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المؤلف الرئيسي:	El Bahloul, Sara Ahmed Mostafa
مؤلفين آخرين:	El Shourbagy, Hazem E.، El Makky, Mohamed Y.، El Midany, Tawfik Tawfik(Super، Super,)
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ABSTRACT

Manufacture of a product in a desired shape and size with specific characteristics and properties depends not only on the design of the product but also on the selection of the appropriate manufacturing process(es) that requires knowledge about various available alternatives.

This thesis presents a software for selecting the optimal non-traditional machining process(es). Twenty one non-traditional machining process (NTMPs) have been considered. This includes thirteen basic NTMPs [i.e. Ultrasonic Machining (USM), Abrasive Jet Machining (AJM), Water Jet Machining (WJM), Abrasive Water Jet Machining (AWJM), Abrasive Flow Machining (AFM), Magnetic Abrasive Finishing (MAF), Chemical Milling (CHM), Electrochemical Machining (ECM), Electrical Discharge Machining (EDM), Electron Beam Machining (EBM), Laser Beam Machining (LBM), Plasma Arc Machining (PAM), and Ion Beam Machining (IBM)], as well as five derived NTMPs [i.e. Rotary Ultrasonic Machining (RUM), Photochemical Milling (PCM), Electrostream Drilling (ESD), Shaped Tube Electrolytic Machining (STEM), and Wire Electrical Discharge Machining (WEDM)], and three hybrid NTMPs [i.e. Electrochemical Grinding (ECG), Electrochemical Honing (ECH), and Electrical Discharge Grinding (EDG)].

The selection procedures are based on elimination and ranking techniques considering important attributes such as workpiece material and shape generation requirements, NTMPs operational capabilities, and NTMPs economical and environmental aspects. Elimination technique is applied on work material and shape generation requirements, while ranking technique, based on fuzzy logic, is applied on NTMPs operational capabilities, economical aspects, and environmental aspects.

The designed software has been developed using MATLAB, version (V7.8) release (R2009a), as programming language with the help of graphical user interface (GUI), visual aids, and fuzzy logic toolboxes.

There are many features in the developed software have been chosen to make it user friendly. One of the most important features appears through making modifications in the entire data concerning NTMPs operational capabilities through software screens. Another important feature shows the ability to analyze the final results by using bar charts. In addition, the user can insert the product drawing with its details through the software easily. Important notes about some NTMPs can be displayed to the user through file. Cases of partial suitability of a particular process with respect to the operational requirements and providing unequal importance to them are considered. The use of these facilitating features lead to time and effort saving to the user, as well as increasing the accuracy of the developed software.

Many real industrial case studies, which help to measure the performance of the developed software according to its final results, have been implemented. Among these applications are; inclined drilling of turbine blade cooling holes, formation of a medium size turbine blade, drilling of rod lenses of endoscope instruments, and manufacturing of micro internal gear for watch industry. These case studies have been chosen from various companies such as Luxcelis, electrochemical machining (ECM) Technologies, Temicon, and DMG. From these case studies, the validity of the developed software has been proves as a precise and accurate tool for selecting the optimal process.

الملخص

تصنيع منتج بالشكل والحجم المطلوب ذو مواصفات وخصائص محددة لا يعتمد فقط على تصميم المنتج ولكن أيضا على اختيار عملية/عمليات التصنيع المناسبة، الأمر الذي يتطلب المعرفة بمختلف بدائل التصنيع المتاحة.

هذه الرسالة تقدم برنامج يساعد على اختيار افضل عملية/عمليات التشغيل الغير تقليدية لمنتج ما. فى هذه الدراسه تم اختيار احدى وعشرون عملية، منهم ثلاثة عشر عمليات اساسية (USM، AJM، WJM، AWJM، AFM، MAF، CHM، ECM، EDM، EBM، LBM، PAM، IBM)، وخمسة عمليات مشتقة (RUM، PCM، ESD، STEM، WEDM)، وثلاثة عمليات مخلقة (ECG، ECH، EDG).

وتستند اجراءات الاختيار على تقنيات الحذف والترتيب، مع الاخذ فى الاعتبار سمات هامة مثل مادة الشغلة، الشكل المطلوب تشغيله، القدرات التشغيلية لعمليات التشغيل الغير تقليدية، وايضا الجوانب الاقتصادية والبيئية لهذه العمليات. يتم تطبيق تقنية الحذف على مادة الشغلة والشكل المطلوب تشغيله، ولكن يتم تطبيق تقنية الترتيب-بناء على المنطق الضبابي-على القدرات التشغيلية لعمليات التشغيل الغير تقليدية، وايضا الجوانب الاقتصادية والبيئية لهذه العمليات.

تم عمل البرنامج باستخدام لغة البرمجة MATLAB بمساعدة واجهة المستخدم الرسومية، معينات بصرية، والمنطق الضبابي.

هناك العديد من المميزات للبرنامج المقترح. وأحد أهم هذه السمات يظهر من خلال إجراء تعديلات في البيانات المتعلقة بالقدرات التشغيلية لعمليات التشغيل الغير تقليدية من خلال شاشات البرنامج. وميزة أخرى هامة هى القدرة على تحليل النتائج النهائية باستخدام شريط الرسوم البيانية. بالإضافة إلى ذلك، يمكن للمستخدم إدراج صورة لرسم المنتج بتفاصيله من خلال البرنامج بسهولة. كما يمكن عرض الملاحظات الهامة حول بعض عمليات التشغيل الغير تقليدية للمستخدم من خلال ملف. ايضا يمكن اعطاء اولاوية ما بين الصفر والواحد اعتمادا على القدرة التشغيلية لعملية التشغيل والمتطلبات، مع تحديد اولويه نسبية لهذه المتطلبات. هذه المميزات تؤدى إلى توفير الوقت والجهد للمستخدم، وزيادة دقة البرنامج المقترح.

وقد تم تطبيق عدد من دراسات الحالة لمنتجات حقيقية والتى تساعد على قياس اداء البرنامج بناءا على نتائجها النهائية. من بين هذه التطبيقات؛ عمل ثقوب مائله للتبريد فى ريش التربينات ، عمل ريش التربينات المتوسطة الحجم، عمل ثقب فى العدسات القضيبية والتى توضع داخل المنظار الطبى، وايضا عمل ترس داخلى دقيق يستخدم فى ساعات اليد. تم اختيار هذه المنتجات من شركات عديده ومنها: Luxcelis، ECM Technologies، Temicon، DMG. وقد اثبتت هذه التطبيقات صلاحيه ودقه البرنامج المقدم فى هذا البحث.

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Computer Aided Selection of Optimal Manufacturing Processes

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Whose knowledge and guidance provide many useful advices that have helped alot during the preparation of this work.

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ACRONYMS LIST

Abbreviation	Description
AFM	Abrasive Flow Machining
AHP	Analytic Hierarchy Process
AJM	Abrasive Jet Machining
AWJM	Abrasive Water Jet Machining
CAPP	Computer Aided Process Planning
CHM	Chemical Milling
CMP	Chemical Mechanical Polishing
CP	Critical Problem
EBM	Electron Beam Machining
ECG	Electrochemical Grinding
ECH	Electrochemical Honing
ECM	Electrochemical Machining
EDG	Electrical Discharge Grinding
EDM	Electrical Discharge Machining
EDMM	Electrical Discharge Machining Milling
ESD	Electrostream Drilling
GUI	Graphical User Interface
H	High
HAZ	Heat Affected Zone
HTW	High Tool Wear
IBM	Ion Beam Machining
L	Low
LBM	Laser Beam Machining
M	Medium
MAF	Magnetic Abrasive Finishing
MCG	Mechanical Contour Grinding
MTW	Medium Tool Wear
MRR	Material Removal Rate
NA	Not Applicable
NP	No Problem
NRP	Normal Problem

ACRONYMS LIST

Abbreviation	Description
NTP	Not Possible
NTW	No Tool Wear
PAM	Plasma Arc Machining
PCM	Photochemical Milling
QFD	Quality Function Deployment
RUM	Rotary Ultrasonic Machining
STEM	Shaped Tube Electrolytic Machining
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
USM	Ultrasonic Machining
VH	Very High
VL	Very Low
WEDM	Wire Electrical Discharge Machining
WJM	Water Jet Machining

SYMBOLS LIST

Symbol	Definition
a_{ij}	Most common range first value
b_{ij}	Most common range last value
c_{ij}	Attainable value
d	Hole diameter
L/d	Aspect ratio
N	Number of rules
w_i	Firing strength (Weightage) of the rule
z_i	Output level priority of the rule

INTRODUCTION

INTRODUCTION

Manufacturing is the science and technology to convert a material into functional useful shape and size with the desired structure and properties that are optimized for the service environment. Various operations and processes that are involved in the product's manufacturing can be grouped into six basic families namely: (i) Primary forming or material additive processes, (ii) Deforming or formative processes, (iii) Material removal or machining processes, (iv) Joining or consolidation processes, (v) Finishing and surface treatment processes, and (vi) Property enhancing or heat treatment processes. Further, each of these families can be divided into traditional (or conventional) and non-traditional (or unconventional or advanced) processes [1].

Casting, molding, powder processing, metal forming, and conventional machining techniques dominated the manufacturing industry until the mid-1900s. Their total dominance, however, has been reduced with the introduction of numerous new non-traditional manufacturing techniques since 1940s, ranging from ultrasonic machining of metal dies to the nano-scale fabrication of optoelectronic components using a variety of lasers [2].

Parts manufactured by casting, forming, and various shaping processes often require further operations before they are ready for use or assembly. In many engineering applications, parts have to be interchangeable in order to function properly and reliably during their expected service lives; thus control of the dimensional accuracy and surface finish of the parts is required during manufacturing [1, 3].

Machining is the removal of the unwanted material (i.e. machining allowance) from the workpiece, so as to obtain a finished product of the desired size, shape, and surface quality. Machine tools form around 70% of operating production machines and are characterized by their high production accuracy compared with metal forming machine tools [1-4].

Ever-growing demand for better, durable, and reliable product performance has brought about a materials revolution thus greatly expanding the families of some alloys (i.e. super-alloys) and that of the non-metallic materials namely polymers, ceramics, and composites. These materials can be engineered to have a wide variety of unique properties and characteristics like very high strength and stiffness at elevated temperatures, extreme hardness and brittleness, high strength to weight ratio, very good oxidation and corrosion resistance, chemical inertness, etc., making them commercially attractive [1-6].

These materials development related factors along with the requirements like high precision machining of complex and complicated shapes and/or sizes, machining at micro- or nano-levels, machining of inaccessible areas, demand for new standards of product performance and durability, surface integrity, tool wear considerations, economic return, burr free machining, low applied forces, etc., have contributed significantly in the development of various non-traditional machining processes (NTMPs) [1-5].

NTMPs development took place after the World War II and is still continuing with the development of hybrid processes by combining two or more processes or modifying a basic NTMP for specific types of requirements [1-3].

To classify NTMPs, one needs to understand and analyze the differences and similar characteristics between traditional and non-traditional machining processes. The following are the advantages and limitations obtained by making a comparison between them [7]:

- Traditional machining requires the presence of a tool that is harder than the workpiece and in physical contact with it. Moreover, a relative motion between the tool and the workpiece is required for forming or generating the required shape, so tool wear problem increase. In most NTMPs, there is no physical contact between the tool and workpiece. Although in some NTMPs tool wear exists, it is rarely a significant problem.

- In traditional machining, the relative motion between the tool and workpiece is typically rotary or reciprocating. Thus, the shape of the work surfaces is limited to circular or flat shapes. In spite of widely used CNC systems, machining of three dimensional surfaces is still a difficult task. Most NTMPs were developed just to solve this problem.

- Chip formation by shear deformation occurs during traditional machining, while material removal may occur with chip formation or even no chip formation in NTMPs.

- Traditional processes are well established; use relatively simple and inexpensive machinery and readily available cutting tools. NTMPs require expensive equipment and tooling as well as skilled labour, which increases significantly the production cost.

- NTMPs easily deal with such difficult to cut materials like ceramics and ceramic based tool materials, fiber reinforced materials, carbides, and titanium based alloys since these materials generally contain fibers and fillers that exhibit brittle behaviour.

Thus, NTMPs can be classified into various groups according to the basic requirements, as shown in Table 1 [1].

Most of NTMPs are associated with relatively higher initial investment or capital cost, power consumption and operating cost, tooling and fixture cost, and maintenance cost. Also NTMPs are non-versatile from the application point of view, as a particular NTMP that is found suitable under specific condition may not be equally effective and efficient under different conditions. Therefore, effective, efficient, and economic utilization of the potential and capabilities of NTMPs necessitates careful selection of an appropriate process.

Table 1. NTMPs classification.

	Energy Type	Basic Mechanism	Source of Implemented Energy	Transfer Energy Medium	Example
Non-Traditional Machining Processes	Mechanical	Shear	Cutting tool	Physical contact	MCG
		Erosion	Pneumatic or hydraulic pressure	High velocity particles	USM AJM
				High Velocity liquid	WJM
	Electrical	Ion displacement	High current	Electrolyte	ECM ECG
	Chemical	Ablative action	Chemically reactive agent	Environment	CHM PCM
	Thermal	Vaporization	High voltage	Electron	EDM EBM
			Amplified light	Radiation	LBM
		Fusion	Ionized material	Hot gases	PAM IBM

In this regard, experts often make correct decision regarding process selection, but transfer of this experience and expertise is a time consuming process and sometimes almost infeasible. While industrial applications of NTMPs are increasing constantly, the availability of the skilled experts is reducing day by day due to an increasing level of automation and diversities in the field of manufacturing.

In this context, collection, computerization, and integration of the widely scattered knowledge, experience, expertise, and skills related to the selection of NTMPs, and subsequently implementation in the form of an integrated, automated, intelligent, interactive, and rational Computer Aided Process Planning (CAPP) system can help different users of NTMPs, particularly to the mid-level manufacturing engineers working at shop-floor and lacking in-depth technical expertise about NTMPs.

Therefore, the aim of this work is to aid an engineer in making the right decisions regarding NTMPs selection and manufacturability evaluation at the design stage itself, by developing a software for selecting the optimal NTMPs from twenty one processes. It has been developed using MATLAB, version (V7.8) release (R2009a), as programming language with the help of graphical user interface (GUI), visual aids, and fuzzy logic toolboxes. The selection procedures are based on elimination and ranking technique, considering important attributes such as workpiece material and shape generation requirements, NTMPs operational capabilities, and NTMPs economical and environmental aspects. The validity of the developed software has been tested by real industrial case studies.

This thesis is organized as follows:

- Chapter one presents the literature survey.
- Chapter two presents fuzzy logic concepts and explains MATLAB fuzzy logic toolbox.
- Chapter three presents the proposed NTMPs selection methodology.
- Chapter four presents detailed explanation of the software development.
- Chapter five presents the results and discussions obtained from four real industrial case studies.
- Chapter six presents the conclusions, as well as the suggested future works.

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أختيار أفضل عمليات تصنيع بمساعدة الحاسب الآلى

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للحصول على درجة
ماجستير الهندسة
فى هندسة الانتاج

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Mansoura University
Faculty of Engineering
Production Engineering & Mechanical Design Department

Computer Aided Selection of Optimal Manufacturing Processes

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