WEB-BASED KNOWLEDGE BASE SYSTEM FOR SELECTION OF NON-TRADITIONAL MACHINING PROCESSES

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ABSTRACT

This paper presents a web-based knowledge base system developed for identifying the most appropriate non-traditional machining process to suit specific circumstances based on the input parameter requirements such as material type, shape applications, process economy and some of the process capabilities namely, surface finish, corner radii, width of cut, length to diameter ratio, tolerance etc. The selection procedure proposed in this study is based on the idea that certain characteristics of a part restrict the choice of certain non-traditional machining processes for it to have a relatively small number of alternatives. Designers and Engineers who are geographically separated but well connected by the Internet can use this web-based system to realize process selection. Web technology has immense potential to develop a collaborative design and manufacturing environment. It simplifies the sharing of process knowledge and provides intelligent decision-making in a collaborative way through the Internet. This system employs three-tier web architecture for implementing user module to do the selection and expert module to update the knowledge base. The web-based non-traditional machining process selection system can cut down the product cost, enhance the product quality, and decrease the product lead-time considerably. A wide range of industrial parts has been evaluated in order to demonstrate the performance of the proposed selection procedure.

Keywords: Non-Traditional Machining Processes, Knowledge Base, Web-based Process Selection, Three–Tier Architecture, Limiting Requirements

1.0 INTRODUCTION

At present, large number of (more than 30) different non-traditional machining processes is available [1]. Table 1 gives a classification of those non-traditional machining processes that have industrial applications. The classification is based on the type of energy used, the mechanism of metal removal, the source of energy requirements. When selecting a particular non-traditional machining process, the design engineer must carefully consider a large number of factors that relate directly to the processes as well as the influence of many other factors that are not directly related to Non-traditional machining processes. To make efficient use of non-traditional machining processes, it is necessary to know the exact nature of the machining problem. It should be understood that these methods cannot replace the conventional machining processes and a particular machining method found suitable under given conditions may not be equally efficient under other conditions. Therefore careful selection of the given problem is essential. Experienced design engineers often make correct decisions regarding processes almost instinctively, in particular when they are dealing in areas of mature technology with which they are familiar. However, as the rate of technological change continues to increase and become more specialized, less experienced engineers become involved in design, and there will be a growing need for expert systems (in the form of intelligent computer programs) to aid the designer in making decisions regarding process selection and manufacturability[2]. A selected non-traditional machining process at the beginning of design stage affects the manufacturability and cost of the final product designed. In order to assist the designers to compare different non-traditional machining processes and determine the suitable non-traditional machining process, a web-based decision making system was created in a more intuitive way.

Automation of knowledge through a “knowledge-base system” will greatly enhance the decision making process. The benefits of building a knowledge-based system can be summarized as follows: (1). Helping the design engineer in selecting the suitable non-traditional machining processes for the current problem. (2). Dealing with a large amount of data and responding quickly. (3). Standardizing the conclusions for a given set of data. (4). Allowing the problem solving capability of several people to be combined. (5). Capturing the scarce expertise and making it available for the effective use [3].

A number of conventional selection procedures for conventional machining processes are already in existence [4]. Most of these are simple proprietary guides to aid customers in making a selection from a company’s product line [5]. A major deficiency in many systems is that they assume that the material, processing method or part geometry is already fixed. Many selection procedures are limited in their scope [6]. Another problem with many systems is that they are not organized in such a way as to be adaptable to computer processing [7]. To the best knowledge of author, there is not enough published work on the web-based knowledge base system for selection of non-traditional machining processes.

Published work by Sirilertworakul et al. [8] and Darwish et al. [9] presented a typical knowledgebase system for Alloy and process selection of casting and metal welding processes respectively. Alder et al.[10] outlined the background and some of the problems associated with the selection of both conventional and non-conventional processes. A range of material types to achieve a given task by a knowledge-based expert system is also examined. In their work, two small demonstration expert systems are described for selection of conventional machining processes. Can Cogun [11] presented a novel database system for the preliminary selection of non-traditional machining processes. His work is not intended to make final selection of non-traditional machining processes, but rather to provide a short list of alternatives, which will contain the best combinations. Vinod Yadava et al.[12] presented a simplified procedure for computer aided selection of non-traditional machining processes. In their work, only the work material and some of the process capabilities such as minimum surface finish, tolerance, corner radii, taper, hole diameter, maximum height to diameter ratio and minimum width of cut are included. Shankar Chakraborthy et al. [13] developed an analytic hierarchy based expert system for non traditional machining process which relies purely on the priority values for different criteria and sub-criteria, as related to a specific non-traditional machining problem. It also depends on the logic table to discover the non-traditional machining processes that lie in the acceptability zone, and then selects the optimal process having the highest acceptability index value. This survey shows a need for more comprehensive selection of non-traditional process among different non-traditional machining processes. So, the main objective of this work is to establish a user-friendly web-based knowledge base system to identify the most suitable range of non-traditional machining processes.

2.0 KNOWLEDGE-BASE FOR MACHINING PROCESS SELECTION

The most important of an expert system is the knowledge implemented in the system. The information that has been used to build the knowledge base of the non-traditional machining process selection of the present work was collected from two main sources. They are both documented and undocumented knowledge. The undocumented knowledge was collected through numerous interviews conducted with experts in the field of non-traditional machining processes of Lucas TVS, Makino India, Electronica, Promech industries, Mission technology and BS spark technology, India [14]. The knowledge base is organized into four different capsules namely (a) material applications, (b) shape application (c) process capabilities and (d) process economy.

Table 1. Existing classification of non-traditional machining processes [15]

Type of energy	Main Process	Mechanism of material	Transfer media	Energy source	Tool
Mechanical	USM	Erosion or Abrasion	Abrasive slurry	Ultrasonic vibration	Sonotrode
	AJM	Erosion or Abrasion		Pneumatic pressure	Abrasive jet
	WJM		Air	Hydraulic pressure	Water jet
	AWJM		Air	Hydraulic pressure	Abrasive-Water jet
	IJM		Air	Hydraulic Pressure	Ice jet
	AFM		Putty	Hydraulic pressure	Abrasives
	MAF		Air	Magnetic field	Magnetic Abrasives
Chemical	CHM	Chemical dissolution or Ablative relation	Etchant or reactive environment	Corrosive agent	Mask
Electrochemical	ECM	Anode dissolution through ion displacement	Electrolyte	High current	Electrode
Thermal	EDM	Melting and vaporization	Dielectric	High voltage	Electrode
	EBM		Vacuum		Electron beam
	IBM		Atmosphere	Ionized material	Ion beam
	LBM		Air	Ionized material	Laser beam
	PAM		Plasma	Amplified light Ionized material	Plasma jet

USM, Ultrasonic Machining: AJM, Abrasive Jet Machining: WJM, Water Jet Machining: AWJM, Abrasive Water Jet Machining: IJM, Ice Jet Machining: AFM, Abrasive Flow Machining: MAF, Magnetic Abrasive Finishing: CHM, Chemical Machining: ECM. Electrochemical Machining: EDM, Electric Discharge Machining: EBM, Electro Beam Machining: IBM, Ion Beam Machining: LBM. Laser Beam Machining: PAM, Plasma Arc Machining.

2.1 Material applications

This capsule includes material types that can be machined using non-traditional machining processes. The suitability of materials with respect to each process is shown in Annexure 1.

2.2 Shape application attributes

This capsule is concerned with the shape application attributes. Table shown in Annexure 2 lists the quality level of shape applications associated with the different non-traditional machining processes.

2.3 Process capability attributes

This capsule is concerned with the process capabilities of various non-traditional machining processes. Tables shown in Annexure 3a & 3b give the quality level of process capabilities of different non-traditional machining processes.

2.4 Process economy attributes

This capsule consists of attributes associated with process economy. It gives the quality level of process economy for different non-traditional machining processes. This includes all the information required to select the most appropriate non-traditional machining process to match certain economic conditions. The selection process begins with the type of material to be machined followed by the shape application, process capabilities and process-economy.

3.0 WEB-BASED EXPERT SYSTEM FOR PROCESS SELECTION

A web-based non-traditional machining process selection system for non-traditional machining processes has been developed. Using this system, the users can select adequate machining processes, which meet the user's requirements on material type, shape application, process capability and economic factors. The users can also evaluate the performance of different machining processes by obtaining the ranking based on the performance criteria from this system. Designers and Engineers who are geographically separated but well connected by the Internet can use this system to realize process selection. This web-based machining process selection system can cut down the product cost, enhance the product quality, and decrease the product lead-time considerably. Web technology has immense potential to develop a collaborative design and manufacturing environment. It simplifies the sharing of process knowledge and provides intelligent decision-making in a collaborative way through the Internet.

This knowledge-based system follows the three-tier architecture having Client browser, Web server and Database components. The development environment includes Apache Web Server, MySQL Database with PHP as server-side scripting language and DHTML and Javascript on client-side for the dynamic web pages. This software includes two major modules namely Expert module and Selection module. The Expert module is responsible for creating and managing the knowledge base of non-traditional machining processes and Selection module makes the selection of appropriate processes for the given user requirements with the help of the knowledge base. The Expert module has restricted access and only the registered experts who are authorized to log into the system can update the knowledge base, based on the recent developments and newly acquired expertise in the non-traditional machining processes. All authorized users can access the Selection module and feed the relevant limiting requirements as input and obtain the selection results dynamically. The intuitive web user-interface provides the users an easy-to-use and interactive environment for making the selection process while keeping the knowledge base up-to-date. The object-oriented, cost-effective and platform-independent approach gives the affordable solution for collaborative decision making system. The architecture of web-based process selection system implemented with knowledge base is shown in Fig. 1. The basic functionalities of the software modules are described below:

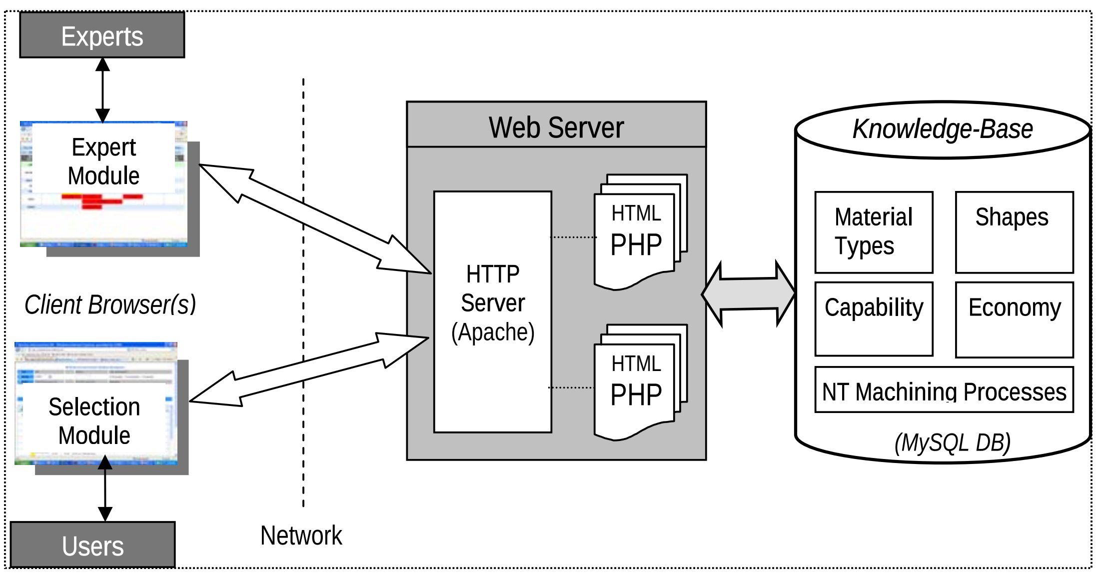

Fig.1: Architecture of web-based machining process selection system

3.1 Expert Module

This consist of two sections namely Process Management and Limiting Requirements Management section. Process Management is used to add a new process, modify the existing processes, and delete the existing processes in the process capsule where as the Limiting Requirements Management is used to add, modify and delete operations on the four knowledge capsules namely material types, shape applications, process capabilities, and process economy.

3.2 Selection Module

This module gets the limiting requirements as input from the user. Search for the relevant records from the knowledge base, perform match-making based on the acquired knowledge and identify the suitable processes and do performance ranking.

Annexure 4 and Annexure 5 show the typical screen-shots of addition of material by expert and process selection performed by user.

4.0 CASE STUDIES

Many case studies have been used to verify the dependability of the proposed approach in the selection of the most suitable Non-Traditional Machining Processes. Only one of them is presented in this paper: The small scale industry currently employs EDM to produce a die block made of OHNS which is used to manufacture Deoball by injection moulding. The part 110 x 100 x 36mm has a complicated hemi-spherical cavity as shown in Fig. 2. In one application, a quality control check on the tolerance and surface finish achieved were with in ± 0.03mm and 0.5 Ra respectively. The depths of cut and corner radii of the part are given as 12.74mm and 0.4mm respectively. Minimum taper is 0.001mm/mm. It is observed from the implemented web based-knowledge base system that EDM, USM, AJM are found to be the most suitable Non-Traditional Machining Processes for the given part with the specified requirements (Annexure 5).

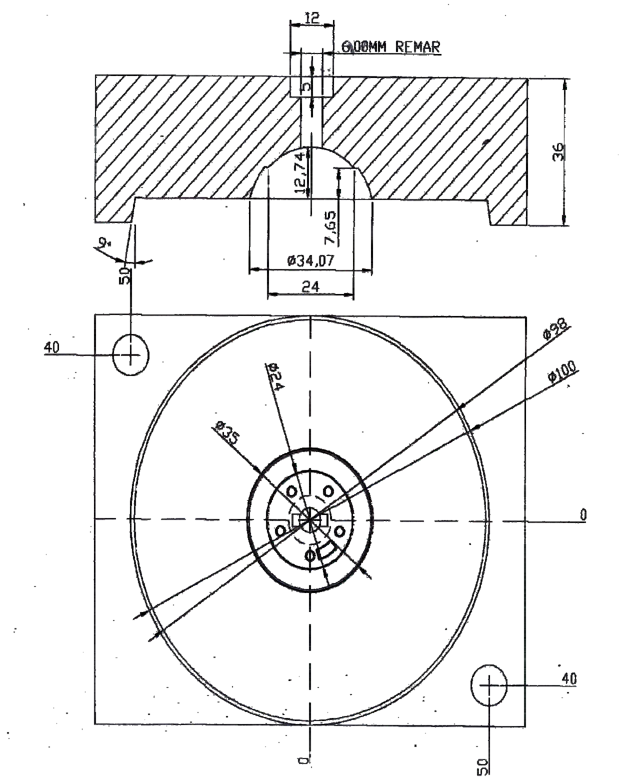

Fig. 2. Part drawing of the Die block used to manufacture Deoball

5.0 CONCLUSIONS

This research resulted in the development of a web-based knowledge base concerning the selection of non-traditional machining processes. The system developed provides appropriate non-traditional machining process selection, which matches practice in industry, since the system has been developed and validated through real-life cases collected from local industries. Design engineers based on cost and availability will judge the final choice among the candidate non-traditional machining processes. Since some of the non-traditional processes often produce waste or vapors with a high risk for men and environment, this factor may be included as a separate information module independent of the cost for clearing away the waste. The developed web-based expert system surely helps the designers in choosing the apt non-traditional machining process with ease. Other improvement will probably become apparent as experience in using the system is gained.

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BIOGRAPHY

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Annexure 1. Material applications of non-traditional machining processes [16]

Process	Metals and alloys					Non-metal		
	Aluminium	Steel	Super alloys	Titanium	Refractories	Plastics	Ceramics	Glass
USM	C	B	C	B	A	B	A	A
AJM	B	B	A	B	A	B	A	A
ECM	B	A	A	B	B	N.A.	N.A.	N.A.
CHM	A	A	B	B	C	C	C	B
EDM	B	A	A	A	A	N.A.	N.A.	N.A.
EBM	B	B	B	B	A	B	A	B
LBM	B	B	B	B	C	B	A	B
PAM	A	A	A	B	C	N.A	N.A.	N.A.

A. Good Application: B. Fair: C. Poor: N.A. Not Applicable.

Annexure 2. Shape applications of non-traditional machining processes[16]

Process	Holes D<0.03 (mm)	Holes 0.13>D >0.03 (mm)	Depth of Holes L/D <20	Depth of Holes L/D >20	TC1	TC2	P1	P2	S1	S2	TCH1	TCH2
USM	-	-	A	C	A	A	C	C	C	-	C	-
AJM	-	-	B	C	C	B	-	-	-	-	A	-
ECM	-	-	A	A	B	A	A	A	A	B	A	A
CHM	B	B	-	-	C	B	A	C	-	-	A	-
EDM	-	B	A	B	A	A	A	A	B	-	C	-
EBM	B	A	B	C	C	C	-	-	-	-	A	B
LBM	A	A	B	C	C	C	-	-	-	-	A	B
PAM	-	-	B	-	C	C	-	-	-	C	A	A

TC1, Through Cavities (precision): TC2, Through Cavities (standard): P1, Pocketing (shallow): P2, Pocketing (deep):
S1, Surfacing (double contour): S2, Surfacing (Surface of revolution): TCH1, Through Cutting (shallow): TCH2 Through Cutting (deep)

Annexure 3a. Process capabilities of non-traditional machining processes [14]

Process	Part material	Min. Tolerance (mm)	Min. surface finish (CLA) (µm)	Min. surface damage µm)	Min. corner radii (mm)	Min. taper (mm/mm)	Min. hole diameter (mm)	Min. width of cut (mm)	Min. overcut (mm)	Max. depth to diameter ratio
EDM	E.C.	0.01 (pract) 0.002 (poss.)	1.0 (pract) 0.3 (poss.)	20 (T.D.)	0.1 (pract.) 0.01 (poss.)	0.001	0.2	0.05	0.025	20
ECM	E.C.	0.03 (pract.) 0.005 (poss.)	1.0 (pract.) 0.1 (poss.)	N.T.D.	0.2 (pract.) 0.025 poss.)	0.001	0.5 0.127 (ESD)	0.1	0.12	30
ECG	E.C.	0.025 pract.) 0.005 (poss.)	0.2(pract.) 0.005 (poss.) 0.002(AECG)	N.T.D.; 2 (M.D.)	0.13 (pract.) 0.01 (poss.)	N.A.	N.A.	N.A.	0.12	N.A.
ECH	E.C.	0.010 (pract.)	0.3 (pract.) 0.05 (poss.)	N.T.D	0.5(poss.)	N.A.	N.A.	N.A.	N.A.	N.A.
AJM	E.N.C.&R	0.03 (pract.)	0.4(pract.) 0.1 (poss.)	N.T.D. 25 (M.D.)	0.1 (poss.)	0.005	0.12	0.12	N.A.	10
WJM	E.N.C. & N.M.	N.A. 0.127(AWJM)	0.4(pract.)	N.T.D.	1.5 (pract.)	0.005	0.15	0.15	N.A.	30

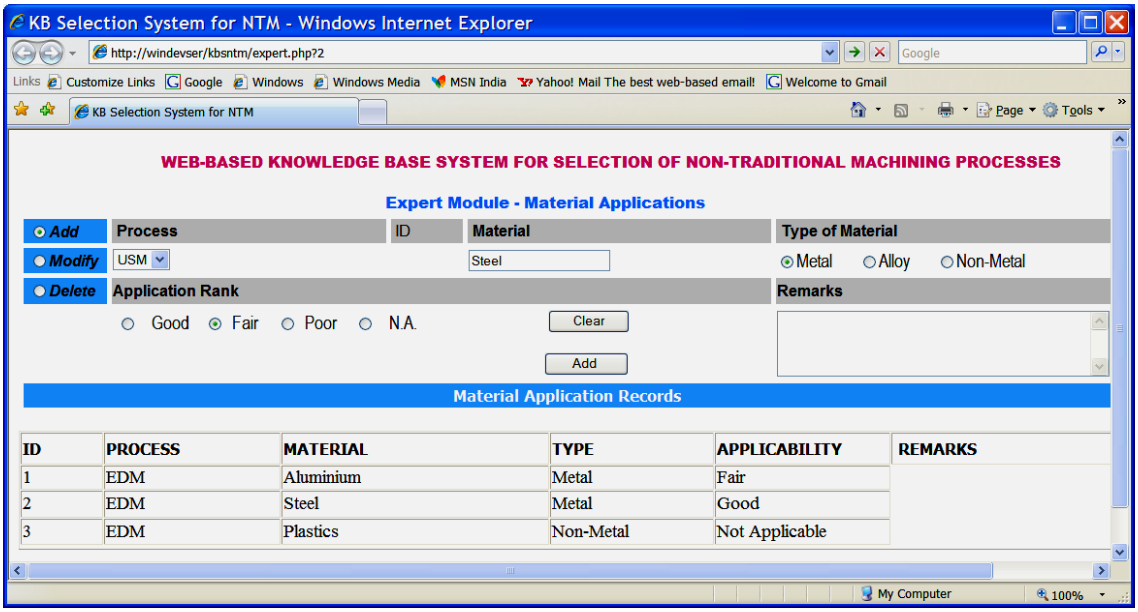
Btl., Brittles: C.D, Chemical Damage: E.C., Electrically Conductive: E.N.C.,Electrically Non-Conductive: M, Metals: M.D, Mechanical Damage: N.A., Not Applicable: N.M, Non-Metal: N.T.D,No Thermal Damage: pract.,Practical: poss.,Possible: R,Refractories: T.D,Thermal Damage: ESD, Electro Stream Drilling: AWJM, Abrasive Water Jet Machining: AECG, Abrasive Electro Chemical Grinding

Annexure 3b. Process capabilities of non-traditional machining processes [14]

Process	Part material	Min. Tolerance (mm)	Min. surface finish (CLA) (μm)	Min. surface damage (μm)	Min. corner radii (mm)	Min. taper mm/ mm)	Min. hole diameter (mm)	Min. width of cut (mm)	Min. overcut (mm)	Max. depth to diameter ratio
USM	EN.C.&E.C	0.010(pract.) 0.007 (poss.)	0.5 (pract.) 0.2 (poss.)	N.T.D. 25 (M.D.)	0.020 (poss.)	0.005	0.05	0.005	0.15	2.5
CHM	E.C.&R	0.08 (poss.) 0.03 (photoresist)	2.0 (pract.) 0.5 (poss.)	N.T.D.; 5 (C.D.)	1.25 (pract.)	0.3	0.5	0.5	N.A	3
LBM	E.C. & E.N.C.	0.02 (pract.) 0.01 (poss.)	1.0 (pract.); 0.4 (poss.)	80 (T.D.)	0.25 (poss.)	0.05	0.05	0.1	N.A.	15
PAM	E.C.	1.0 (pract.)	80 (pract.) 50 (poss.)	600(T.D.)	4 (pract.)	0.07	2	2	N.A.	10
EBM	M& NM	0.03 (pract.) 0.002 (poss.)	5 (pract.)	N.T.D. 10 (M.D.)	0.25	0.02	0.04	0.04	N.A.	20
WEDM	E.C.	0.002 (positioning accuracy)	1 (pract.); 0.3 (poss.)	20 (T.D.)	0.022 (poss.)	0.05	0.11	0.15	0.010	N.A.

Btl., Brittles: C.D, Chemical Damage: E.C., Electrically Conductive: E.N.C.,Electrically Non-Conductive: M, Metals: M.D, Mechanical Damage: N.A, Not Applicable: N.M, Non-Metal: N.T.D, No Thermal Damage:pract. Practical: poss.,Possible: R,Refractories: T.D,Thermal Damage: ESD, Electro Stream Drilling: AWJM, Abrasive Water Jet Machining: AECG, Abrasive Electro Chemical Grinding

Annexure 4. Expert module – addition of material applications in knowledge-base



Annexure 5. User Module - Selection of suitable non-traditional machining processes