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DESIGN OF RECONFIGURABLE MACHINE SYSTEMS: KNOWLEDGE BASED APPROACH

PROJEKT REKONFIGUROWANEGO UKŁADU MASZYN. PODEJŚCIE OPARTE NA BAZIE WIEDZY

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Abstract: The Reconfigurable Manufacturing System (RMS) offers a flexible, changeable and dynamic manufacturing platform which is complex. The RMS evolved from the necessity to satisfy the markets highly customised demands. As the requirements of the customers vary the manufacturing system will need continuous and timely reconfigurations. A Knowledge Based System (KBS) is therefore the critical link in the module selection from a database to configure a machine. Modules will be selected to be timeously assembled into machine tools to manufacture customised goods with minimal disruptions to satisfy customer delivery times.
This paper will review the issues surrounding KBS software and their characteristics, as the appropriateness and requisite for establishing an RMS knowledge based system application is explored. Basic machine tree structures for the KBS application are also presented and discussed.

Keywords: Knowledge Based Systems, Reconfigurable Machine Tool

Streszczenie: Rekonfigurowalny System Wytwarzania (RMS) stanowi elastyczną, zmienną i dynamiczną platformę produkcyjną, będącą złożonym układem. Systemy RMS z potrzeby zaspokojenia wymagań rynków, dostosowanych do indywidualnych żądań klientów. Ponieważ potrzeby klientów się zmieniają, systemy wytwarzania będą wymagały nieustannej rekonfiguracji wykonywanej z zachowaniem określonych ograniczeń czasowych. System Baz Wiedzy (KBS) jest więc elementem krytycznym w sekcji modułów, łączącym bazę danych z procesem konfiguracji maszyny. Wybór modułów będzie dokonywany z uwzględnieniem czasu potrzebnego do zamontowania ich w narzędziach do obróbki skrawaniem i innych maszynach.
W niniejszym artykule dokonano przeglądu zagadnień związanych ze środowiskiem programowym Systemów Baz Wiedzy (KBS) wraz z ich charakterystykami, a także ich przydatności i wymagań pozwalających na opracowanie Rekonfigurowalnego Systemu Wytwarzania (RMS) opartego na bazie wiedzy. Przedstawiono i omówiono także podstawowe struktury drzewa decyzyjnego dla wyboru maszyn i wyposażenia dla aplikacji systemów opartych na bazach wiedzy (KBS).

Słowa kluczowe: Systemy Baz Wiedzy, Rekonfigurowalne Narzędzie Maszynowe

1. Introduction

Reconfigurable machine tools are the precursor to meet the demands of a highly customised environment in which manufacturing organisations find themselves operating in. This challenge is compounded by the global nature of the competition created by liberalised global markets. To meet the demands to be flexible (Chryssolouris , 2005), changeable (Shi and Daniels, 2003), adaptable (Dashchenko , 2006), adjustable (Wiendahl et al, 2007) and reconfigurable it is necessary that the structure of the machine tool is modular. Modularity will facilitate for change in functionality of the machine tool, reuse of old modules in new structures and customised flexibility. Thus the machine tool manufacturer will need to provide the machine tool consumer with a library of modules for reconfiguration of these machines.

A library of modules provides the machine tool investor with the needed tools based on the resource constraints and the flexibility to expand as the market needs detect. This will be achieved by ordering an initial set of modules with the right functionality at that point in time, then further acquiring new necessary modules to expand and diversify production. Similarly the machine tool builder will need efficient and effective means of selecting the precise required modules. This will involve optimising the module selection from the library.

Considerations will be made in this work of the Knowledge Based System requirements for Reconfigurable Machining Systems, to full fill the purpose of arrinving at the reconfiguration goal. A literature review will be presented in section two, utilisation of knowledge based systems in variuos areas is herein assessed. The goals of the knowledge based system that is the; problem criteria, expert criteria and domain criteria for the reconfigurable machine tool will be discussed in section three. Critical Aspects in design of KBS for RMS will be considered in section four and machine tool classification for knowledge based systems will be made in section five.

2. Literature Review

Knowledge based systems are synonymous with expert systems thus in defining them an expert system definition is used. In terms of applications, expert systems have emerged as being very useful and deployable systems that are being utilised internationally (Liebowitz, 1991). An expert system is a computer program that emulates the behaviour of a human expert within a well defined, narrow domain of knowledge (Liebowitz, 1995). Expert systems are computer programs developed around the thinking process of the expert and are capable of answering complicated questions (Juang, *et al.*, 2007). The task of configuring and reconfiguring machine tool structures calls for an expert. Automating this process will eliminate redundancy and redound in better reliability of machines conceived.

Ismail [Ismail, *et al.*, 1995] utilizes a knowledge based system Kappa with a CAD package AUTOCAD in designing a press tool. A mechanism is explained by which it is possible to interface an expert system with a design package. This application reveals such a methodology and parallels can be derived in the development of such an expert system for reconfigurable machine tool design, using commercial off the shelf (COTS) modules as gathered by the researchers in their compilations of the modules.

An integration of a commercial CAD system and an expert system to overcome the challenges brought about by the need for small batch sized products with high variety is implemented. These mass customized market needs brought about the necessity for variation in parameters of products and consequently of the production system in this case which are machine tools. Myung & Han (Myung and Han, 2001) outline a methodology to arrive at this end in machine tools where they manage to bring the aspect of parameter change to the machine assembly, superseding the previous applications in parametric modelling of parts.

The concept of knowledge based selection of machine modules can be extended further to the functioning of a machining centre intelligently. The concept design of an intelligent machining centre which is not bound by rigidity and temperature constraints as in traditional design of the machine tool is proposed by Hatamura et al (Hatamura *et al.*, 1995). The study describes eight principles of mechanical design and six design principles for intelligent manufacturing systems. In the design the static machine structure is integrated with the sensors, actuators and an intelligent controller so as to achieve dynamic machine tool behaviour as the machining conditions vary in terms of rigidity and temperature (Hatamura *et al.*, 1995). In another application Golabchi (Golabchi, 2008) makes use of the knowledge-based expert system for the selection of appropriate structural systems for large spans. The claim describes the application of this methodology in the design of building structures. Using a system design model a narration is given of how Kappa PC an object oriented expert system is used to achieve the structural selection. Parallels can be drawn from this application in the design of machine tools as parts and sub-assemblies also constitute the hierarchy to the final machine tool configured.

The literature review reflects the feasibility of solving the problem of selection of machine tool parts and modules to constitute a reconfigurable machine. The broad application of knowledge based systems in the different stages of designing a selection system is clearly depicted. This has been clearly indicated particularly, by the apparent similarities in the problems that the expert systems have been utilised in solving.

3. Goals of the Knowledge Based System

The goals of the knowledge based system, problem criteria, expert criteria and domain criteria for the reconfigurable machine tool will now be discussed in the following paragraphs. The goals for building a KBS for the RMS are;

1. To provide a mechanism of building the various reconfigurable machine tools for the reconfigurable machine tool user from a module library. This library is provided by the modular modules from the reconfigurable machine tool supplier. In the case of small organisations the size of the organisation will not justify the purchase of such a knowledge based system thus the KBS will be housed with the reconfigurable machine tool manufacturer to meet the customised incremental needs of the small machine tool user market.
2. To preserve the human expertise in configuration and reconfiguration of machine tool modules in a computed format. This being necessary in order to build market relevant machine tools for the customised rapidly changing machine tool global demands.
3. To shorten the time needed to come up with the appropriate reconfigurable machine tool after changes in market requirements. Lead time being a critical aspect of the machine tool user's competitiveness, an automation of some of the processes becomes important. In this way optimum machine configurations can be achieved. This will help in focusing efforts to other critical aspects of for example quality enhancement.
4. To help in educating new researchers in the module selection process. The availability of a KBS implies the relevant procedures in reconfigurable machine tool design have been concretised and this will aid in training of new players in the utilisation of these technologies and their future expansion.
5. The effective use of research time, on the more intellectually demanding research aspects resulting in cost savings and higher research productivity.
6. A means of aid in determining a variety of the detailed designs to be considered. When the process of module selection to build reconfigurable machines is executed, an exhaustive range of configurations with respect to the requirements can be achieved. As opposed to the process being manual.

Liebowitz (Liebowitz, 1995) proposes seven problem type criteria to be followed when selecting an expert system problem. A discussion is herein given which justifies the researcher's choice of approach in solving the problem at hand. The task at hand involves chiefly a symbolic process as the modules are gathered as CAD models which can be represented figuratively in a KBS. Secondly test cases are available as a wide range of modular constituted machine tools are readily available on the web. Thirdly the problem task is well bound as the library of the modules attained from the web module vendors are within particular limits. Fourthly the rapid change in machine tool user requirements implies a high frequency of the performance of this task thus the method is relevant. Reconfigurable machine tool design has been happening for the past decade and a

wide range of publications are available on the web from many institutes (from both academia & industry), journals and other publications, thus written material exists. Though the final consideration of experts agreeing on the solutions may not be fully meet it is however true that all roads are leading to an ultimate position of agreement.

Further on the aspect of expert criteria is also another issue that has to be considered to be able to answer the question of the applicability of this approach to the RMT design. Expert existence is one of the criteria, considering this characteristic there may not be as many experts in this field of machine tool design however the internet age rapidly brings expertise to diligent knowledge seekers. The platform of the internet immediately implies that cooperation is guaranteed as this comes embedded in it the articulate aspect of the web. It is noteworthy however that contact with experts in this field is greatly need for the issues like experience, facts and judgement and also in the process of developing more experts.

As already noted a tremendous need exists in the field of reconfigurable machine tools for such an expert system. Commitment has already been shown at a national level for support in this research area through the range of projects currently happening in South Africa at both university and research institutes. The designers have realistic expectations from the developed application in the machine tool design as this will enhance the other aspects of research that have to be done by concentrating on the critical design aspects like simulation and design of new concepts. The users would definitely welcome the expect system.

4. Critical Aspects in design of KBS for RMS

The selection of modules to configure the reconfigurable machine tools is characterised by several features which render it suitable for an expert system approach (Golabchi, 2008).

- A great deal of information is required from various commercial machine tool module vendors. This is at all the different levels of assembly i.e. from subsystem assembly to the final machine tool level of assembly of the various subsystems to constitute the required machine tool. Over a period of time a procedure will evolve for this process, which can then be conglomerated into an expert system.
- Complications may arise in the evaluation and comparison of possible architectural configurations as well as meeting proposed machine phenomenon and the requirements by the kinematically feasible structures.
- Designers need a broad knowledge base and expertise about behaviour of different structures and structural requirements.
- Modular machine tool concretisation is thus a process worth of knowledge based system application.

5. Machine Tool classification for the KBS

In this section the work that has been done in classifying the required modules to constitute the machine are presented. A generic machine tool and a some specific machine tool type tree diagrams are presented to be used in the design of the KBS. Figure 1 represents the modules that constitute the machine tool in general. From this general view the specific modules that comprise a particular machine tool are given in the following diagrams from figure 2 to figure 4.

In the light of the KBS to be developed, when analysing the specific machine tool tree diagrams (from Figure 1 to Figure 4) it is noted that there are standard modules for any machine tool and then there are modules that are specific to a particular machining process. This has immediate space implications and feature description issues to be considered in KBS design. It is also important to note that when focusing on a particular machining process for instance looking at milling there are variations within the machining process, the mill could be vertical, or horizontal. This configuration change will also result in the change in the necessary modules to fulfil the needed functionality and on the size of the size of the database for the knowledge based system.

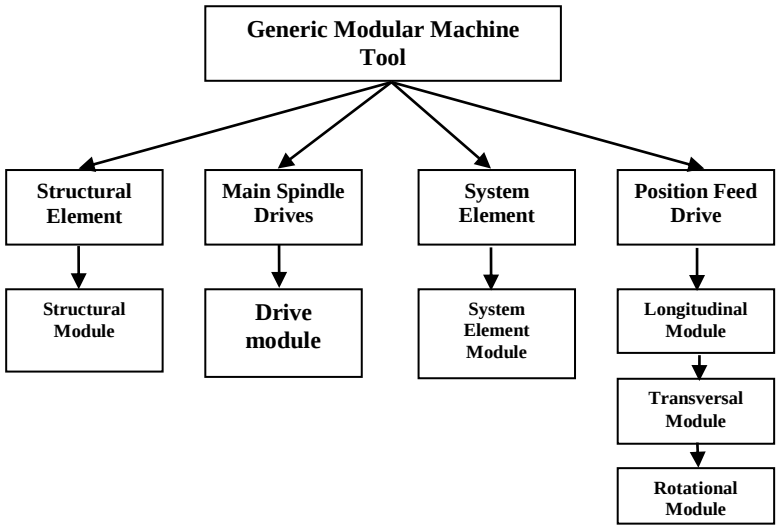

Fig. 1 Generic modular machine tool representation

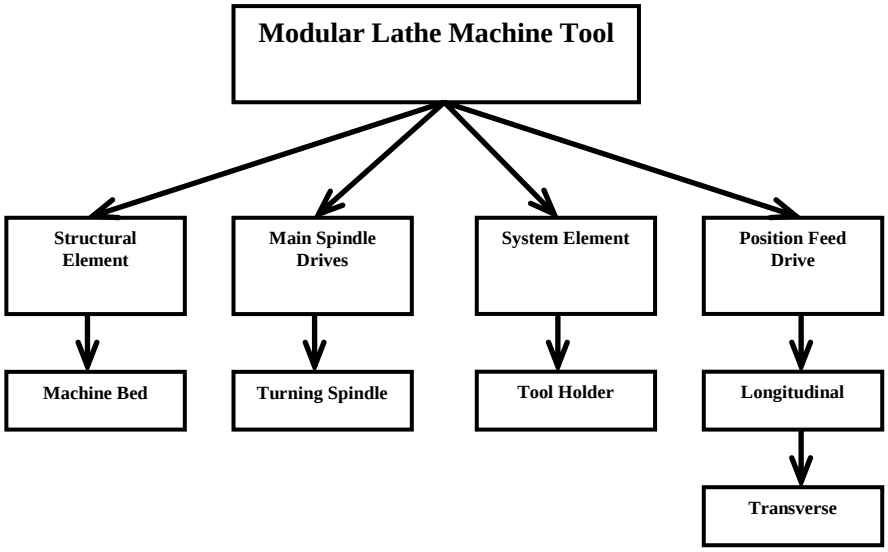

Fig. 2 Modular lathe machine tool representation

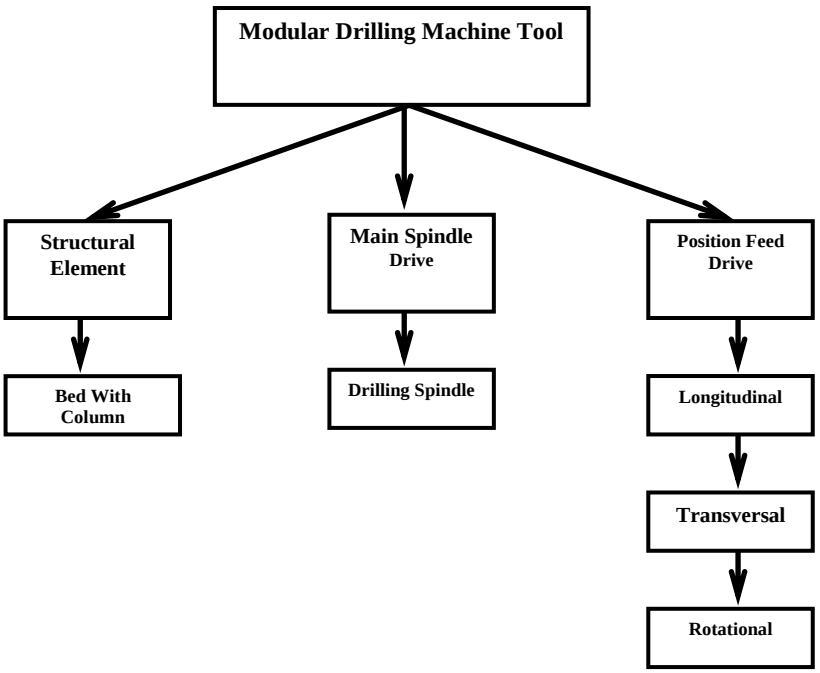

Figure 3: Modular Drilling machine tool representation

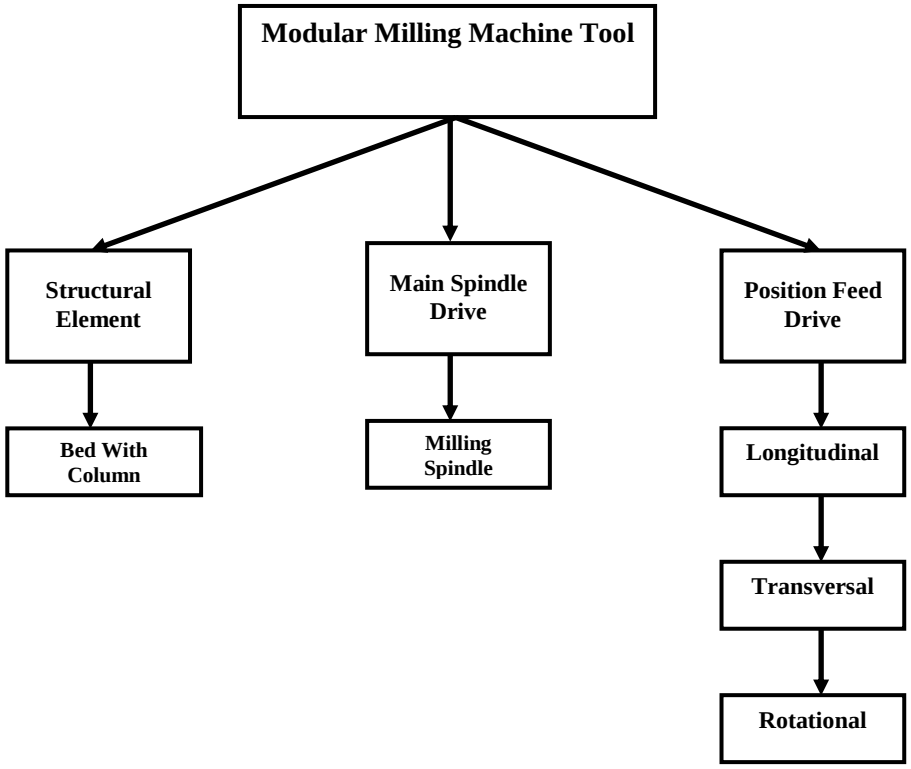

Figure 4: Modular milling machine tool representation

4. Conclusion

In this paper the clarity of the need, of a module selection mechanism which utilises an expert system for reconfigurable machine tool building is presented. A simple classification strategy for the different machine tool types and the respective modules that constitute these machines is proposed. These tree diagrams can be utilised in the grouping of different modules from different module-suppliers. This being done for the purpose of building up the database of the modules for the purpose of designing the KBS for application in the development of various structures of reconfigurable machines which are to be designed to meeting highly customised market needs.

The future work will involve the building up of the KBS which will be utilised in the optimal realisation of necessary RMT configurations with respect to customer demand.

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