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A decision guidance framework for non-traditional machining processes selection

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Abstract In order to realize the manufacturing/machining demands thrived by newer, hard and difficult-to-machine materials being utilized in the present day industries, an assortment of non-traditional machining (NTM) processes has been developed over the past few decades. These processes are capable of generating intricate and complex shapes with high degree of accuracy, close dimensional tolerance and better surface finish. In this paper, a decision guidance framework is developed in Visual BASIC 6.0 to help the process engineers in selecting the most appropriate NTM process for a specific work material and shape feature combination. It also assists in identifying the ideal process parameter combinations for the most suitable NTM process. The derived results highly corroborate with the opinions of the experts in the related field, demonstrating the acceptability of the developed system.

1. Introduction

Components/parts manufactured by casting, forming and various other traditional manufacturing processes often require additional advanced machining operations before they are made ready for use or assembly. In many engineering applications, parts need to be interchangeable in order to perform multi-functional tasks suitably and reliably during their expected service life. Therefore, control over dimensional accuracy and surface finish of those components is of critical importance during any machining operation [1]. In spite of technological advancements, the conventional machining processes are inadequate to generate complex geometrical shapes in harder, tougher, stronger and temperature-resistant materials, such as tungsten carbides, alloy steels, high speed steels, fiber reinforced composites, ceramics and ceramic-based tools, and diamonds, as being frequently utilized in aerospace, electronics, nuclear, missile and automotive industries. It has led to the development of advanced machining processes where the physical properties of the workpiece material do not impose any restriction on the material removal procedure. A diverse range of machining processes involving application of mechanical, thermal, electrical, and chemical energies have been evolved out over the past few decades. These modern machining methods are also known as non-traditional machining (NTM) processes, harness unconventional sources of energies for material removal, like electrochemical reaction, high temperature plasma, high velocity jet of liquids or abrasives,

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high frequency sound waves and coherent lights, instead of electric motors and hard tool materials employed in conventional machining processes [2]. These NTM processes are capable of generating complex shape geometries, such as internal and external profiles, or small diameter holes with better surface finish, close dimensional tolerance, high accuracy, greater surface integrity and required miniaturization. Moreover, in some cases, the workpieces are too flexible or slender to withstand the cutting or grinding forces generated during the conventional machining processes. The NTM processes are also capable of performing machining operations in those cases where there is no direct contact between the tool and the workpiece material. Technological improvements of the NTM processes can further be achieved through innovative techniques or modification of the existing method, while combining together two or more machining actions or phases of the material removal process. These hybrid machining techniques thus developed can exploit the combined advantages of the constituent NTM processes, and avoid the adverse effects of those processes when they are individually applied for carrying out the required machining operation.

Over the years, more than 20 different NTM processes have been successfully developed and implemented in diverse range of manufacturing industries. To exploit the full potential of those NTM processes, it becomes important to understand the exact nature of the machining problem because a NTM process considered suitable for a particular application may not be equally efficient for another application. A NTM setup is usually complex, which demands skilled personnel for its proper operation and maintenance. It is also observed that most of the NTM processes have relatively high capital investment cost, power consumption and operating cost, tooling and fixture cost, and maintenance cost which can easily offset the benefits elicited from the enhanced machining capabilities of those processes. Therefore, selection of an appropriate NTM process from a pool of modern machining methods is a key decision making problem for justification and implementation of the same for performing a given machining operation. The process engineers entrusted with the responsibility of suggesting and identifying the most suitable/feasible NTM method must have an in-depth technological knowledge regarding its applicability and characteristics. But, only a few process engineers are able to keep track with the ever increasing and more specialized technological enhancements in the area of NTM processes. So, the need of a decision guidance framework (in the form of a prototype expert system) is eminently felt to aid the process engineers in making NTM process selection decision. Therefore, in this paper, a database is first created that contains all the information pertaining to various machining characteristics and applicability of 25 NTM processes. It is then integrated with a decision guidance framework to assist the process engineers in selecting the most suitable NTM process for a given machining application.

2. Literature review

The past researchers already applied different mathematical models and developed some distinct expert systems to select suitable NTM processes from the existing alternatives for varying machining applications. Yurdakul and Cogun [3] proposed a multi-attribute selection procedure to help the manufacturing personnel in identifying suitable NTM processes for the given application requirements. Chakraborty and Dey [4] presented a systematic methodology for selecting the best NTM process under constrained material and machining conditions. Chakrabarti et al. [5] developed a management information system for selection of complex machining processes in modern manufacturing organizations. Chakraborty and Dey [6] presented a quality function deployment (QFD)-based methodology to ease out the optimal NTM process selection procedure. Chakladar and Chakraborty [7] employed two multi-criteria decision making (MCDM) methods, i.e. technique for order performance by similarity to ideal solution (TOPSIS) and analytic hierarchy process (AHP) to select the most suitable NTM process for a given machining application. Edison et al. [8] developed a web-based knowledge base system for identifying the most appropriate NTM process to suit some specific requirements on the basis of input parameters, such as material type, shape applications, and process economy, and some of the process capabilities, such as surface finish, corner radii, width of cut, length to diameter ratio, and tolerance. Chakladar et al. [9] designed a digraph-based expert system to aid the decision maker in selecting the most suitable NTM process for a given work material and shape feature combination. Sugumaran et al. [10] investigated the use of artificial neural networks in NTM process selection decision. Chakraborty [11] explored the application of multi-objective optimization on the basis of ratio analysis (MOORA) method to solve NTM process selection problems in real time manufacturing environment. Sadhu and Chakraborty [12] proposed a two-phase decision model for NTM process selection considering ten alternative NTM processes and ten performance criteria. Iç [13] explored the applicability of TOPSIS and design of experiment methods to solve various computer-integrated manufacturing process selection problems for different industrial applications. Karande and Chakraborty [14] combined preference ranking organization method for enrichment evaluation (PROMETHEE) and geometrical analysis for interactive aid (GAIA) techniques to guide the process engineers in arriving at the best NTM process selection decision. Chatterjee and Chakraborty [15] applied Organization Rangement Et Synthese De Donnes Relationnelles (ORESTE) method to solve NTM process selection problems. Chatterjee and Chakraborty [16] explored the applicability, suitability and potentiality of evaluation of mixed data (EVAMIX) method for solving NTM process selection problems. Based on TOPSIS method and using distinct systematic approaches both in fuzzy and in crisp environments, Temuçin et al. [17] proposed a decision support model to deal with the selection problems of appropriate NTM processes. Prasad and Chakraborty [18] developed a decision making model based on QFD technique to automate the NTM process selection procedure with the help of graphical user interface and visual decision aids. Roy et al. [19] employed fuzzy AHP method to calculate the performance scores of various NTM processes taking into consideration product and process characteristics as the basis of comparison. Temuçin et al. [20] identified the most appropriate NTM process for cutting of a specific work material while utilizing different fuzzy MCDM methods. Madić et al. [21] employed operational competitiveness rating analysis (OCRA) method for solving NTM process selection problems.

It becomes evident from the review of past researches that most of the NTM process selection procedures are either