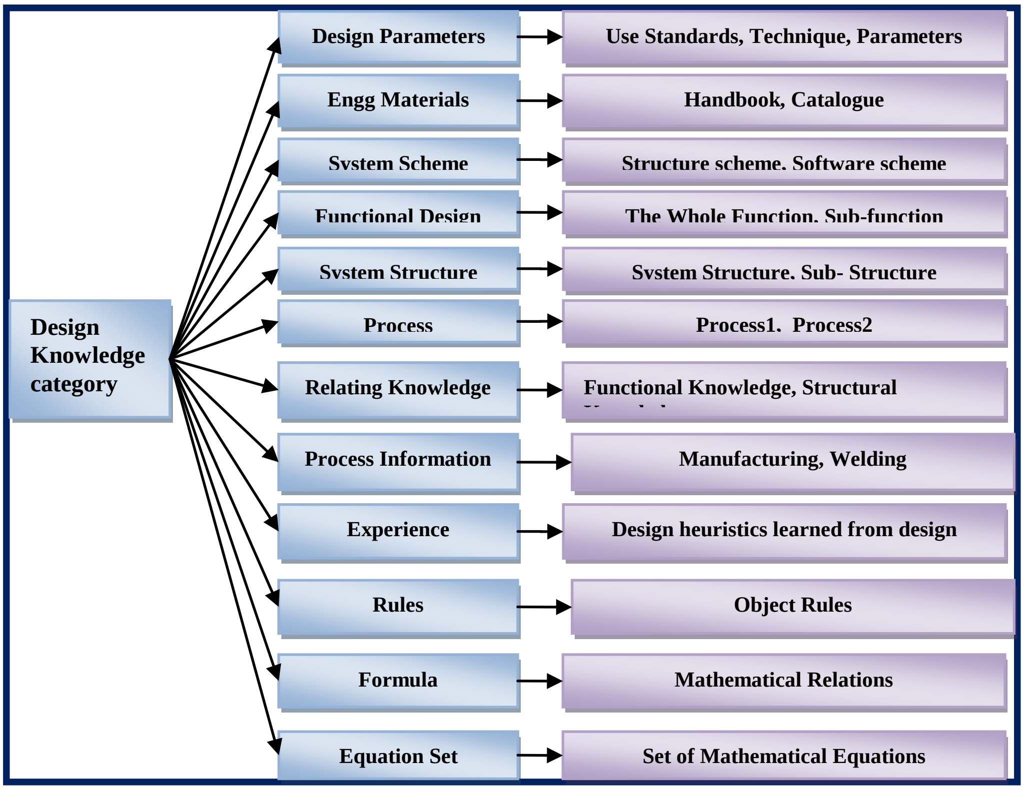

Fig. 2 Design knowledge categories [5].

IV. DESIGN KNOWLEDGE REUSE

The knowledge elements that this method will address are: product, task and process. For a given design project, product knowledge (requirements, dimensions, users, and a range of other parameters) is provided through a design process interface, along with task knowledge (how to carry out that task). Process knowledge forms a central element of the design project, by guiding the design personnel in their activities (what task happens first, which task is next). The process knowledge also includes links to relevant task and product knowledge sources [14].

Figure 3 above, shows how the interaction of these elements enables knowledge reuse. Assuming that the system is in place, and has been used for a previous project, the situation is as follows: the past project informs the current project, by providing product, process and task knowledge. The process knowledge is a formal process model, describing the product development activities and their sequence. Product knowledge includes a parameter set that is required by the design process. As each task is completed, the product parameters are updated. They are also provided to subsequent design tasks to show the task input and constraints [5]. For each task description is provided. Each element will be described in more detail below.

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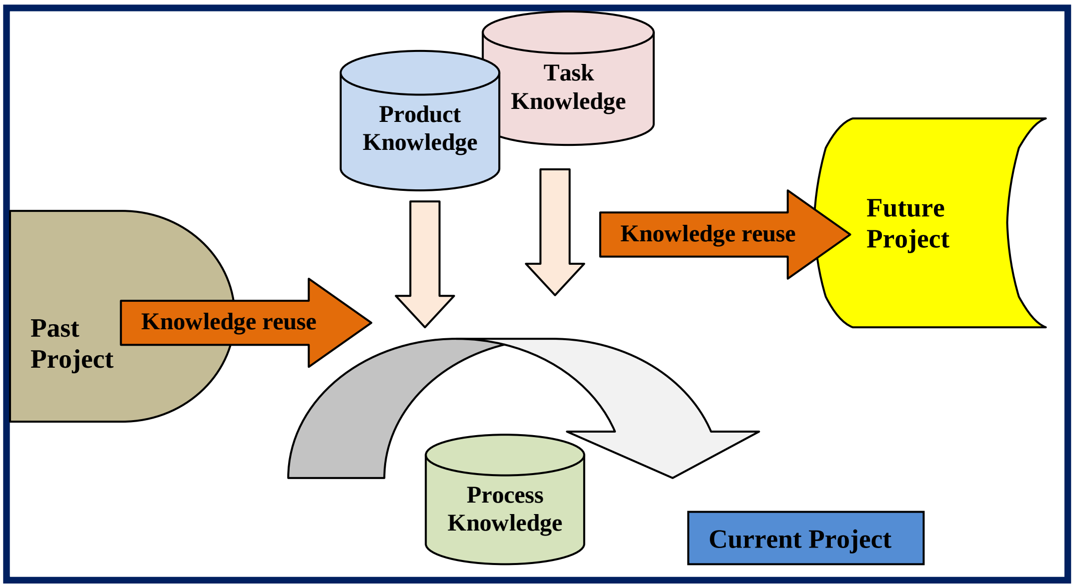

Fig. 3. Components of design knowledge reuse [5].

a. Process knowledge

Process knowledge essentially includes a process model, which consists of tasks and links between tasks. Link types include precedence, iteration, feedback, and feed forward. Through a series of iterations to create a detailed task model of the product development process, important knowledge about relationships between tasks and relationships between those tasks and product features can be identified, and the best practice methods for developing products can be applied to the next generation [15].

A detailed task model of a design process represents a great deal of knowledge about not only the product, but also the organization, its employees and other stakeholders, the competitive environment, suppliers, customers and relationships. In this proposed method these additional elements are not explicitly addressed. In defining the process that is best suited to the development of a particular product type or family in a particular organization, these complex environmental factors must be implicitly addressed. So, aside from the inherent complexities of the technical or engineering focused product development process, mapping a design process must also reflect additional non-technical constraints and influences. It is the combination of the technical product knowledge and the knowledge of additional environmental factors that gives rise to the specification of a product development process that is best suited to a particular product type in a particular organization [16].

Once the process is modeled, the significance of environmental or specific technical factors that gives the process such value could be lost. These implicit elements cannot be easily recorded in a process model. There are techniques, such as relationship diagrams or rich pictures, which can be applied to demonstrate the nature of the environment; however these are outside of the scope of this study. The capability to record additional information, whether environmental, social or technical, must be supported by the design knowledge reuse framework in order that sub-optimal decisions are not made in a later stage where important contextual factors have changed. For example, the selection of a 3-axis milling machine has a significant influence on the product design. If a company has substantial in-house capacity, then that method must be given consideration during design. Other manufacturing method selection influences may be due to production volumes or specific technical requirements, such as low cast porosity. Again, manufacturing method selection has a significant influence on design, so the rationale for the previous selection of a particular method should be visible in a new project. These manufacturing related factors are technical, and quantifiable. There are also non-technical factors that can influence product design, such as the release of a new competitor product, or a request from a large customer for a specific feature [5].

The combination of the technical and non-technical elements into a best practice product design process model should seek to capture the process along with some of the process rationale. Additional knowledge referenced by the task model therefore includes product knowledge (including a data model), as well as task knowledge (how-to descriptions and supporting information). These are described next. The task knowledge allows recording of free text, which enables the description of historical and contextual factors that led to the definition of that process [17].

b. Product knowledge

Product knowledge includes a product data model, product elements and parameters. Every aspect of the

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product that is used or created by a design task must be included in the product data model. That is, where a product feature or parameter is referenced by a task, it should be included in the product data model. Some design tasks will include product data such as 'customer', 'production volume' or 'location', each of which have an indirect influence on the product design. Other tasks will reference product data such as 'component x material', 'component x axial length', and a range of other geometrical and physical descriptors [18].

It is not the intention that the product data model replaces (or includes) a full geometry description, since the complexity of this task would be very high for a limited return: CAD systems are already very good at representing product geometry and it is not the intention to replace them. The aim of the product data model is to support the creation of the product, by storing any additional data required for or created by design, engineering, manufacturing (and any other) calculations and analysis. From the earliest stages of design, a range of product data is generated [19].

Requirements data, for example, is applied in very early calculations for product feasibility analysis, product costing and project planning. Capturing a shared view of the product data from a whole-life-cycle perspective will enable reuse of the data and the complex knowledge structures supporting them. A 'whole-life-cycle' perspective means that rather than considering just one stage of product development, all stages can be represented from requirements capture to design, manufacturing, maintenance, remanufacture, recycling and disposal [20].

In order to enable concurrent application of the various elements of product data, including distributed access and updating, the product data model must be a centrally managed, shared model based on a shared understanding. Common access to product data is an important issue, and must be considered from a variety of technical and socio technical perspectives. This issue will be addressed to some extent in the method development and analysis stages. The more relevant issue at this stage is common understanding of the product data.

c. Task knowledge

Task knowledge includes textual and graphical how-to descriptions, rules, and a full range of linking options to additional sources of information. It also enables the recording of contextual factors.

The content of the task knowledge will be dependent upon the needs of the user and the knowledge and experience of the author. It will also vary greatly depending on the nature of the task. The description could be a how-to description supporting a structured form to fill in, or a selection of images and text to describe the background of a task. Hypermedia provision through modern Office systems and Internet browsers provides a very flexible means to represent a wide range of data, information and knowledge. 'Additional knowledge' may refer to a detailed step-by-step task description, an online supplier parts catalogue, a British Standard document, a web page with information on a specialist subject, or a discussion group [21].

The main requirement of the task knowledge method is flexibility; however it should also be structured to support knowledge capture and reuse.

V. Design Reuse: Benefits and Problems

Around 20% of the designer's time is spent searching for and absorbing information. Furthermore, around 40% of all design information requirements are met by personal stores, despite the fact that more appropriate information may be available from other sources. The type of information used changes during the design process. The Design Reuse Process Model is a cyclic process where knowledge is abstracted from a new design and used to build or enhance the domain model and reuse library, which in turn are used to support the new design. Design for reuse was considered to provide greatest benefits, followed closely with design by reuse, the reuse library and the domain model. Design for reuse is a more fundamental approach to design reuse than design by reuse, and requires greater change [22].

Design reuse, with all its perceived benefits, remains problematic. Most reuse problems were cases of reuse not taking place: belief that reuse was desirable but not practiced.

The next most common problem was an unexpected amount of additional effort to reuse. Others include knowledge loss through inappropriate replication, and error where existing designs were reapplied to new purposes (performance failure). Most problems were caused by organizational factors, followed by environmental, engineering factors, cognitive factors and finally motivational factors. Organizational factors inhibiting reuse include: reuse of specific designs instead of standard designs caused problems, large numbers of designs make classification problematic, and project managers are accountable for project performance, so have no incentive to spend extra time making designs reusable [23].

The application of design for reuse is made complex by organizational factors. The benefits of reuse are provided by fast access to the right information, and hindered by organizational, environmental, engineering, cognitive and motivational factors.

VI. Conclusion

In conclusion, it is crucial to consider design reuse within the context of design. The design reuse approach should be developed alongside the design methodology, since the

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methodologies are not mutually exclusive. Rather, design methodology and design knowledge reuse are reliant on one another: each leads the other. Conceptual design should be considered as an important element of design knowledge reuse. With that, it is also important to note that different knowledge types require different representations and reuse methods. Users of a knowledge reuse system must be considered.

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