Rapid prototyping and toolings engineering essay

Engineering

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Recommendation

We are pleased to recommend that the thesis work of Mr. name of student entitled " title of thesis" to be accepted in partial fulfillment of the degree of Bachelor of Engineering in Electrical & Electronics Engineering.

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Certificate

This is to certify that this Thesis entitled " Title of thesis………" submitted by Mr. name of student towards partial fulfillment of the requirement for the award of the degree of Bachelor of Engineering in Electrical & Electronics Engineering is a satisfactory account of his work based on syllabus and is approved for the degree of Bachelor of Engineering in Electrical & Electronics Engineering.

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Chapter 1

Introduction

INTRODUCTION

To compete in today's industry environment, companies must keep up with the leading technologies and processes and also push the boundaries and develop new and improved productsand processes. The Manufacturing Industry is an area where time, efficiency and accuracy are the major driving forces behind innovation and research. The most competitive companies are those who continually reduce process times, increase efficiency and improve accuracy. Rapid Prototyping and Tooling is an area that has and is continuing to reduce production time and increase efficiency and accuracy in developing and manufacturing prototypes compared to traditional prototype manufacture. The main function of Rapid Prototyping (RP) is to give the manufacturing the neededonfidence to go on to tooling and mass manufacture of the product they have designed. Once the product has met the design criteria through RP it is then needed to meet the functional criteria and that is where Rapid Prototyping has developed and evolved into Rapid Tooling. RP is an extremely useful process but it cannot always provide the manufacturer with a functional prototype in the material of choice. Rapid Tooling can provide this solution giving the manufacturer a functional prototype in the material of choice and that allows functional testing to be done on the product. The use of Rapid Tooling means a reduction in the time-to-market for aProduct and also better testing to meet functional criteria. Rapid Tooling is also useful in helping start production and getting the product into the market, while the more expensive and durable traditional tool is being produced for the mass manufacture of the product. Therefore the competition lies in researching possible ways to increase the effectiveness of Rapid Tooling and reducing the time and cost of getting the customers product to market. Electro-Discharge Machining (EDM) is a manufacturing process that has been affected by developments in Rapid Prototyping and Tooling. EDM is commonly used by toolmakers for complex injection moulds, punch dies and cavities made from hardened tool steels. EDM is ideal for materials and complex shapes that traditional machining processes are unable to perform. In die and mold production, the EDM cycle can account for 25 to 40% of the toolRoom lead-time [1, 2]. The electrode production represents over 50% of the cost andtime of an EDM operation [2]. The goal is to reduce the time and cost of the EDMcycle and to do this, alternate methods of electrode production is a key area ofresearch. Since conception EDM electrodes have been manufactured from solid conductivemetals including copper and tungsten, and also from non-metals mainly graphite. Using traditional machining operations in producing complex electrodes from solidcopper or graphite may require the production of several smaller electrodes andjoining them together, or running several machining cycles to get the required cavity shape. Therefore increasing the complexity of the electrode increases the electrodeproduction time and also increases the machining time if several machining cycles are required. Investigation into alternate methods of electrode production is required toreduce cost and time. To gain a good comparison of the various electrode manufacturing methods, the experiments include the use of Electroformed Copper, Copper Spray-deposition and traditional Solid Machined Copper Electrodes tested under several machining conditions. Electroforming is a process that can be controlled to a high degree and can operate with precision and reliability. Electroforming can be employed to produce electrodes with complex shapes that in the past would require the use of several conventional techniques that might include machining, pressing and welding to manufacture a similar electrode. The other manufacturing process used in attempts to produce copper electrodes isSpray Deposition or Spray Metal Deposition as it is also named. Spray metaldeposition has been used to produce moulds for many different moulding processes. It is possible for the moulds to be manufactured quickly and inexpensively for thoseprocesses [4-9]. As a different rapid prototyping technology and quick productiontechnology, spray metal tooling is used in a flexible system for producing smallnumbers of parts. Spray metal deposition is normally used to produce moulds but inthis project it is used to spray into a mould to produce the electrode shells. When comparing the different electrode manufacturing methods, the machiningonditions include a roughing setting, semi-roughing setting and a finishing setting. The performance of the EDM process is measured with respect to machining rate orMaterial Removal Rate (MRR), electrode wear (TWR), and surface finish of the workpiece (Ra). The design of the electrodes evolved from previous research in the design and use ofelectroformed electrodes. The tool used by Subramanian was found to produceexcess wear on the protruding surfaces and very little wear on the cavities. Thereforeit was decided to do the tests using separate portions of similar design. The toolsdeveloped include a simple conical shape, a triangular protrusion and a more complexshape that would be almost impossible to machine a similar cavity. The simple andcomplex designs are used to compare the various manufacturing methods

1. 1 AIMS AND OBJECTIVES

In the proposed research an attempt will be made to investigate the following:(a) Testing the viability of electroformed copper electrodes for EDM byconducting electrode wear studies,(b) Testing the performance of an electroformed copper electrode in comparisonto a machined copper electrode, based on tool wear and economy of toolmanufacture,(c) Study the effect of texture of the EDM tool on the work piece material, and(d) Developing Rapid Tooling for EDM and injection moulding by using SprayMetal Deposition technique .

1. 2 METHODOLOGIES

This project involves the following steps:• Development of CAD models of Electrodes• Rapid prototyping and tooling to produce electrode master patterns,• Electroforming negative tool to produce copper shells for electrodes, andbackfilling to give the shell support,• Machining of Solid Copper Electrodes for comparison to alternativelyproduced electrodes,• Production of Spray-metal copper shells for electrodes,• Testing Electrodes comparing Material Removal Rate (MRR), Tool Wear Rate(TWR) and Surface finish for the different production methods,• And evaluating results and developing conclusions.

Chapter 2

Literature review

LITERATURE REVIEW AND BACKGROUND

The tremendous advancements in EDM technology have been achieved for more than50 years through the collective efforts of many dedicated engineers from some of theworld's leading institutions and research centres. The research fields mainly coverEDM control systems and EDM technology. EDM control system includes the servocontrol unit and the parameters that control the system. EDM technology covers themachine abilities and electrode research.

2. 1 RAPID PROTOTYPING AND TOOLING

Rapid Prototyping (RP) and tooling is a continuation from three-dimensional CADmodelling. RP uses the CAD data to produce layer information that is fed into RPmachines to produce a three dimensional solid model from a chosen process andmaterial. Common RP processes include Stereolithography (SL), Selective LaserSintering (SLS), Laminated Object Manufacturing (LOM) and Fused DepositionModelling (FDM). The majority of RP processes involve the conversion of the CADdata into cross-sectional information and the model is built layer-by-layer. In the production of EDM electrodes many RP processes have been previously used. The most promising process involves the use of stereolithography and producingmodels as either positive or negative master patterns. Stereolithography (SL) usesinformation from a computer generated three-dimensional model to produce a solidthree-dimensional model from various types of laser-curing polymer resins. TheStereolithography Apparatus builds the three-dimensional solid model layer by layer. The computer file is broken down to layers and the SLA reproduces the layer on thesurface of the resin. The part is then lowered by the relative layer thickness, and theprocess is repeated until the completed model is produced. The StereolithographyApparatus used is developed and marketed by 3D Systems Inc, Valencia, California, USA. The machines produce models with high detail and accuracy and have theability to produce multiple parts simultaneously. Using the positive master pattern is termed as " Direct Electrode Manufacture" in thatthe SL pattern is plated with a conductive material and used as the electrode. Alternatively, using the SL pattern as a negative and removing the plated shell istermed as " Indirect Electrode Manufacture". Research in the area of Direct Electrode Manufacturing process includes work fromArthur et aland Leu et al. [15]. Results using the direct manufacturingmethod have shown advantages in that the electrodes are comparable to traditionalsolid electrodes in finishing, semi-roughing and roughing machine settings andelectrode production time is reduced as large quantities of electrodes can be producedsimultaneously. The results also concluded disadvantages including the possibility ofnon-uniform distribution of electrodeposited material resulting in unknown platingthickness, EDM machining time is quite high, the SL master pattern is sacrificial andthe electrodes are prone to premature failure if the plating thickness is less than 180µm. Alternatively the area of Indirect Electrode Manufacture has been researched anddeveloped by Jensen and Hovtun [16], Rennie et al. [17] and Yarlagadda et al. [3, 18, 19]. Advantages for using indirect electrode manufacture include relatively lowmanufacturing cost, multiple electrodes can be produced simultaneously, the masterpattern can be reused multiple times and the electrodes can be manufactured to highaccuracy and quality. Jensen and Hovtun were also able to show that the performanceis comparable to solid electrodes. Jensen and Hovtun [16] found disadvantages that include unacceptably high wearrate, poor accuracy, long process time and internal details can be problematic. Rennieet al. [17] provided similar disadvantages in that narrow internal cavities are notplated to the same thickness as external features and failure still occurs with excesswear and uneven material distribution. Yarlagadda et al. indicated that differentsections of the tool performed more work than other sections, triangular protrusionshad split and tool failure occurred and course machining can deform the tool. 7

2. 2 ELECTROFORMING

Electroforming uses electro-deposition of a metallic coating to a mould to produce anegative copy, which is a hollow shell that is removed from the pattern as the finishedproduct, or the metallic coating is added to the pattern to produce a platted positiveproduct on the surface of the pattern. The process is shown in Figure 2. 1. First a mould is produced from the master pattern to be copied. The mould may consistof a non-metallic substance or sometimes a low-melting-point alloy. A suitablesubstance (silicon tooling) used for the production of the mould and plastics, inparticular, have the advantage of producing moulds that have a long service life - i. e., can be reused a large number of times. Moulds may comprise one, two or three parts, depending on the complexity and shape of the model. For a non-conductive mould the surface of the mould is coated with an electricallyconductive material to allow the electrical circuit to flow. The preferred method is afine film of silver sprayed to the surface, other methods include brushed fine graphitepowder or a metallic powder suspended in a thin lacquer. Using direct current and the principle of electrolysis electro-deposition of metalliccoatings are done in an acid or alkaline salt solution containing the metal to bedeposited. The mould becomes the cathode when connected to the negative pole andthe anode or positive pole is usually made from the metal being deposited. The anodeis gradually consumed during the process. Various auxiliary techniques are applied -such as the use of internal anodes, masking, etc. - to ensure that a uniform and smoothmetallic coating is formed. By the addition of special substances it is possible toenhance the smoothness, fineness and lustre of the coating. When a coating of thedesired thickness has been attained, the shell is rinsed, removed from the mould and, ifnecessary, given a finishing treatment. Next, the shell may be given backing or fillingof low-melting-point alloy, or some other material, to strengthen it. [20]C: Users 0000000000000000000Desktop151. jpgFigure 2. 1 – Electroforming ProcessElectroforming is used for a variety of purposes: e. g., making copies of archaeologicalor art objects, printing plates, metal discs in the manufacture of phonograph records, embossing dies, templates, molds for casting, and many object used in mechanical andelectrical engineering.

2. 3 SPRAY DEPOSITION

Spray deposition is a process also known as spray-metal deposition, plasma spraydeposition, plasma spraying and plasma deposition. Research in recent years hasshown advances in the use of spray metal and the resulting properties [4-9]. Spray metal deposition involves spraying atomised molten metal on to a pattern toproduce a copy of the surface required as shown in Figure 2. 2. The process producesa shell on the surface of the pattern that is usually removed and back filled to providea low cost alternative to producing a solid metal model. The moulds can be made costeffectively from wood, metal, plastic, ceramic or even leather. These moulds canbecome very inexpensive due to the fact that they can be used more than once. C: Users

0000000000000000000Desktopimages (1). jpgFigure 2. 2 – Spray Metal Deposition ProcessThe benefits of Spray Metal Tooling are that it cost 75% less and moulds can be madein 1/5 of the time. There are various applications in which spray metal tooling isused:• Prototype Injection Moulds• Polyurethane Tooling• Structural Foam• Thermoform Tooling• Blow Moulds• I. S. P. (instant set polymers)• Spray Metal Tooling can be used to reduce cost of prototype moulds for; o Evaluating Injection Moulding Compoundso Make Custom Trade Show Sampleso Test Physical Characteristics of Moulded Productso Develop Spray Masks From Moulded partso Determine if Shrink Fixtures are Necessary

2. 4 EDM

The Electro-Discharge Machine, shown in Figure 2. 3, used in the project is the SodickMould-Maker 3 NF40 situated at QMI Solutions in Brisbane. 11C: Users 0000000000000000000Desktopdownload. jpgFigure 2. 3 – Sodick Mold-Maker 3 NF40The EDM system consists of a shaped tool (electrode) and the work piece, connectedto a DC power supply and placed in a dielectric fluid. When the potential differencebetween the tool and the work piece is sufficiently high, a transient spark dischargesthrough the fluid and removes a small amount of metal from the surface of the workpiece. The amount of metal removal rate, surface finish and tool wear are dependent on thevoltage, current and frequency of sparks. Increase in voltage and current results in anincrease in material removal rate and surface roughness. Due to the machining process occurring without any machining forces, EDM is theideal machining process for very fine detailed machining to be done. EDM allows thesteel to be hardened prior to machining to remove the possibility of distortion aftermachining. 12

2. 5 LITERATURE REVIEW

Research groups have been researching into many areas of Rapid Prototyping andTooling. Areas of Rapid Tooling that research has been conducted and is continuingin include forming tools[21], stereolithography injection mould tools[22, 23], Rototoolsfor casting[24] and polymer infiltration for rapid tools[25]. These areas in rapidtooling show that there is still a large scope for potential research to improvetraditional and non-traditional tooling. Harris et al. [22, 23] indicates that productionof low volume of parts can be done in much less time and lower costs using the rapidtooling technologies. Noguchi and Nakagawa [21] have shown that combining RPprocesses (SLA and Sintering) provides a useable method of producing metallic rapidforming tools. Chan et al. [24] provide a proven case for the introduction of rapidtooling into a traditionally labour intensive and expensive process. Areas of Rapid Prototyping have been more extensively investigated and researched. RP covers areas like Laminated Object Manufacture (LOM), Stereolithography(SLA), and Selective Laser Sintering (SLS). These RP processes are often used as theinitial steps to lead in to Rapid Tooling. Mueller and Kochan [26] have researchedand shown that LOM provides a cheap and effective option as the initial steps forfoundry casting patterns. Extensive use of SLA has been used in the initial steps ofprototyping and manufacture in the areas of injection mould tooling [22, 23, 27], sheetmetal drawing [28], precision forming tools [21], and EDM tooling [3, 10, 11, 14, 15, 18, 19, 29, 30]." EDM has the advantage of allowing tool steel to be treated to full hardness beforemachining, avoiding problems of dimensional variability which are characteristic ofpost treatment"[14]. EDM (Electric Discharge Machining) or spark erosion is a nontraditionalmachining process used on hardened tool steels when complex and detailedsurfaces are required. In die and mould production, the EDM cycle can account for25 to 40% of the tool room lead-time [1, 2]. The electrode production represents over50% of the cost and time of an EDM operation [2]. In today’s manufacturingenvironment cost reduction is a main goal, and a great emphasis is placed on thereduction of time to complete tasks. 13Decreasing time and improving efficiency of processes is the main focus of manyresearchers. Advancements in Rapid Prototyping have allowed for great time savingin current processes. Rapid Prototyping (RP) and associated techniques like RapidTooling have played a major role in research of cost and time reduction. RapidTooling technologies offer an alternative method of production the promises todrastically reduce the time involved in design and manufacture of tools [1-3, 10-12, 14-19, 21-25, 29-34]. Within RP, Stereolithography is one of the main methods usedin producing tools. RP is now considered to have a vital role in product development, cost reduction and time saving [31]. The conventional methods of producing electrodes include stamping, coining, grinding, extrusion/drawing, turning and milling from materials including copper, brass, steel and graphite. RP Technology can be used directly or indirectly in theproduction of EDM electrodes. Main methods of RP electrode manufacture includesintering [25, 35-37], electroforming [14, 17-20, 27-29, 38-49], and spray metaldeposition [5, 7, 45]. A facility to sinter metal powder wasn’t available for theresearch so electroforming and spray metal deposition was used. The direct method uses a manufactured model as the electrode or a model that hasbeen coated by deposition or sheet formed. The direct method has been previouslycarried out using the following three approaches: Electrically Conductive Plastic[32] (doesn't have sufficient electrical conductivity at present); Metal PowderImpregnated SL Resin Substrate [16, 32] (dismissed due to the inability to cure thecomposite resin); Application Of Coatings To Substrates (Various routes from SLmodel through metallising and coating to EDM electrode have been identified andshow potential to be viable)[10-12, 15]. The indirect method of electrode manufacture involves the manufacture of a negativemould in which a shell is produced using material deposition or sheet deformation. The shell is then backed with a suitable resin or low melt alloy [14]. The followingtechniques have been used: Coated Electrodes from Negative Pattern (the negativepattern is used with electroforming, galvanic plating and spray metal. All have shownpromise except spray metal has poor efficiency due to porosity) [1, 14, 16, 32]; Tartan14Tooling and Rotational Copper Casting (Has promising results with electrodes incopper/tungsten claiming better wear rates than graphite) [33]Experiments using the direct manufacturing [11, 12, 14, 15, 17] and indirectmanufacturing [16] methods have been attempted to differing degrees of detail. Arthur et al. [11, 12, 14] mainly researches the electroformed electrodes by optimisingthe parameters to get the best MRR, TWR and Ra as possible. Rennie et al. [17]researched into how the wall thickness of the electroformed shell affects themachining time. Leu et al. [15] and Jensen et al. [16] have shown comparisons between non-traditionalelectroformed electrodes and traditional machined electrodes. Jensen et al. [16] haveshown a general comparison between electroformed electrodes and machinedelectrodes but don't give much detail into performance of the electrodes. Research byLeu et al. [15] shows a more details comparison of the different electrodes in terms ofMRR, TWR and Ra but their work is on directly manufactured electrodes. Thereappears to be insufficient information in the investigation of the efficiency of indirectmanufactured electrodes (using electroforming and spray metal) compared totraditional solid electrodes through the manipulation of EDM process parameters. The lack of information on indirectly manufactured electrodes provided the need toresearch further into the non-traditional methods of manufacturing electrodes. Therewas also a lack of research into using complex shaped electrodes manufactured inmethods other than the traditional machining. The previous work carried out that lead into this proposed project includes work doneby Ang in 1998 [30], Hung in 1999 [29] and Yarlagadda, et al. in 1999 [19]. Angapplied Rapid Tooling techniques to produce electroformed electrodes that were usedin experiments to replace traditional machining with non-traditional machining EDM. Experimental results showed the potential of the electroformed electrodes incomparison to solid copper electrodes, but inadequate flushing lead to the failure ofthe electrodes. 15Hung [29] performed experiments based on the work of Ang [30] and concluded thatthe electroformed electrodes performance was based on the shell thickness. A shellthickness less than 2mm couldn't withstand long process times of EDM. Yarlagaddaet al. [18, 19] continued research into the electroformed copper electrodes. The focuswas on using stereolithography rapid prototyping to produce the master patterns andvacuum casting to produce a negative pattern. The negative pattern was used in theelectroforming process to produce the copper shells. The electroformed copper shellswere backed with aluminium epoxy. Their experiments proved the potential forapplications of electroformed electrodes to EDM.

Chapter 3

EXPERIMENTAL DESIGN

EXPERIMENTAL DESIGN

The experiments in this research are based on a similar procedure to Leu et al. - " AFeasibility Study of EDM Tooling Using Metalized Stereolithography Models". The procedure allows an indication of the difference in the performance of differentmanufacturing methods. Leu et al. provided a comparison betweenelectroformed copper electrodes and traditional solid electrodes by runningexperiments at three different machine settings for a set time of ten minutes. Therewere a total of eight experiments per electrode type at each machine setting. EDM performance is dictated by the machine parameters and the optimisation ofthose parameters has been the basis of research by the majority of research groups inthe field of EDM. Many researches have used methods such as neural networks [50-54] and Taguchi method [55-57] to optimise performance characteristics and machineparameters. Due to time and budget restrictions the number of experiments determined the type ofanalysis that could be done. The Taguchi method and neural network experimentsrequire a large number of experiments to prove the methods and the budget didn'tallow that size research. Leu et al. [15] completed eight experiments per machinesetting for each electrode type and to get results that are comparable, within thebudget, only two experiments for each machine setting and electrode type wereconducted. A comparison of the three electrodes (solid copper, electroformed copper and spraymetal copper) will be made using the same machining conditions and measuring theperformance attributes. The performance attributes measured include materialremoval rate (MRR), tool wear ratio (TWR) and surface roughness (Ra). The electrodes will be tested under three machining conditions and measured tocompare the performance attributes. The machining conditions include a roughingcut, semi-roughing cut and a finishing cut. Using the same machine parameters for allthree electrodes will allow a good comparison to be made. 17Using additional test experiments it was determined that using standard presetmachine settings for the three different cuts would be the best way to get comparableresults from the different electrodes at the three different cut settings. The codeschosen for the machine settings are - C110 – Finishing, C140 – Semi-roughing, C170 – RoughingThe machine settings for cutting steel using copper electrodes range from C100 toC190 when aiming for minimal wear to the electrodes. C110 setting was chosen for afinishing cut because C100 was extremely fine and the machining time was too highfor the timeframe of these experiments. C170 setting was used because the C180 andC190 settings were too aggressive for the electroformed electrodes and the C170 setting allowed the test electroformed electrodes to actually machine the test pieces. The C140 setting was chosen on the fact that it evenly divided the other two settings. The settings for the three different experiments involve the following parameter settings –

Machine

Setting

DischargePulse Duration onQuiescentPulse Duration

OFF

QuiescentTime

MA

Peak Current

IP

Servo Voltage

SV

Polarity

PL

C11001201201002. 003

+

C14001601601005. 005

+

C17001901901010. 005

+

Table 3. 1 – Machine Settings or Finishing, Semi-Roughing and Roughing CutsThe values given are not actual values. They are machine setting numbers for thescale on the machine. The actual values for the machine settings are as follows

Machine

Setting

DischargePulse Duration onQuiescentPulse Duration

OFF

QuiescentTime

MA

Peak Current

IP

Servo Voltage

SV

Polarity

PL

C11080 micro sec20 mic secX2002. 003

+

C140180 mic sec20 mic secX2005. 005

+

C170350 mic sec019 mic secX2010. 005

+

Table 3. 2 – Actual Settings or Finishing, Semi-Roughing and Roughing Cuts

Chapter 4

EXPERIMENTAL PROCEDURE

EXPERIMENTAL PROCEDURE

The experimental results compare the performance of the different electrodemanufacturing methods at the three different machine settings. The aim is to comparethe electrode performance at different workloads on the electrode from roughing cuts, semi-roughing and finishing cuts. The three settings cut at different speeds so thedepth of cut for the finishing cut was reduced. This was to prevent the machining timefrom climbing too high. The selection of electrode shapes (Figure 4. 1) was to help compare different areas oftool manufacture and performance. Tool shapes were developed from previousresearch carried out by Subramanian [3], who showed that trying to test the differentgeometries in one tool was not as helpful so the shapes were developed separately. The three shapes developed highlighted the tools machining performance and theability to cope with a broad range of tool features and shapes. The new tool shapesinclude smooth curved surfaces, sharp corners, low draft angles and complex deepholes and this differs from previous work carried out by Leu et al. [15] because theirresearch was done using very simple shaped machining into a flat work piece. Thecomplex shapes were also used to get an indication of the limitations of theElectroforming and Spray Metal processes to produce the various shapes and thentheir suitability to be used in the EDM process. The electrodes were all set up in the same conditions and the similar shapes made thesame cuts at the same settings. The depth of cut is measured from the top surface ofthe work piece and the experiments begin with the depth of the hole in the near netcasting. The first four experiments are 1mm cut added to the previous measurementand the final two experiments are 0. 5mm extra.

Chapter 5

Result

EXPERIMENTAL RESULTS

A total of six experiments were carried out. Due to manufacturing costs two sets ofthree solid copper electrodes, six sets of three electroformed electrodes and two setsof three spray metal electrodes were produced. As explained later in this chapter thespray metal electrodes didn’t work as expected. Due to the porosity and uneventhickness in the spray metal electrode shells the backing material penetrated and madethe electrodes unusable. Therefore the performance of the spray metal electrodesfailed before making it to the EDM stage.

5. 1 EXPERIMENT 1

A roughing cut was used in the first set of experiments with the machine set on astandard machine setting of C170. This produced high MRR and Ra with lowmachining time and TWR. The machine and actual settings were as follows: Nominal ActualMachine Setting: C170 C170Discharge Pulse Duration (ON): 019 350μsecQuiescent Pulse Duration (OFF): 019 30μsecQuiescent Time (MA): 01 X2Peak Current (IP): 010. 0 10AServo Voltage (SV): 05 60VPolarity (PL): + +The following is the depth of cut for the first set of experiments: Cone Electrode – 28mmTriangle Electrode – 26mmBase Electrode – 19mm

5. 1. 1 Solid Electrodes compared to Electroformed Electrodes

The performance of the electrodes can be compared in several ways. Tool wear showsthe durability of the electrode itself. Results of experiment 1 show that the tool wearis greater in the electroformed electrodes. The following have been given the same measurement scales to give a true indication of thecomparison in wear. Figure 5. 1 shows that solid electrode has very little wear andany wear that has occurred is less than 0. 05mm. The electroformed electrode hasn’tperformed as well as the solid electrode and this is emphasised by thewear being greater than 1mm on the sharp corners and over 0. 1mm around the edges. are shown as an example of the difference in wear and in theOne of the problems encountered when using the electroformed electrodes was theability to damage the electrode when beginning the experiment. The expanded view in fig 5. 2C: Users 0000000000000000000Desktop1RQS5UX01weldingelectrodes. jpgFig 5. 1 A perfect welding electrodeC: Users 0000000000000000000Desktopimages (2). jpgFig 5. 2 solid electrode makingshows the damage that can happen. The damage was caused by a lack ofconduction through the electrode holder and the electrode. During the setup theelectrode came in contact with the work piece and did not produce a circuit to registerin the z axis. Thegreen line gives an estimate on the shape of the original electrode.

Chapter 6

Conclusion

CONCLUSIONS

Manufacture of three different shapes of electrodes in three different manufacturingmethods was achieved. The solid copper and electroformed copper electrodes weremanufactured successfully to the experimental stage however the spray metalelectrodes were unusable. The experiments with the solid electrodes and electroformed electrodes wereconducted with success at three different machines setting and comparisons were ableto be made. The solid electrodes consistently performed better than the electroformedelectrodes at all machine settings as shown in the summary graphs of the performancesin Machining Time, MRR and TWR. The major problems encountered with the electroformed electrodes included:• problems with setup and conductivity,• shell thickness is hard to control and cavities are difficult to build evenly,• the electroformed shells are easily damaged,• the backing material doesn’t have the same conductivity as the copper,• the copper shells are prone to warping under thermal stress,• Delamination is possible, Although the solid electrode has outperformed the electroformed electrodes in theMajority of the experiments, the solid electrodes are much more expensive to produce. The standard workshop is more likely to have a machining centre to machine solidelectrodes as opposed to an electroplating system to produce electroformed electrodes. So the convenience of the solid electrodes will often out way the use of electroformedelectrodes. The cost of electrodes becomes a major factor as soon as the electrode manufacturingprocess becomes more comparable.

Even though the solid electrodes out performedthe electroformed and spray metal electrodes, the cost of manufacture plays a vital rolein the tooling process. This research has shown that the cost of solid electrodes is77$810 each which is six times that of electroformed and spray metal electrodes at $130each. Solid electrodes take approximately six hours to produce where as a singleelectroformed electrode will take up to 50 hours to produce. The cost of production issometimes not the critical factor when rapid tooling is required. For low numbers ofelectrodes it is probably more economical in terms of time to use traditionalmachining. However when a large number of electrodes are required, electroformingwill take a similar amount of time to produce one electrode as it will take to producean infinite number of electrodes and therefore becoming faster as long as more than 10electrodes are required.. The research has given similar results to research done by Leu et al. [15], Jensen et al.[16] and Arthur et al. [14] in that the traditionally produced electrodes performed in asimilar manner to the non-traditional (electroformed) electrodes. If the electroformedelectrodes could be produced with a much more even shell thickness it might reducethe erratic performance of the electroformed electrodes. Although the electroformedelectrodes performed on average comparable to the solid electrodes there seemed to bea greater difference between the best and worst performances of the electrodes at eachmachine setting. It is recommended that more refinements need to be done on the electroformingprocess to get a greater understanding of the performance characteristics of theelectrodes. Also a greater number of experiments need to be conducted to prove therepeatability of the electroformed electrodes. Leu et al. [15] conducted eightexperiments at each machining level and others like Arthur et al. [14] conducted over72 experiments in Fractional Factorial Experiments and Taguchi methods to optimisethe parameters for MRR and the same amount of experiments would be needed tooptimise TWR and Ra. Optimising the machine parameters using Fractional FactorialExperiments and Taguchi methods is a way that research could promote the use ofelectroformed electrodes. The electroforming process could be a viable option for the EDM process if theelectrodes could be produced more robust and consistent shell thickness. with the shell thickness produced warping and delamination on some of the larger flatsurfaces. With greater control over the wall thickness and greater heat conductivity ofthe backing material would give better performance of the electroformed electrodes. With more investigation into spray metal applications and capabilities it would proveto be a promising method of electrode manufacture. This project was unable to applythe time and resources needed to research spray metal to the degree that would beneeded to get the process to a usable standard. Other areas in EDM that could benefit from more research include:• Flushing systems for deep cavities,• Conductive backing materials for the electrode shells,• Setup and tooling for the electrode attachment to the EDM toolpost to increase the conductivity,• And investigation into the thermal stresses occurring in theelectroformed electrode shells and backing material