العنوان:	CAM system for CNC wire cutting machine tools
المؤلف الرئيسي:	ابراهيم، حمدي توفيق محمد
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SUMMARY

Wire cutting process is widely used for making stamping dies, tools, templates, extrusion dies, and progressive dies. It is also used for prototype production of parts to be made later by die stamping or CNC milling.

The wire-EDM programming starts with a manual method. With the increased use of NC systems and growth in complexity of production the manual programming became a tedious work, time consuming. The manual method depends to a very great extent on the experience of the operator, which leads to many human errors. So, the part programmer was no longer able to calculate efficiently the required tool path, and the use of CAM systems as an aid to part programming became a necessity.

Many trails have been carried out to develop the wire-EDM programming methods. But, applications of many wire-EDM techniques in these methods are not satisfactory and have different shortages. For example, generation of standard radius, sequence of wire path, fixation stability, No-Core cut, etc.

Thus, the objective of this thesis is to design a CAM system to sequence the wire path in a way to minimize the programming time, and generating the standard radius. No-Core cut, fixation stability, and optimizing the wire cutting process can be achieved through the proposed CAM system.

Some of the wire-EDM techniques such as, making the conical

cutting, trim cut, and calculating the optimum location for the threading point of the wire, are also achieved through the proposed system.

Through different applications of the proposed system, the results show a great saving in programming time, user effort, high precision for all steps of the cutting process, and a powerful monitoring. The proposed system uses an advanced simulating module for verifying cutting process, and to minimize calculation errors.

The thesis consists of five chapters. ***Chapter one*** presents an introduction to the wire-EDM cutting process, wire-EDM machine tools, and the applications of the wire-EDM process. Also, the illustrations of the more relevant works as a literature survey finally the aim of this work. ***Chapter two*** contains the details of the wire-EDM cutting process and some of the wire-EDM techniques such as, standard radius, No-Core cut, taper cut, trim cut, etc. ***Chapter three*** presents in details the structure, the information flow, the main algorithm, and the flow charts of the proposed system. ***Chapter four*** introduces the applications of the proposed system compared with LAMA, EasyCut and contains the output data of the proposed system. ***Chapter five*** illustrates the main results, conclusions and the future work. Finally, the ***References*** were listed.

Three appendices and the ***Arabic Summary*** have been provided in this thesis. ***Appendix A*** contains the ISO codes of the wire cutting. ***Appendix B*** contains illustration of the main technology codes. ***Appendix C*** offers the main functions of the job file.

Arabic Summary

كما اشتملت أيضا على نظام محاكاة (Simulating System) لمساعدة المستخدم لتصور عملية القطع و اكتشاف الأخطاء وبما يوفر وقت الماكينة للقطع الفعلى.

وقد أثبتت التطبيقات مدى ما يتمتع به هذا النظام من دقة عالية فى كل مراحل الحسابات وكذلك توفير وقت ومجهود المستخدم. كما أظهرت أيضا، الرقابة الكاملة للبرنامج على كل مراحل الحسابات واكتشاف الأخطاء و المساعدة فى حلها.

و قد اشتملت هذه الرسالة على خمسة فصول، حيث يمثل ***الفصل الأول*** مقدمة عن عمليات القطع بالسلك، و أهم تطبيقات هذه الطريقة، كما يشتمل على دراسة شاملة لكل ما سبق نشره فى هذا الموضوع، كما زود هذا الفصل بتحليل الهدف من وراء إجراء هذا البحث.

ويقدم ***الفصل الثانى*** دراسة شاملة لعملية القطع بالسلك، كما يحتوى أيضا على معظم الأساليب (Wire-EDM Techniques) المستخدمة فى إنتاج المشغولات المختلفة.

و يشتمل ***الفصل الثالث*** على شرح واف للنظام المقترح (Proposed CAM System)، و لوحات العمليات التى توضح انسياب البيانات عبر أجزاء (Modules) النظام المقترح.

ويوضح ***الفصل الرابع*** تطبيقات النظام المقترح بالمقارنة مع النظم الاخرى مثل (EasyCut & LAMA) عن طريق ثلاثة أمثلة و التى اختيرت بعناية لتبرز أهم ما قدمه النظام المقترح من توفير لخطوات الإنتاج و خاصة فى حالة (Compound Dies).

ويشتمل ***الفصل الخامس*** على أهم النتائج وملخص واف للخلاصة المستفادة من البحث، كما يشتمل أيضا على أهم النقاط و التى تصلح للعمل المستقبلى (Future Work).

الملحق (A) ويشتمل على الشفرات (Codes) المختلفة التى يتكون منها ملف التحكم الرقمى (NC File) والخاصة بماكينات القطع بالسلك. ***الملحق (B)*** ويشتمل الشفرات المختلفة التى يتكون منها ملف التكنولوجى (Technology File). ***الملحق (C)*** ويشتمل الشفرات المختلفة التى يتكون منها ملف الشغلة (Job File). قائمة ***بالمراجع*** المستخدمة، و أخيرا ***الملخص العربى*** للرسالة.

الملخـــــص العربـــــى

تعتبـــر عملية القطـــع بالســـلك (Wire-EDM) مـــن طـــرق القطـــــع الغـــير تقليديـــة (Non-Traditional Machining) والتى لا تتأثر بصلادة أو نوع الشغلة و تتميز بالدقة الكبيـــرة.

ومـــن أهـــم تطبيقـــات هـــذه الطريقـــة، هـــو مجـــال إسطمبـــات قطـــع الصـــاج (Sheet Metal Cutting Dies) والتى تستخـــدم على نطاق واســـع فـــى الإنتـــاج الكمـــى. كمـــا تستخـــدم هـــذه الطريقـــة أيضا، لإنتـــاج مختلف أنواع العِـــدد والتى تكون على درجـــة عاليـــة مـــن الصلادة مما يصعب معها إنتاجها بالطـــرق التقليديـــة.

ولقد اســـتخدم الكمبيوتر منذ فترة طويلة كوســـيلة فعالة و ناجحـــة لإدارة الماكينـــات الرقميـــة للقطـــع بالســـلك (CNC Wire-Cutting Machine Tools)، وذلك عـــن طريـــق استـــخدام أنظمـــة (CAM Systems). وعلى الرغم من ظهور العديد من أنظمة (CAM Systems) إلا أن معظـــم هـــذه الأنظمة اكتنفتها مشـــاكل كثيـــرة، كما أنها لم تعالج الكثيـــر من الأساليب المســـتخدمة فـــى قطـــع المعادن بالســـلك المعالجة الفعالة. فعلى سبيل المثال، تحديد مســـار الســـلك، موضع دخول الســـلك إلـــى الكـــنتور(بداية منطقة القطـــع)، شطف الأركان الحادة، تحديد نوع الكنتور (Punch / Die)، التعامل مـــع القطع المخروطى، و غيرها ...، وكلها تعالج بطريقـــة يدوية تعتمـــد فـــى المقـــام الأول علـــى مهـــارة و خبـــرة المســـتخدم فى مجال القطـــع بالســـلك.

لذلك فقد اشـــتملت هذه الرســـالة على نظام جـــديد (Proposed CAM System) لمعالجة معظـــم المشاكل التى تكتنف الأنظمة الموجودة حاليا. مثل عملية اختيار مســـار الســـلك، شطف الأركـــان الحـــادة، تحديـــد نـــوع الكنتـــور، التعـــامل مـــع القطـــع المخروطـــى، تحديـــد موضعـــى لضـــم وقطـــع (Threading & Breaking Points of the Wire)، و عمـــل (No-Core cut)، و غيرها...، و كلـــها تعـــالج بطريقة آليـــة لا تعتمـــد إطلاقا على مـــدى ما يتمتع بـــه المســـتخدم مـــن مـــهارة و خـــبرة فـــى مجـــال القطـــع بالســـلك.

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بسم الله الرحمن الرحيم

يؤتي الحكمة من يشاء

ومن يؤت الحكمة فقد

أوتي خيرا كثيرا وما يذكر

إلا أولوا الألباب

صدق الله العظيم

الآية رقم (٢٦٩) سورة البقرة

DEDICATION

To My Family…Specially

To My lovely "PARENTS"

For Their Sincere…Warm

Feeling… Great Support…Encouragement

…And Their Unlimited Care…

GOD Bless them forever and ever.

To my dear Prof. Dr. El-Midany

&

To my dear Dr. El-Keran

HAMDY

Jan., 1999

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I'd like to greatly acknowledge their guidance, sincere help, assistance encouragement and invaluable suggestions through the supervision of this thesis.

Hamdy Tawfik

15th Jan., 1999

NOMENCLATURE

&	And
*.cnc	Proposed System ISO Code File
*.geo	EasyCut Numerical Control File
*.pgf	Programmed Geometry File
*.pof	Proposed System Position File
*.prg	EasyCut Source Program File.
*.ted	Proposed System Technology Data File
*.wcf	Proposed System Sorting Format File
2-D or 2 D	Two Dimensions
3-D or 3 D	Three Dimensions
Al	Aluminum
ASCII	American Standard Code for Information Interchange
AWT	Automatic Wire Threading
Ca	Calcium
CAD	Computer Aided Design, or Computer Aided Drafting
CAM	Computer Aided Manufacturing
camo	EasyCut Executable File
cc	Cubic Centimeter
CCW	Counter Clock Wise Direction

CNC	Computer Numerical Control
Co.	Company
Cu Zn	Brass
Cu	Copper
CV	Computer Vision
CW	Clock Wise Direction
d	Correction
DXF, or *.dxf	Drawing Interchange File, or Drawing Exchange File
ECG	Electro-Chemical Grinding
ECM	Electro-Chemical Machining
EDM	Electrical Discharge Machining
Ele or ELE	Element
F.Gr	Graphite
gm	Gram
IGES	Initial Graphics Exchange Specification File
Kg or kg	Kilo Gram
Ltd.	Limited
Max or max	Maximum
Min or min	Minimum
MM	Millimeter
MRR	Metal Removal Rate

MWT	Manual Wire Threading
NC	Numerical Control
No.	Number
PGF	Programmed Geometry Data
R.	Release
S.E	Spark Erosion
S.R	Standard Radius
So_4	Sulphate Group
SQ. or Sq.	Square
TED or Ted	Technology Data
Ver. or ver.	Version
WCF	Wire Cut Sorting Format Data
Windows 95	Microsoft Windows Version 4.00.950a
Windows NT	Microsoft Windows New Technology
Wire-EDM	Spooling Wire Electrical Discharge Machining
X, Y, Z, U, and V	Wire-EDM Machine Axes
X210 Cr W12	Steel with the Specified Composition

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SUMMARY

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The wire-EDM programming starts with a manual method. With the increased use of NC systems and growth in complexity of production the manual programming became a tedious work, time consuming. The manual method depends to a very great extent on the experience of the operator, which leads to many human errors. So, the part programmer was no longer able to calculate efficiently the required tool path, and the use of CAM systems as an aid to part programming became a necessity.

Many trails have been carried out to develop the wire-EDM programming methods. But, applications of many wire-EDM techniques in these methods are not satisfactory and have different shortages. For example, generation of standard radius, sequence of wire path, fixation stability, No-Core cut, etc.

Thus, the objective of this thesis is to design a CAM system to sequence the wire path in a way to minimize the programming time, and generating the standard radius. No-Core cut, fixation stability, and optimizing the wire cutting process can be achieved through the proposed CAM system.

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Chapter One

Introduction and Literature Review

Chapter One

1 Introduction & Literature Review

1.1 Introduction

Electrical discharge machining, the process normally referred to as EDM, came into industrial use shortly after *World War II*. Its initial applications were in "tap-busting," the electrical erosion of broken taps in parts and die sections too valuable to discard. It was soon discovered, however, that the process of electrical erosion could be controlled to machine cavities and holes. After that, the wire EDM was used to execute the through cutting of EDM [1]. Through half century of researching and development, EDM occupied 75 % of all non-traditional machining Fig. 1.1. Next comes Ultrasonic 17 %, then Electro-Chemical Machining

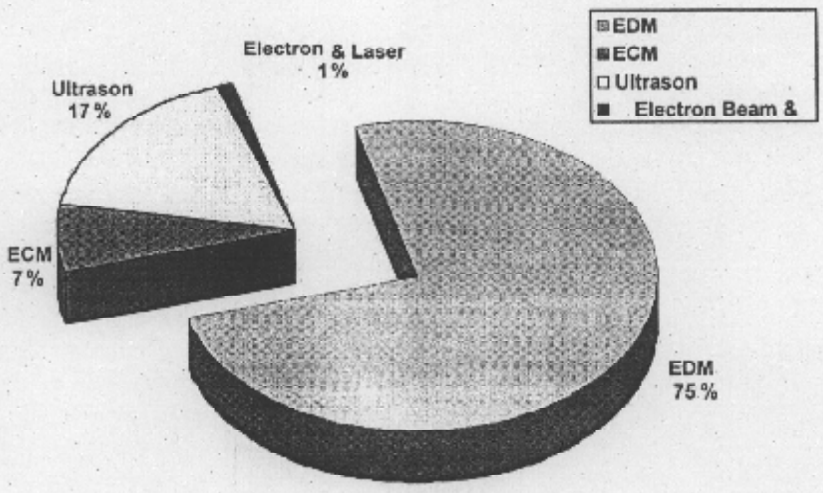

Fig 1.1 Non-traditional Machining Comparison

Machining (ECM) 7 %, and lastly Electron Beam & Laser 1 % [2].

The wire EDM is a specialized form of EDM in which the electrode is a continuously spooling conducting wire. The wire moves with respect to the work piece by a numerically controlled table. The contour cutting is similar to the contour cutting in a band saw so, wire EDM sometimes called "Electronic Band-Saw" [1]. The diagram of a traveling wire EDM machine is shown in Fig. 1.2. The wire EDM machines have at least two controlled axes (X and Y). Most machines can tilt the wire to produce tapered work piece using two auxiliary horizontal axes (called U and V). Controlled vertical and rotary axes are also available.

The wire is usually made of brass, copper, or tungsten and typically about 0.25 mm in diameter, making narrow cuts possible [3]. The wire is usually used only once, as it is relatively cost inexpensive. It travels at sufficiently high and constant velocity, 2.5-150 mm/s, and constant gap (kerf) is maintained during the cut [3]. High tensile strength, high electrical conductivity, and good wire drawing are the most important factors needed for choosing wire type and ideal cutting.

Researches in wire material and diameter are still active. The trend is toward layered wires Fig. 1.3 with different materials for different functions. Wire with a steel core for tensile strength, a copper layer for

conductivity, and a graphite outer layer for good wire drawing, is an example of layered wire.

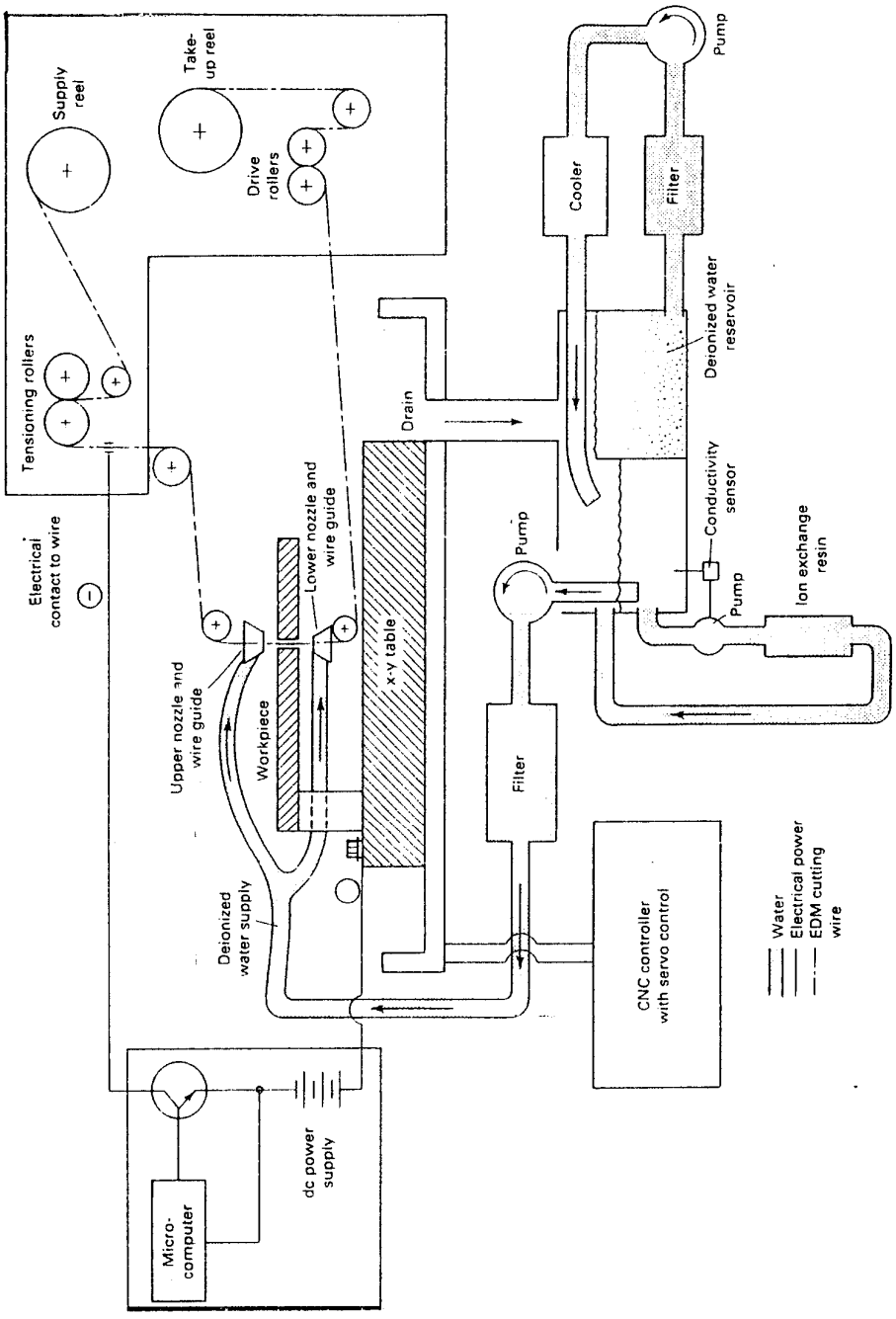

Fig. 1.2 Travelling Wire-EDM Machine

The outer layer in particular can be selected to suit the application. Although the layered wire is more expensive but, it cuts faster than the brass wire. Zinc-coated brass and molybdenum core wires are also available. High tensile strength wires are specially good when a small diameter wire must be used to make small corner radii.

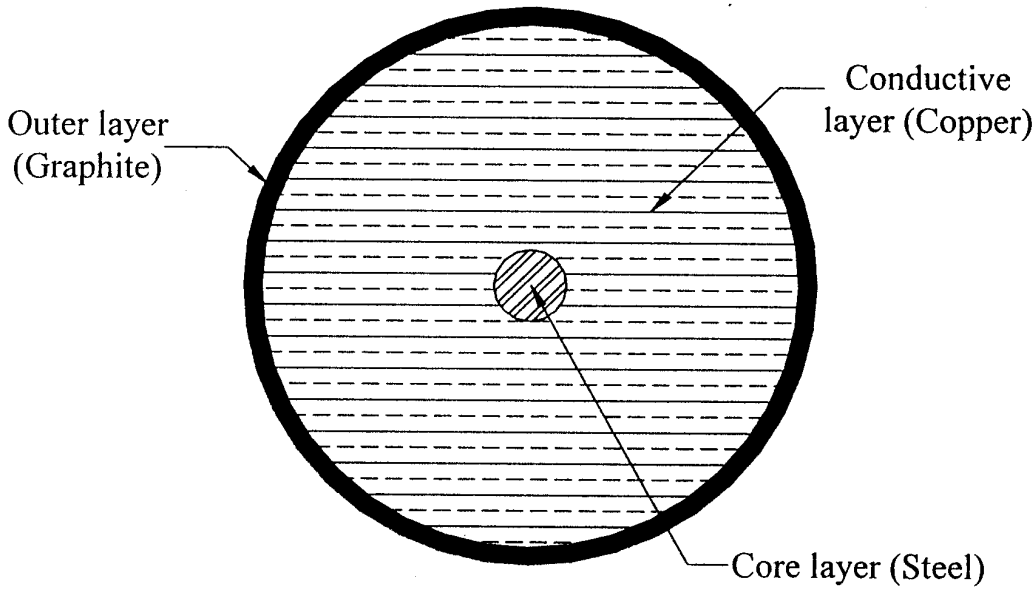

Fig 1.3 Layered Wire

Servo control of the machine tool is similar to that of vertical CNC machines. Flushing problems or work piece distortion sometimes makes it necessary for the wire and work piece to separate. The controller must ensure that the separation takes place along the path previously cut. Work piece thickness capacity of 150 mm is average with some machines capable of up to 500 mm [4].

Flushing is provided by nozzles at the upper and lower wire guides, with the stream of dielectric, usually de-ionized water, being coaxial with the wire. Swarf is removed by filtration and settling.

Normal accuracy is about ±0.013 mm. Special measures such as multiple passes and precise temperature control are used for a higher accuracy of ±0.005 mm [3]. Power setting may be decreased with each pass for improved surface, as with vertical EDM.

Constant wire tension must be maintained. The tension must be high enough to keep the wire straight in the cutting zone, but not high enough to break the wire. The right tension is a function of the wire material and diameter. Wire guides are made of a hard material such as sapphire or diamond to minimize wear. The guides are required to keep the wire vertical, which is necessary to maintain straight sides on the work piece.

It is a good practice to use a start hole (startron). If entry is made from outside of the stock, the effect (near the end of the cut) is similar to picture frame with one corner not joined. Internal stresses in the frame cause distortion during the cut, with resulting loss of accuracy. The effect can be lessened if the frame is massive compared to the slag. A so-called glue strap, or piece of metal with spots of glue on frame and slug, is often used to bridge the slug and frame.

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كليـــــة الهندســـــة

قسم هندسة الإنتاج والتصميم الميكانيكى

إستخدام الحاسب الآلى فى تصنيع منتجات على ماكينات القطع بالسلك ذات التحكم الرقمى

رســـــالة مقدمـــــة مـــــن

المهندس/ حمـــدى توفيـــق محمـــد إبراهيـــم

(بكالوريوس هندســـــة الإنتاج ١٩٩٤)

توطئة للحصـــول علـــى درجـــة

الماجستير

فى هندســـــة الإنتاج

١٩٩٩

MANSOURA UNIVERSITY
FACULTY OF ENGINEERING
Mechanical Design & Production Engineering Dept.

CAM SYSTEM FOR CNC WIRE CUTTING MACHINE TOOLS

By

Eng. Hamdy Tawfiek Mohammed Ibrahim

B. Sc. (Production Engineering)

A Thesis

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