Implementation of agile manufacturing — an AI and Internet based approach

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Abstract

This paper presents a new approach to implementing agile design and manufacturing concepts. The approach is based on the integration of artificial intelligence (AI) and Internet technologies with the conventional design and manufacturing techniques. An architecture based on AI and Internet programming is proposed for remotely and quickly accessing bearing design and manufacturing expertise at low cost and thus implementing design and manufacturing agility. The expertise includes the intelligent selection of journal bearings and their mounting techniques as developed so far. The expertise can be accessed globally through the Internet interface with the selection of a bearing type and configuration for a specific rolling bearing application, the bearing mounting details and the bearing lubrication and sealing devices design. The paper concludes with a discussion on the potential benefits, and the future applications of AI and Internet based agile manufacturing technology in industry. © 1998 Elsevier Science S.A. All rights reserved.

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1. Introduction

Global competition has dramatically increased the need for companies to produce high-quality, competitively priced products both quickly and efficiently. Within such an environment, success reflects the ability of a company to quickly respond to customers’ requirements and design, prototype, manufacture, test, and deliver a high-quality product to the market in the least time possible. Agile manufacturing is an emerging technology for a firm to achieve flexibility and rapid responsiveness to the changing market and customers needs.

The path to agile manufacturing paradigm can be paved by re-engineering the enterprise, re-design its processes, and to be more radical, using various enabling technologies. There are many publications from researchers and practitioners on agile manufacturing [1–5]. However, the work reported has mainly focused on formulating concepts and developing strategies. In this paper, an artificial intelligence (AI) and Internet based approach is presented achieving design and manufacturing agility. The approach is implemented by taking journal bearings selection and design as exemplars. The work presented here is based on the primary results from an ongoing research project undertaken at Glasgow Caledonian University.

2. Agile manufacturing conception and enabling technologies

As shown in Fig. 1, manufacturing industry has experienced some notable changes, from mass production through flexible and lean manufacturing towards agile manufacturing philosophy, in the past two or more decades. The changes are directly driven by the requirements for products’ price, quality, delivery performance, customer choice, etc., which may result from the factors of unexpected changes of competitive market environment, globalisation of market, a variety of customers’ demands, customer-designed products, and shortened product life cycle. These factors have a great impact on all of the manufacturing-related activities.
such as order, design, planning, manufacturing, workshop floor control, assembly, delivery, maintenance, and marketing, etc. Manufacturers must work hard to achieve not only high quality, productivity, and reduced cost, but also the ability to react quickly and effectively to the market which is becoming more international, dynamic and customer-driven. This phenomena is getting to be more common in manufacturing industry in the 1990s.

The term ‘agile manufacturing’ came into popular usage with the publication of the Iacocca report in 1991 [6]. The manufacturing agility they defined is the ability to thrive in a competitive environment with continuous and unanticipated change, to respond quickly to rapidly changing, fragmenting and globalising markets which are driven by demands for high-quality, high-performance, low cost customer-oriented products and services. Manufacturing agility is accomplished by integrating all of the available resources including technology, people and organisation into a naturally co-ordinated independent system which is capable of achieving short product development cycle times and responding quickly to any sudden market opportunities.

Typically, agile manufacturing has the following features:
- It implies breaking out of the mass production mould and producing much more highly customised products based on when and where the customer needs them in any quantity.
- It amounts to striving for economies of scope rather than economies of scale, without the high cost traditionally associated with product customisation.
- Increased customer preference and anticipated customers needs are an integral part of the agile manufacturing process.
- It requires an all-encompassing view rather than only being associated with the workshop or factory floor.
Agile manufacturing further embodies such concepts as rapid formation of a virtual company or enterprise based on multi-company merits alliance to rapidly introduce new products to the market.

It requires more transparent and richer information flow across product development cycles and virtual enterprises without any geographical and interpretational limitations.

Compared with other manufacturing technologies, agile manufacturing is primarily a business concept but new technology is still one of its most important driving forces. Agile manufacturing has to be further developed based on the past development in terms of applying new technology but with a new dimension of customer-oriented virtual manufacturing. Fig. 2 shows a scenario using Internet/Intranet networks to speed up information flow in a product development cycle and thus to achieve reduced development time and costs. Within this scenario, a product design is developed through information media including design notes, graphics, images, numerical data, technical drawings, etc. Alternative designs are evaluated and design issues addressed through solid modelling and simulation analysis. Final design is converted into manufacturing codes through CAD/CAM, CAPP and other CAX tools. The information from workshop floor and the market is simultaneously fed back to the product development team. The team functions in a fast-paced, concurrent engineering environment in which decisions are made quickly and often involve geographically dispersed participants. To a significant degree, the success of an agile enterprise hinges on the application of new technology which supports comprehensively accessing, exchanging, sharing and use information, and speeding up the information and work flow in the product development cycle.
3. A proposed approach and its application in journal bearing design

3.1. Journal bearings

Journal bearings are basic mechanical elements for supporting rotational and reciprocating motion in a variety of engineering products. Journal bearings are a massive family and are normally divided into seven main categories as shown in Fig. 3. Bearing design includes the selection of bearing type, configuration and materials, bearing life calculation, mounting details, sealing devices, and lubrication specification. Therefore, the selection and design procedure of a journal bearing is very complicated and relies heavily on specialist knowledge and practical experience [7].

Current methods of selection and design of journal bearings can be loosely classified as manual and computer aided. The manual method normally uses manufacturers’ catalogues and design handbooks (book type) or electronic catalogues (CD-ROM media). In this method many complicated factors have to be considered by the designer in the decision making process toward the final selection and design outcome. Obviously it is very tedious, ineffective and even difficult to make the trade-off among these factors. Computer aided methods are usually implemented in algorithm-based systems or expert systems. These computer programs provide automated design procedures or rule based expertise. The paradigm is that of replacing human beings by intelligent design support systems. There have been some successful applications but the systems also have their disadvantages. The most serious limitation of such systems is an inability to learn from operating experience and the difficulty in building inference sequence with particular reference to the multi-disciplinary requirements from an engineering application. These systems are normally machine based and unable to be remotely accessed over networks.

3.2. An AI–Internet based approach and its implementation

Fig. 4 shows the architecture of an AI and Internet based system for journal bearing design. The system is an open system which can be accessed through Internet anytime globally. The system is designed based on agile manufacturing philosophy. The system allows a customer (or a designer) to input the application requirements and then it quickly responds and provides an optimal selection and design solution.

At Glasgow Caledonian University worldwide web (WWW) site, an intelligent bearing design system is implemented, which includes seven modules such as electronic catalogue, intelligent selection, mounting details, sealing devices, lubrication, manufacturing database and design module. These modules are developed through the integration of AI with the conventional bearing design and manufacturing techniques. A designer can remotely interact with these modules and thus access the bearing design and manufacturing expertise to quickly and effectively solve the problem.

For instance, a designer or a customer can access the intelligent selection module and interactively input the application requirements, the module search engine responds and provides an appropriate selection of bearing type and associated configuration. Fig. 5 illustrates the diagram of the search engine which was developed...
using combined artificial neural networks (ANN) and fuzzy logic systems (FLS) techniques[8]. The certainty or uncertainty inputs such as load, speed and working temperature etc., from the designer are fuzzified through the fuzzification module (FLS). Its output within 0 and 1 is used directly as the input to an ANN. The output of the ANN corresponds to each type of journal bearings depending on the computing results.

Fig. 6 shows a specific Glasgow Caledonian University WWW site page which is programmed with hyper-text make-up language (HTML). Eventually, a designer or customer will access the intelligent bearing design system through such an interface via Internet. The accessibility of the system can be controlled by issuing a password.

4. Further work

The work presented is based on the primary results as the project progressed so far. The following work needs to be undertaken to further fulfil the project goals:

- Further developing and validating the electronic catalogue and other modules. An Internet based bearings catalogue has great significance for the broad publicity and accessibility of bearing products.
- Further developing and implementing the Internet based intelligent selection and design support system for journal bearings. The system aims at not only providing a comprehensive design support for the bearings but also with design and manufacturing agility in terms of responsiveness and accessibility.
- Integrating the system developed with virtual manufacturing and enabling the system as a part of a virtual company as requested.

5. Conclusions

In this paper an AI-Internet based approach is proposed for implementing design and manufacturing agility with particular reference to journal bearing design and application. Primary development and exploration results show the approach having great potential in terms of quickly providing design expertise and solutions based on the customer's requirements. However, there are still some technical issues which need to be further tackled such as the linkage of HTML and Java programming, remotely executing a system and its associated data flow, the linkage of Java and C++ programming, data flow rate over the networks, etc. The authors believe the approach will be practically implementable with the advance and broad application of computer networks and Internet technologies.
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References