COMPUTER AIDED MANUFACTURING OF
STREAMLINED EXTRUSION DIES

A Thesis Presented to
The Faculty of the College of Engineering and Technology
Ohio University

In Partial Fulfillment of the Requirements for the Degree
Master of Science

by
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November, 1990
Dedicated to my parents, Pratika & Krupa
ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation to Professor Jay S. Gunasekera for all the guidance and assistance during this research. He also wishes to thank Asst. Professor, John A. Deno, Department of Industrial Technology for his invaluable help and advice and Dr. M. Dehghani for consenting to be on the thesis committee.

The author would like to thank Mr. Bhavin Mehta for his guidance and kind co-operation.

The author also expresses his gratitude to the technical staff for their assistance, particularly Mr. Jim McKnight, Mr. Harvey Strausbaugh and Mr. Ron Porter.

Special thanks is due to the author's wife for her patient and encouragement.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>INTRODUCTION</th>
<th>01</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAPTER II</td>
<td>THEORY OF EXTRUSION</td>
<td>06</td>
</tr>
<tr>
<td>2.1</td>
<td>Extrusion</td>
<td>06</td>
</tr>
<tr>
<td>2.2</td>
<td>Extrusion Process</td>
<td>06</td>
</tr>
<tr>
<td>2.3</td>
<td>Extrusion Dies</td>
<td>08</td>
</tr>
<tr>
<td>CHAPTER IV</td>
<td>COMPUTER AIDED DIE DESIGN</td>
<td>12</td>
</tr>
<tr>
<td>3.1</td>
<td>STREAM</td>
<td>13</td>
</tr>
<tr>
<td>3.2</td>
<td>Procedure to run the STREAM</td>
<td>14</td>
</tr>
<tr>
<td>3.3</td>
<td>B-spline method</td>
<td>14</td>
</tr>
<tr>
<td>3.4</td>
<td>Drawing the die design by using the DFPI</td>
<td>16</td>
</tr>
<tr>
<td>CHAPTER V</td>
<td>COMPUTER NUMERICAL CONTROL PROGRAMMING</td>
<td>26</td>
</tr>
<tr>
<td>4.1</td>
<td>The history of Numerical Control</td>
<td>26</td>
</tr>
<tr>
<td>4.2</td>
<td>Basic component of an NC system</td>
<td>27</td>
</tr>
<tr>
<td>4.3</td>
<td>Basic NC input data</td>
<td>28</td>
</tr>
<tr>
<td>4.4</td>
<td>Motion control system</td>
<td>29</td>
</tr>
<tr>
<td>4.5</td>
<td>NC part program</td>
<td>32</td>
</tr>
<tr>
<td>4.6</td>
<td>NC; Application, advantage and disadvantage</td>
<td>34</td>
</tr>
<tr>
<td>4.7</td>
<td>Automated generation of NC program through a feature-based component description</td>
<td>35</td>
</tr>
<tr>
<td>4.8</td>
<td>The generation of NC programs through a NCPS system</td>
<td>38</td>
</tr>
</tbody>
</table>
CHAPTER VI EXPERIMENTAL WORK

5.1 Introduction

5.2 The Bridgeport CNC milling machine

5.3 Downloading a NC-file into the Bridgeport CNC machine

5.4 Electrode machining

5.5 Preparation of tool steel die for EDM

5.6 Electrical Discharge Machining (EDM) of dies

5.7 Results

CHAPTER VI SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

6.2 Conclusion

6.3 Recommendation

REFERENCES


APPENDIX-B Procedure to run the STREAM

APPENDIX-C Data files

(1) Data file for Square section

(2) Data file for L-section

(3) Data file for H-section

(4) APT file for Square section

(5) APT file for L-section

(6) APT file for H-section

APPENDIX-D NC Files

(1) NC file for square section
(2) NC file for L-section------------- 139
(3) NC file for H-section------------- 141
APPENDIX-E Photographs--------------------- 143
APPENDIX-F DFPI program to draw the die---------- 149
APPENDIX-G Procedure to download a NC-file into the Bridgeport CNC machine-------------- 155
CHAPTER I
INTRODUCTION

The extrusion process does not have a long history of development. The hydraulic extrusion process, which was designed for the extrusion of lead, was invented in 1810 by the Englishman, S. Bramah [7]. Currently the basic principle of the extrusion of lead tubes is still the same. The extrusion of high temperature melting alloy was successfully applied for the first time, in the 1890's by a German, A. Dick [7]. He located a separate dummy block in front of the extrusion stem, allowing the discard and dummy block to be ejected together. This was the first decisive invention that lead to the extrusion of metals other than lead.

Further development has been closely connected with advances in the mechanical construction of press installations, the improvement of tool design and the development of hot working steel [7]. The spectacular technological advances of the past thirty years have greatly increased the economic importance of extrusion. These advances are a result of extensive practical experience and numerous fundamental investigations into the extrusion process, tooling and metal flow [2].

Die design is an important topic in tool development. There are two main dies that are used in the extrusion process, and they are classified on the basis of their shape. One is a square die (or flat-faced die) and the other is a shaped die (or converging die) [3]. Generally a square die is used in hot extrusion technology that
normally requires higher extrusion force. This die produces a less uniformly deformed product when compared to a shaped die.

The shaped die makes the material deform with a gradual change in the cross section. Due to its complicated shape, the shaped die is more difficult to manufacture. If it can be manufactured with the desired accuracy, then extrusion can be done with less force, better quality product and more productivity.

Most of the products in extrusion industries are non-circular in cross section. In the shaped die there are two types of surfaces. One surface is connected from entry to exit with a straight line. While the other surface is connected with B-spline curves, which are smoother and more accurate. A B-spline surface can be created by using these B-spline curves.

In this study, the ‘STREAM’ package, which is commercially available, has been used to design the streamlined die [6]. The APT (Automatically Programmed Tool) data file can be obtained by running this package. The output contains X, Y, and Z coordinates of the electrode. A DFPI (Design File Processor Input) program has been written in which the subroutine for B-spline curve has been used to draw the streamlined die. By using the die design APT data file, the die has been drawn into the design file with the help of the program. A B-spline surface has been created by using the MEDS menu [41].

A die design file has been prepared for CNC (Computer Numerical Control) programming. Numerical Control Programming
System (NCPS) package is available on the Intergraph system to generate the NC program of the die [43]. This program can follow the B-spline surface (which is used to design a streamlined die). Due to this a more accurate shape of the die can be achieved. A 3-axis Bridgeport milling machine has been used to mill the graphite electrode. The die is made of D2 tool steel. Heat treatment has been given to the die after machining to achieve the desired Rockwell hardness. This allows the die to take a higher extrusion force. The die cavity has been generated in the die by using Electrical Discharge Machining (EDM).

The objective of this study is to design and manufacture streamlined (B-spline surface) dies by using STREAM and NCPS and to check the variation between the designs and the finished product. The flow charts of the Computer Aided Manufacturing of streamlined extrusion dies are shown in Fig. 1.1.
COMPUTER AIDED MANUFACTURING
OF
STREAMLINED EXTRUSION DIES

- DESIGN OF DIE BY USING 'STREAM'
- GETTING THE APT DATA FILE OF THE ELECTRODE FROM 'STREAM'
- DRAWING OF DIE IN THE INTERGRAPH DESIGN FILE
  BY USING A DFPI PROGRAM
- CREATING THE TOOLPATH BY USING THE INTERGRAPH
  NCPS SOFTWARE
- GETTING THE CLF FILE BY PROCESSING THE TOOLPATH
- GETTING THE G CODE FOR CNC BRIDGEPORT MILLING MACHINE
  BY USING THE POSTPROCESSOR
- TRANSFERING THE NC PROGRAM TO BRIDGEPORT MACHINE

CONTINUE

FIGURE 1.1
CONTINUED FROM PREVIOUS PAGE

MILLING OF GRAPHITE ELECTRODE FOR MAKING THE DIE CAVITY BY USING EDM

PREPARATION OF TOOL STEEL DIE

ELECTRICAL DISCHARGE MACHINING OF DIE ON THE TOOL STEEL BY USING GRAPHITE ELECTRODE

DIE IS READY FOR EXTRUSION
2.1 EXTRUSION:

Extrusion is a metal forming process, in which the billet is squeezed from a closed container through a die orifice to form a product uniform in the cross-section along its length [7]. The billet is usually of a circular cross-section whereas the product can have a desired complex geometry. Extrusion can be done at room temperature or at higher temperatures, depending on the alloy and the method.

2.2 EXTRUSION PROCESS:

The extrusion process can be classified into different categories depending upon the movement of extrusion relative to ram, position of the axis of the press, types of drive and the nature of the load application. There are four basic methods of extrusion [2]:

- Direct extrusion;
- Indirect extrusion;
- Hydrostatic extrusion;
- Impact extrusion.

In direct extrusion, also called forward extrusion, billet and extrusion ram travel in the same direction (fig. 2.1). The surface of the billet slides along the container wall. Due to this the ram force is increased by wall friction considerably. Direct extrusion can be carried out with or without lubrication dependent upon its material
1 - Billet  
2 - Container  
3 - Die  
4 - Extrusion Stem  
5 - Dummy Block  
6 - Die Holder

**FIGURE 2.1 DIRECT EXTRUSION [7]**

1 - Billet  
2 - Container  
3 - Die  
4 - Dummy Block

**FIGURE 2.2 INDIRECT EXTRUSION [7]**
property. In any case, the extrusion load depends upon the length of the billet, friction between the billet and container, and the material property [7].

In indirect extrusion, the die at the hollow stem moves relative to the container but there is no relative displacement between the billet and the container (fig. 2.2) [7]. Therefore, there is no friction between the billet surface and the container. There is also no displacement of the billet's center relative to the peripheral region. As a result, there is a 20 to 30% reduction of the load with less heat produced (due to friction), and higher extrusion speed achieved. Also it is possible to achieve longer tool life and uniform deformation compared to direct extrusion. The disadvantage of indirect extrusion is that impurities on the billet surface affect the surface of extrusion and are not automatically retained as a shell in the container.

In hydrostatic extrusion the billet in the container is extruded through a die by a liquid acting as a pressure medium instead of a direct application of the load with a ram (fig. 2.3) [2]. As a result there is no friction between the container and the wall. Due to the complex nature of tooling required to avoid the leakage of high pressure liquid, this method has limited use in industries.

Impact extrusion is similar to indirect extrusion (fig. 2.4). It is particularly useful for the extrusion of hollow shapes [2].

2.3 EXTRUSION DIES:

There are two common types of extrusion dies. The first type
FIGURE 2.3 HYDROSTATIC EXTRUSION [2]

1 - Fluid

FIGURE 2.4 IMPACT EXTRUSION [2]

1 - Punch
2 - Extruded Tube
is called the square die or shear die or flat-faced die. The second type is the shaped die or streamlined die or converging die.

The square die has one or more openings, each of which is similar to the section of the desired product (fig. 2.5 a). It is not necessary for the opening to be identical, because the die may deform under load, and the extruded section itself may exhibit some post-extrusion recovery. This die is used in the conventional extrusion of high strength aluminum alloys.

The shaped die (streamlined die) has a smooth entry with a circular cross-section and changes gradually towards the final extruded shape (shown in Fig. 2.5 b). The following are the advantages of lubricated extrusion through streamlined dies compared to non-lubricated extrusion with a flat-faced die [5]:

- Smooth and streamlined flow;
- High extrusion speed;
- Lower extrusion force;
- Lower energy for deformation;
- Less local adiabatic heating;
- Prevention of hot shortness.

However, there are also some limitations in the application of shaped extrusion dies, because they are difficult to design and manufacture.
1 - Die
2 - Dead Metal Zone
3 - Shear Line
4 - Deforming Region
5 - Ram
6 - Container

(a) SQUARE DIE

1 - Die
2 - Deforming Region

(b) SHAPED DIE

FIGURE 2.5 EXTRUSION DIES
CHAPTER III
COMPUTER AIDED DIE DESIGN

Die design is one of the important fields in the extrusion industries. The technology of designing extrusion dies is increasingly based on the application of Computer Aided Design. The analysis and computer-aided design of streamlined dies has been studied by several researchers. Some of the earlier work was undertaken by Nagpal and Altan [44,45] at Columbus Battle laboratories, where they developed approximate methods for the analysis of extrusion of the complex shape. Other researchers [46-48] obtained upper- and lower bound solutions to the process of extrusion and the drawing of shapes. Prakash and Khan [46] also found an upper bound solution for the extrusion or the drawing of polygonal sections where the geometrical similarity is presented throughout the deformation, utilizing generalized boundaries for the zone of the plastic deformation. Hoshino and Gunasekera [18,49] developed a new upper-bound solution for the extrusion of a polygonal section from the round billets.

The FEM-based metal forming analyzing software ALPID3D (Analysis of Large Plastic Incremental Deformation 3D) was improved [51] to handle a complex 3-dimensional die contact problem. A simulation of the round-to-square extrusion process was carried out by Dewasurendra [51] and the streamlined die manufactured in this study used for the physical modeling of the same process to validate the results.
3.1 STREAM

The efforts of Gunasekera [17,18,21] have resulted in a complete die design CAD package called "STREAM". This package was modified by Mehta [22] and again further modified by Gunasekera, Mehta and Walters [23] to design part-conical and part-streamlined dies. STREAM is a fully interactive and user friendly package which is capable of designing dies for re-entry product shapes. This package can be used without any prior knowledge of computer programming or advanced die design technology [6].

STREAM has a capability to design the following types of die geometries (shapes) [6]:

1. Straight - converging die;
2. Convex - extrusion die;
3. Concave - drawing type;
4. Parabolic;
5. Cubic streamlined (based on radius);
6. Streamlined (based on area);
7. Part conical-part streamlined;
8. Constant strain rate;

In this study the cubic streamlined geometries have been used to design the extrusion die. There are three different product geometries that were used in this study. (square section, L-section and H-section) The data files of the product geometry are listed in Appendix C. For each case the billet shape is round but the product geometry is different.
3.2 PROCEDURE TO RUN THE STREAM [6]:

The complete procedure to run the "STREAM" to design a round to square die has been given in the Appendix-B. The name of the product geometry data files are PSQR.DAT, PLDIE.DAT, and PHDIE.DAT for Square, L and H section respectively and are given in Appendix-C. The "STREAM" package created the APT data files which are given in Appendix-C. This data file has been used to draw the B-spline curve in the Intergraph design file by using the DFPI program. In a similar way, the L- and H-sections have been designed.

3.3 B-SPLINE METHOD:

For the successful application in computer aided design, a thorough understanding of the mathematical properties of the shape representations is required [14]. Curves and surfaces are essential requirements for modeling and displaying the subject.

The dominant form used to model curves and surfaces is the parametric function. A point on a curve is represented as a vector:

\[ P(u) = [ x(u) y(u) z(u) ]. \]

For surfaces, two parameter are required:

\[ P(u,v) = [ x(u,v) y(u,v) z(u,v) ]. \]

As the parameters \( u \) and \( v \) take on values in a specified range, usually 0 to 1, the parametric functions \( x, y \) and \( z \) trace out the location of the curve and surface. Both Bezier and B-spline curve formulations use polynomial parametric functions.
These functions were originally introduced by Curry and Schoenberg in 1947 [13]. The letter B in the word B-spline is derived from “basis”. Therefore B-splines are often called basic spline or base.

The formulation of B-spline curves is as follows [5,15]:

\[ P(u) = \sum_{i=0}^{n} P_i N_{i,k}(u). \]

\( N_{i,k}(u) \) is the blending function. The parameter \( k \) controls the order of continuity of the curve. The equation for determining the blending function is:

- \( N_{i,1}(u) = 1 \) if \( t_i \leq u < t_{i+1} \), or
- \( N_{i,1}(u) = 0 \) otherwise.

The equation for \( N_{i,k}(u) \) is

\[ N_{i,k}(u) = \left\{ \begin{array}{ll}
(u-t_i) N_{i,k-1}(u) / (t_{i+k-1} - t_i) \\
(t_{i+k} - u) N_{i+1,k-1}(u) / (t_{i+k} - t_{i+1})
\end{array} \right. \]

The above expression for \( N_{i,k}(u) \) contains \( t_i \) which is known as a knot value which depends on whether the spline is open or closed and on the relation of \( i \) to \( k \) and \( n \). For open loop the following rules can be used:

(1) \( t_i = 0 \) if \( i < k \);
(2) \( t_i = i - k + 1 \) if \( k \leq i \leq n \);
(3) \( t_i = n - k + 2 \) if \( i > n \).

The best way to generate the blending function for the closed spline is to let \( t_i = i \). The surface form of the B-spline is given by [5]:

\[ P(u,v) = \sum_{i=0}^{n} \sum_{j=0}^{m} P_{i,j} N_{i,k}(u) N_{j,l}(v). \]

The B-splines share many advantages of the Bezier curve. The B-spline form is smoother than any other form because the B-spline cubic representation does not pass through any control points.
(except the two ends), but is continuous and also has the continuity of the tangent vector and curvature while the bezier forms have only first derivative continuity at the endpoints [13]. In the B-spline the control points affect curve shapes in a natural way. The curve is variation-diminishing, and the axis is independent and multivalued [15]. The main advantage of the B-spline formulation over the Bezier curve is local control of the curve shape. It also reduces the need to piece many curves together to define a shape.

3.4 DRAWING THE DIE DESIGN BY USING THE DFPI:

The DFPI (Design File Processor Input) interface subroutines are a set of FORTRAN subroutines on the Intergraph CAD system which allow the user to place elements in an IGDS design file using DFPI [50]. All files used by DFPI must be preallocated, contiguous files of sufficient size contain all elements to be placed. The first four blocks of a design file must contain initialization elements. DFPI searches the design file for the end-of-design at the end of the new element. All programs using DFPI interface subroutines must call INDFPI for the initialization of the DFPI and DEDFPI for detaching DFPI.

All the sections for the die design are B-spline curves. For complex geometry like a streamlined die (round to square), continuity is required when piecing the curves together. The use of a spline function avoids this problem by using mathematical constraints to allow only those curves that possess the required continuity at joints. The most common spline techniques provide this convenience at the expense of local control. The B-spline
formulation avoids this problem by using a set of blending functions that have local support only - the location of the curve depends only on a few neighboring control points [15].

The subroutine used for this is BSGPBGN. This subroutine is used to inform DFPI to start placing a B-spline curve. A B-spline element is created by first calling this subroutine, then calling the appropriate subroutine to generate the desired components, and finally calling the BSPEND subroutines to end the placement of the B-spline element. The subroutine must be called in the following order for the element to be placed correctly [50]:

CALL BSPBGN - Begin B-spline placement;
CALL BHDFPI - Place curve header;
CALL PODFPI - Place pole elements;
CALL BSPEND - End placement.

These subroutine are used as follows:

CALL BSPBGN (FLAG, IRC).

FLAG - Flag to specify placement of B-spline curve or surface (I*2).
   0 - If placing B-spline curve.
   2 - If placing B-spline surfaces.

IRC - Return code (I*2).

CALL BSPEND (FLAG, IRC).

FLAG - I*2.
   0 - If ending B-spline curve.
   2 - If ending B-spline surface.

CALL BHDFPI (GG,LEVEL,SPEC,TYE,ORDER,CFLAG,RFLAG,
PFLAG,DFLAG,NKNOT,IRC,ATTLK).

GG = Two element array (1*2).
GG(1) - graphic group code:
    0 - no operation (continue current association).
    1 - start graphic group number.
    2 - cancel GG number, update type 9.

GG(2) - graphic group number:
    0 - use next available number.
    n - use n as graphic group number.

LEVEL = (1*2) The level (1-63) on which the element is to be placed.

SPEC = Specification (five-word array) (1*2).
    SPEC(1) - class.
    SPEC(2) - status.
    SPEC(3) - style.
    SPEC(4) - weight.
    SPEC(5) - color.

TYPE = Type of B-spline curve (1*2).
    0 - General B-spline curve.
    1 - Line.
    2 - Circular arc.
    3 - Circle.
    4 - Elliptical arc.
    5 - Ellipse.
    6 - Parabolic arc.
    7 - Hyperbolic arc.

ORDER = Order of B-spline.
        = 4 (in this program).
CFLAG = Closed/open flag (I*2).
   1 = closed B-spline.
   0 = open B-spline.
RFLAG = Rational/non-rational flag (I*2).
   1 = rational B-spline.
   0 = non-rational B-spline.
PFLAG = Polygon display flag (I*2).
   1 = display polygon.
   0 = don’t display polygon.
DFLAG = Curve display flag (I*2).
   1 = display curve.
   0 = don’t display curve.
NPLOE = Number of poles (I*2).
   1 ≤ NPOLES ≤ 100 for closed B-spline.
   ORDER ≤ NPOLES ≤ 101 for open B-spline.
NKNOT = Number of knots (I*2).
   0 for uniform B-spline curve.
   (NPOLES - 1) for closed B-spline.
   (NPOLES - ORDER) for open B-spline.
ATTLK = A variable-length array describing attribute linkage.
IRC = Return code (I*2).
CALL PODFPI (NPOLE, POLES, IRC).
NPOLE = Number of poles (cannot be 0) (I*2).
   NPOINT (in this program).
POLES = Variable length array containing pole coordinates
   (I*4).
   The length of this array is
   NPOLE * 2 for 2-D.
FLOW CHART FOR DRAWING B-SPLINES CURVE

CREATE A DESIGN FILE USING FILEALO

INITIALIZE DFPI USING INDFPI

ENTER THE NAME OF DATA FILE

READ
NPOINT (NO. OF POINTS)
NFILE (NO. OF DATA SETS)
X,Y,Z COORDS.

I = 1

FOR I = 1 TO NPOINT
X = XPOLE(I)
Y = YPOLE(I)
Z = ZPOLE(I)

PUT: ORDER = 4
NPOLE = NPOINT + 1
NKNOT = 0

CONTINUE

FIGURE 3.1
CALL **BSPBGN**
TO BEGIN PLACING
B-SPLINE ELEMENT
IN THE DESIGN FILE.

CALL **BHDFPI**
TO PLACE CURVE
HEADER.

CALL **PODFPI**
PLACE POLE
ELEMENTS.

CALL **BSPEND**
END PLACING
B-SPLINE CURVES.

IF ANY ERROR OCCUR
WRITE THE NUMBER
OF THE ERROR.
or NPOLE * 3 for 3-D.

IRC = Return code (I*2).

Using these subroutines each section is drawn as a B-spline curve by giving the number of the APT data file point as NPOINT. The flow charts to draw the B-splines are shown in Fig. 3.1. The next step is to connect these curves to form a B-spline surface. This is obtained using the MEDS (Mechanical Engineering Design System) menu [41]. Using commands surface by curves, a B-spline surface is obtained and the polygon display is put off using change display command. The die design drawing of the square section, L-section and H-section are shown in Fig. 3.2, 3.3, and 3.4 respectively. The design file has been prepared for CNC programming to manufacture the extrusion die.
4.1 THE HISTORY OF NUMERICAL CONTROL:

In 1725, a knitting machine was the first real numerical control machine which was controlled by sheets of punched cardboard [10]. Due to an increase in demand in U. S. defense after world war II, the Massachusetts Institute of Technology (MIT) successfully demonstrated a model of a three-axis contouring machine in 1959 (the N/C machine of today) [8]. The successful application of NC depends upon two major factors: the improvement of the NC machine tool controller system and the development of software programming aids. Due to improvement in the computer technology in the 1970's the computer was incorporated with an NC controller and that technique is called the computer numerical control (CNC) [11].

In 1958, the development of a program was carried out by a group of researchers from aircraft companies under the coordination of MIT. This computer program was named APT (Automatically Programmed Tool) [8]. Later many other languages were developed which were based on APT. These include, for example, ADAPT, EXAPT, IFAPT, MINIAPT, NELAPT, AND COMPACT II. APT and COMPACT II are most commonly used in the United States [9].
4.2 BASIC COMPONENTS OF AN NC SYSTEM:

There are three basic components of the numerical control system [25]:

- Program of instruction;
- Controller unit or Machine Control Unit (MCU);
- Machine tool.

The program of instruction is the detailed step-by-step set of procedures which tells the machine tool what to do. It is coded in numerical or symbolic form on some type of input medium that can be interpreted by the input medium. There are two methods of input, one is the Manual Data Input (MDI) and the second is the Direct Numerical Control (DNC).

The controller unit consists of the electronics and hardware that read and interpret the program of instructions and convert it into the mechanical action of the machine tool [25]. All modern NC systems have a microcomputer as a controller unit and are called computer numerical control (CNC) systems.

The machine tool is the part of the NC system which performs useful work. In general, the machine tool for an NC system consists of a worktable, spindle, motor, controls, cutting tool, fixture and other auxiliary equipment needed in the machining operation. Machining centers are also machine tools which have the capabilities to perform different operations [33], because of an on-board tool changer.
4.3 BASIC NC INPUT DATA:

The command data contained in an NC block is obtained using methods that range from referring to simple tabular information to performing rather complex mathematical calculations [1]. There are different types of functions used in the formulation of a block. The manner in which the functions are expressed will differ with the NC machines. The NC functions in a block are given in the following order.

Sequence number: The sequence number (N code) is used to identify each block within the NC program.

Preparatory function: The preparatory function (G code) is used as a communication device to prepare the MCU. For example, the word G01 is used to prepare the NC controller unit for linear interpolation. The appropriate function can be found by using the preparatory function table (EIA standard RS-273) [1].

Coordinates: (x-, y-, and z- words) These give the coordinate positions of the tool. In two-axis machines, only two of the words would be used. In four- or five-axis machines, an additional a-word and/or b word would specify the angular position.

Feed rate: This specifies the feed (F) in the machining operation.

Spindle speed: This specifies the spindle speed (S) of the process, the rate at which the spindle rotates. (RPM)

Tool change: The tool function (T code) is used in conjunction with the miscellaneous function for tool changes (M06), and as a means of addressing the new tool [1].

Miscellaneous function: Miscellaneous function (M code) are used to designate a particular mode of operation for a numerically
controlled machine tool. For example, M08 for coolant on and M09 for coolant off. The appropriate function can be selected from the miscellaneous functions table (EIA standard RS-273) [1].

4.4 MOTION CONTROL SYSTEM:

In the NC system there are three basic types of motion control system [25]:

- Point-to-Point;
- Straight cut;
- Contouring.

Point-to-point NC represents the lowest level of motion control between a tool and workpiece. (Fig. 4.1 a) It is sometimes called a positioning system. This system is very useful in NC drilling operations where the drilling is to be done from point-to-point and there are no machining operations between two points. This is the least expensive system due to simplicity in the motion.

Straight-cut control systems are capable of moving the cutting tool parallel to one of the major axes at a controlled rate suitable for machining. (Fig. 4.1 b) Therefore it is very suitable for milling operations. This system cannot combine two motions simultaneously, therefore it can not do the angular motion. This system can do PTP and straight cut.

Contouring NC represents the highest level of control (Fig. 4.2). It is the most complex, the most flexible and the most expensive type of machine control [25]. In this system, the path is continuously controlled to generate the desired geometry of a
Drilling operation performed at each point location.

(a) POINT-TO-POINT NC

Operations performed during tool motion parallel to $X$ or $Y$ axes.

(b) STRAIGHT-CUT SYSTEM

FIGURE 4.1
FIGURE 4.2 CONTOURING NC SYSTEM

1 - Starting point
2 - Cutting tool
3 - Curve
4 - Workpiece
workpiece. Straight, circular, or any complex shape can be generated by using this control.

4.5 NC PART PROGRAM:

There are two methods of NC part programming: manual part programming and computer assisted part programming [25]. NC part programming is the procedure by which the sequences of processing steps to be performed by the NC machine are recorded. To prepare an NC manual part programming, the programmer writes the machining instructions on a special form called a part programming manuscript. Manuscripts come in various forms, depending on the machine tool and tape format to be used. For example, the manuscript form for a two-axis point-to-point drilling machine would be different than one for a three-axis contouring machine.

It also includes other data such as preparatory functions, miscellaneous functions and speed/feed specifications. The manual programming is very appropriate for a point-to-point job. For contouring, it is much more appropriate for computer-assisted part programming. Computer-assisted part programming is used for more complicated jobs where the part program can be done more efficiently and accurately in less time. The part programmer enters the program written in the APT or other language. The input translation converts the coded instructions contained in the program into a usable computer form.

The arithmetic calculations unit of the system consists of a comprehensive set of subroutines for solving the mathematics
required to generate the part surface. These subroutines are called by the various part programming language statements. The final task of the computer in the computer-assisted part programming is to take the general instructions and make them specific to a particular machine tool system [8]. The unit that performs this task is called a postprocessor.

As the numbers and complexity of NC programming application have grown, many NC languages have been developed. An NC input programming language consists of a software package (computer program) plus the special rules, conventions and vocabulary words for using that software [25].

The most comprehensive and best known of all NC language processors is APT (automatically programmed tool) [1]. The APT processor program supports a language of more than three hundred words. The vocabulary has been designed to be open-ended, so that new words representing new capabilities can be incorporated into the language [9]. The major function of APT systems are geometric definitions, tool definitions and motion statements, machine tool functions and computer system commands [1].

Motion commands in APT are specified for absolute (GO TO) or incremental (GODLTA) movements. Not only is the direction of travel of the tool controlled using GO (up, down, left, right, back, backward) commands, but the orientation of the tool with respect to drive surface can be specified. The commands TLLFT, TLRGT, and TLON indicates the position of the tool axis with respect to the
4.6 NC; APPLICATION, ADVANTAGE AND DISADVANTAGE:
Numerical control is widely used in industries today. This has been used in the different types of metal removal processes such as, milling, drilling, turning, boring, grinding and sawing. NC would be most appropriate where [25]:
- Parts are processed frequently.
- The part geometry is complex.
- More operations are required.
- More accurate parts are required.

Besides metal removal, NC is also used in press working machine tools, welding machine, flame cutting, automatic riveting, and assembly machines, etc.

The following are the advantages of NC [25]:
- It reduces the nonproductive time so that productivity will increase.
- It reduces the fixturing so that simple and less costly fixtures can be used.
- It reduces the machining lead time.
- It provides greater manufacturing flexibility.
- It improves quality control.
- It reduces inventory and floor space requirement.

Higher investment and maintenance costs are a disadvantage of NC. To operate the NC machine, management has to train the NC personnel. Therefore, the initial cost is higher for NC.
4.7 AUTOMATED GENERATION OF NC PROGRAM FROM A FEATURE-BASED COMPONENT DESCRIPTION [24]:

The automatic generation of the NC part program can be created from a feature-based component description. Such a system would subdivide the overall machining task into separate features/feature groups such that the complete machining of the component would be achieved by separate machining of all features/feature groups in the component. NC code for each feature/feature group in the component would be generated parametrically. The major problem for the development of such an integrated system is the different data representation used in the design and manufacturing environment. The design data is in the form of 2D geometrical information, such as lines and arcs but process planning environment requires 3D information describing features, such as profiles and holes.

A solid model of component can be generated from its feature description which can also be used as a data source for automatic process planning as it contains much information lost in solid model generation. The feature description of a component consists of two lists. The first list is of all the features in the component and the second is of the connectivities between the features. A geometrically shaped feature is defined by its type (pocket, hole, etc.) and a list of its faces. (Fig. 4.3) Each face is in turn defined by its normal unit vector and a list of its edges. The edges in a face are defined by the start and end point coordinates and the radius of the edge in the plane of the face. Straight edges are represented by
FIGURE 4.3 THE FEATURE DESCRIPTION [24]
Automatic cutter path generation macros are available for the machining of single features such as holes or profiles and features groups such as pocket containing islands. These macros are used in part-programming language which relies on the programmer to visually identify features, select the appropriate macros and specify the cutting parameter to machine the feature.

MAGILL and MCLEOD developed a software package called MCAM which generates a GNC (part programming language) command file for a range of single-sided 2.5D milled components. At present the software can process components containing four feature types: holes, pocket, profile, and islands. In profile machining procedures the removal of excess billet material around an external profile feature is accomplished in two stages. The first stage involves a strip-milling and the second stage involves finish machining. A pocket type feature is arranged sequentially in the feature machining order with islands connected directly to it.

The tool libraries contains a listing of the attributes of all the cutters available for the machining process. To obtain the cutter speeds and feed rates for specific machining operations the existing tabulated values have been used. Details of the tool size, depth of cut, and width of cut are used to look up the appropriate cutter speed, and feed rates from tabulated values. This software is not capable of doing multi-faced 2.5D components. In this field, future development can be done by developing a 3D package and generating a
suitable clamping/fi.xturing procedure with the generated machining sequence.

4.8 THE GENERATION OF NC PROGRAMS THROUGH A NCPS SYSTEM:

The NCPS (Numerical Control Programming System) has a capability of generating an NC program based on a design drawing. In this report, the NC programming of streamlined extrusion dies has been done. For this study three different shapes have been taken, i.e. square, L, and H section. The generation of a die design drawing has been already explained in chapter-3. Programming can be done interactively using this package. The overall flowchart of generating NC program has been given in fig. 4.4.

A complete step-by-step procedure (with figures) to generate a NC program is explained in appendix-A. The same procedure has to be followed for the extrusion dies programming, such as, creating a machine/tool library, program description, machine description, tool/toolpath description, and surface identification. The toolpath has been created and verified by using the NCPS. The toolpath verification of square section die is shown in fig. 4.5.

By processing the toolpath, the NCPS generates the CL file (cutter location file). It is a standard output file for any general purpose of an NC processor. According to (International Organization for Standardization) ISO 3592-1978 Standard, the CLDATA consists of logical records, each representing a postprocessor command or a cutter position calculated by an NC processor [8]. The ISO standard does not define the physical representation of a logical record.
FLOW CHART FOR GENERATING NC PROGRAM

DIE DESIGN CONCEPT

PART DRAWING (CAD DRAWING)

DEFINING PROGRAM SPECS. IN NCPS

DEFINING CUTTING PATH SPECS. IN NCPS

CL (CUTTER LOCATION) FILE

PART MACHINING PROGRAM IN BRIDGEPORT NC CODE

MACHINING PLAN

POST PROCESSOR

FIGURE 4.4
Fig. 4.5 TOOLPATH VERIFICATION FOR SQUARE SECTION DIE
Therefore NC processors designed by different vendors may have different record formats of the output file (CL file).

In this study, the postprocessor is used for the Bridgeport 3-axis milling machine. The output of the processor is in Bridgeport ISO G-code language for a BOSS 9 controller. All the 3-axis movements in the G-code program have been written in the G0 and G1 functions. The final output of the processor is given in Appendix-D. The first and the last line of the output have been modified before loading into the Bridgeport machine for milling. The machining operations of tool steel die are explained in the next chapter.
CHAPTER V
EXPERIMENTAL WORK

5.1 INTRODUCTION:

In this chapter the experimental work regarding the manufacture of the die is explained in detail. The NC-file (which is generated from the NCPS package) has been transferred to the Bridgeport milling machine by using the PROCOMM software. The machining of the graphite electrode also has been done. The premachining of toolsteel die has been done before EDM (Electrical Discharge Machining). Heat treatment has been given to the die for hardening. Then an appropriate fixture has been made for EDM and the EDM has been done by using a graphite electrode. The final finishing has been done after EDM to obtain a good finish.

5.2 THE BRIDGEPORT CNC MILLING MACHINE:

The Bridgeport R2E4 control is a compact design made possible through the extensive use of VLSI (Very Large Scale Integrated) circuits, and an internal hardware architecture that uses four microprocessors [29]. The system provides 3-axis linear and 2-axis switchable plane circular interpolation. A picture of the milling machine is shown in Appendix E. A CRT (Cathode Ray Tube) is provided to help the programming in entering the manual data input. BOSS-9 (Bridgeport Operating System Software) has a large memory, which is capable of storing approximately 7000 lines of a NC program.
The control uses one of the four modes during machining operations: RUN, SETUP, MDI (Manual Data Input), MDI STORE [30].

RUN Mode: This mode runs a complete part-program previously loaded into either an Automatic or Block mode.

SET UP Mode: This mode prepares the machine for part making, which includes defining machine reference points, tool characteristics, initial axis positions, and loading part programs.

MDI Mode: In this mode the operator can input and execute a single program block without storing it.

MDI Store Mode: This mode allows the operator to input and execute a part program on a block-by-block basis, and store each block at the end of the part program text buffer.

Machine Specifications [29]:

(1) Controlled axes: x, y, and z; Rotary axes: c (optional).

(2) Simultaneous controlled axes:
   3-axes of the four available (linear interpolation).
   2-axes in any plane (circular interpolation - xy, xz, yz).
   x, y, axes circular, z lines (helical or spiral interpolation).

(3) Least input increment:
   Inch: 0.0001.
   Metric: 0.001.
   Degree: 0.001.

(4) Least output increment:
   Inch: 0.0001 (0.00254 mm).

(5) Maximum programmable dimensions:
   Inch: +/- 838.8607.
   Metric: +/- 8388.607 mm.
   Degree: A +/- 720.000 +/- 8388.607.
(6) Part programming code EIA RS-356-A.

(7) Part programming code format:

Inch system:  
5 N4 G3 a+34 b+33 P+34 Q+34 F31 S4 T2 M2;

Metric system:  
5 N4 G3 a+43 b+33 P+43 Q+43 F4 S4 T2 M2.


‘b’ represents A, B, E.

‘;’ represents end of block.

Decimal points are required in all a, b, F, and P fields.

(8) Feedrate: 0.1 to 250 IPM (2 to 6350 MMPM).

The required basic functions for the program are G and M codes which are explained in chapter IV. For more information please refer to the Bridgeport programming manual [29]. The operator controlled program options are not contained in a part program, but will affect the program if initiated by the operator before the program is run. These options includes block delete, part program find, operator part program message, definition blocks, dry run, operator option and key lock.

Data Input/Output Interface:

(1) Local RS232 or RS422 serial interface designated as port A. It can be used in conjunction with the on-line debugging monitor to check system operation.

(2) Remote RS232 or RS422 serial interface designated as port B. This part can be used to transfer the Bridgeport program.

5.3 DOWNLOADING A NC-FILE INTO THE BRIDGEPORT CNC MACHINE:

The NC files which are generated by the NCPS package can be
downloaded into the Bridgeport machine by using two softwares: WORDPERFECT and PROCOMM. The procedure to download a NC-file into the Bridgeport CNC machine is given in Appendix-G.

5.4 ELECTRODE MACHINING:

The selection of electrode material is one of the important decisions for EDM. Surface condition, surface finish, metal removal rate, and cut-to-wear ratios will be affected by the type of the electrode chosen to do the job. Graphite is the best material that can be use for the electrode. Certain grades of graphite are fast becoming the universal electrode material for forging and stamping die work in steel. Graphite is the only electrode material for use in no-wear machining [27]. Most graphites will tend to arc and will have a exceptionally poor electrode wear in high voltage range (300-400 V).

In this experiment, KOSTKUTTER 8 (KK8) graphite has been used as EDM electrode material. This material is suitable for all thru-hole applications, forging dies and die casts or plastic mold dies. KK8 has an average particle size of 30 microns, an apparent density of 1.65 gm/cc, a flexaral strength of 3700 PSI, an electrical resistance of 0.00034 ohm-in, and a scleroscope hardness of 36.

In this experiment, a graphite round bar which has a one inch Dia. and three inch length has been selected before the milling operation. The faces of the round graphite bar have been checked by using a dial indicator. This bar has been fixed perpendicular to the milling machine table by using the machine vice. The picture of
milling machine set-up is shown in Appendix E.

The zero position of the program has been defined at the center of the top surface of the graphite electrode. All x, y, and z coordinates of the NC program have been calculated with reference to that zero position. The appropriate motion of the tool can be selected by JOG/KNOB/INCR key (xyz, “+”, “-” and Axis motion knob). The X/Y/Z key has to be used with JOG/KNOB/INCR key to select the desired axis. To obtain the zero position perfectly, a dial indicator has been used. Once the tool has been moved to the desired position, use the SET key to define X, Y, and Z as zero coordinate values. Enter the tool number and diameter which is defined in the program [30]. The specifications of the tool are as follows:

1. Diameter of tool = 0.5 Inch;
2. Length of tool = 3.0 Inch.

The electrodes were machined using machinable wax stock in order to verify the postprocessor output. The part program has been tested by using the DRY RUN key where the operator can select the desired axis movement. Then finally the square shaped graphite electrode has been machined. After the machining, the finishing of the surface has been done by using 500 emery paper. Then the L and H shaped electrodes have been machined by using the wax stock. The picture of the square section graphite electrode is shown in Appendix E.
5.5 PREPARATION OF TOOL STEEL DIE FOR EDM:

The tool steel rod (size: 5 Inch dia. * 1.5 Inch length) of type D2 has been purchased from ALRO Specialty Metals. According to the ALRO catalog, type D2 is air-hardened, cold-worked tool steel. The following is the composition of the tool steel (type D2) [26]:

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>1.50/0.60</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.70/0.90</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.40/0.60</td>
</tr>
<tr>
<td>Chromium</td>
<td>11.50/12.25</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.30/0.50</td>
</tr>
<tr>
<td>Vanadium</td>
<td>0.85/1.05</td>
</tr>
</tbody>
</table>

This tool steel has a very high hardenability and size stability. It has also high resistance and good toughness. The machinability of annealed carbon tool steel is 100%. This tool steel gives full hardness when air cooled and is particularly useful for tools and dies requiring close dimensional accuracy in hardening. This type of a tool steel is useful for extrusion dies, lathe centers, draw dies, shear blades and punches [26].

The tool steel extrusion die set up has two parts: one is the die and the other is the ram. The ram part of the die, which was used for the round to round section of the die, is already available in the extrusion lab. This ram is shown in fig. 5.1. Premachining of the die has been done before the heat treatment for hardening. The pilot hole (0.4 Inch dia.) has been drilled on the die so that there will be less material removal during EDM. This was also used for flushing which eliminated the need for drilling flush holes in the electrode itself which results in longer tool life. The figure of the die is shown in fig. 5.2.
A - 3/8" TAP 16 TPI (4 NO.)
B - 3.754" DIA
C - 6.600" DIA
D - 2.03" DIA.
E - 4.490" DIA
F - 0.678"

G - 2.200"
H - 0.150"
I - 0.05"
J - 2.170" DIA
K - 0.998: DIA
L - 1.965"

FIGURE 5.1 RAM
A - 3/8" DIA HOLE (NO.)
B - 3.750" DIA.
C - 5.0" DIA.
D - 0.55" DIA.
E - 4.490" DIA.
F - 0.1"
G - 1.0"
H - 0.15"
I - 0.40" DIA.

FIGURE 5.2 DIE
The next step is to harden the tool steel die. According to ALRO (heat treatment specification) the following specifications are required to harden this tool steel [26]:

- **Preheating temperature**: 1450 °F
- **Preheating time in furnace**: 3/4 hour per inch of thickness
- **Hardening temperature**:
  - up to 1 inch thick: 1800 °F
  - 1 inch to 2 inch: 1825 °F
  - 2 inch and over: 1850 °F
- **High heat time**: 10 min. per inch of thickness with 30 min. minimum
- **Quenching medium**: Still air or light fan blast
- **Tempering**:
  - **Temperature**: 900 °F to 1000 °F
  - **Time**: 1 hour per inch of thickness with 2 hour minimum

The overall dimension of the die is 5 inches in dia. * 1.25 inches in length. According to the above table, the preheating temperature was kept at 450 °F and the preheat time in the furnace was one hour. The hardening temperature was 1825°F and the high heat time was 30 minutes. The tempering has been done in the furnace with 450 °F for 2 hours. After all these processes, the hardness of the die has been measured by using the Rockwell hardness tester and it was found to be 55 RC.
5.6 ELECTRICAL DISCHARGE MACHINING (EDM) OF DIES:

The Basic Process: EDM is a process of electrically vaporizing or eroding metal by means of bombardment by sparks. This will make a crater in both the conductors, workpiece and electrode. If this procedure is carried out in a dielectric fluid medium, it can be more stable and controlled. The dielectric fluid is also used for flushing which will wash away the particles and keep the workpiece cool. The EDM process was discovered by the Lazarenco brothers in the 1940's [27].

In the EDM machine, the electrode is fixed with a servomechanism so that the movement of the electrode is possible. The workpiece is fixed on the table by adopting the proper flushing arrangement. In this process the workpiece is the cathode (-ve) and the electrode is the anode (+ve) or vice-versa. A DC power is connected through a transistor so that on and off functions can be achieved.

Dielectric Fluids: There are different types of fluids which can be used as dielectric fluids such as, kerosene, mineral and silicone oils, glycerol, deionized water, sodium silicate solution and electronegative gases. These fluids should be circulated through pressure or vacuum so that fluids can carry away the particles and some heat [27]. The size of the particles is determined by the magnitude of the spark and the amount of metal that will be liberated. For a good finish cut, dielectric fluids free of particles are required. To achieve clean fluids, the filtering can be done by using the 3 micron aperture filter which removes about 85 per cent
of particles. In this experiment the Vectra oil No. 2 (Mobile Brand) has been used as a dielectric fluids. The function of this oil is to ionize locally, become temporarily conductive, allow a spark to pass, and then carry away the debris and some heat.

Surface-Finish Characteristics: The surface-finish is dependent upon the energy (amperes) and the frequency (spark per second). Frequency is the number of complete “ON/OFF” cycles in a given time period. In the EDM process, “ON” time creates the crater from the spark and the amount of energy determines the size of the crater. The different cases of surface finish have been explained in FIG. 5.3. In case-I, the metal removal rate can be increased by increasing the amperes and keeping the frequency constant (Fig.5.3 a). In this case the metal removal rate can be increased but with less surface finish. In case-II, the frequency has been varied by keeping the amperes constant (Fig.5.3 b). Due to this, the finishing of the surface can be increased. In case-III, the surface finish can also be affected by varying both frequency and amperes. The surface finish also depends upon the proper flushing system. Excessive flushing can also cause the localized electrode to wear and disturb the stability.

Advantages [28]:

(1) The EDM is very useful in situations where conventional machining is difficult. Different types of materials can be machined by using this process such as, hard or tough alloy steels, fully heat-treated tool & die steel, stainless and corrosion resistant steel, etc.
A- Electrode
B- Workpiece

(a) CASE-I

1 spark/second
2 spark/second
5 spark/second

(b) CASE-II

1 spark/second
2 spark/second
5 spark/second

(c) CASE-III

1 spark/second
2 spark/second

FIGURE 5.3 EDM
(2) This process is also useful when some complicated difficult shape is to be machined, for example; deep narrow pockets, narrow slots and small bore holes.

(3) Heat treatment can also be done before EDM so that distortion is machined out during the operation.

(4) This process has no cutting load so that the fixture cost can be minimized.

(5) A fine surface finish can be achieved by an appropriate setting of the frequency, amperes and flushing.

EDM of Extrusion Dies: Before starting the EDM the proper fixture has been prepared. Before designing the fixture, proper flushing is to be decided for the EDM of extrusion dies. Different types of flushing systems can be applied for EDM; viz. pressure flush through electrode, reverse pressure flush through workpiece, manifold suction flush through workpiece, and suction flush to electrode. In this experiment, the reverse pressure flush through the workpiece has been selected. The drawing of the fixture is shown in fig. 5.4. The fixture has been made from an aluminum plate. The picture of the complete EDM set-up is shown in Appendix-E.

In this experiment, two graphite electrodes have been machined. One is used for a rough cut and the other is used for the finishing cut. In this process the cathode is the workpiece and the anode is the electrode. The total depth of cut is 1.1 Inch. The ampere and frequency for rough and finish cuts are shown in table 5.1.
A - 5.0"
B - 5.0"
C - 0.65" DIA.
D - 3/8" DIA.

E - 1/8" DIA. PIPE THREAD
F - 3/4"
H - 1/2"
G - 3.754" DIA.

FIGURE 5.4 EDM FIXTURE
ROUGH CUT:

<table>
<thead>
<tr>
<th>Depth</th>
<th>Frequency</th>
<th>Amperes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0&quot; - 0.5&quot;</td>
<td>400</td>
<td>4.0</td>
</tr>
<tr>
<td>0.5&quot; - 1.1&quot;</td>
<td>600</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Time for rough cut = 8 hours 45 minutes

FINISH CUT:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Amperes</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>0.5</td>
</tr>
<tr>
<td>300</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Time for finish cut = 23 hours 30 minutes

**TABLE 5.1 AMPERE AND FREQUENCY TABLE**
The optimum gap can be maintained by varying the frequency, flushing rate and amperes simultaneously. The gap can be adjusted by manually changing the different values of the dependent factors (frequency, ampere, flushing rate, etc.,) and keeping the gap indicator on the green zone. In this process, obviously the finish cut was very slow in order to achieve a good surface finish. In the finishing cut, on an average, the electrode takes 15 minutes to travel one thousand of an inch. This EDM machine is not completely computer controlled. Due to this, during the EDM, an operator has to watch the gap every hour so that better machining can be achieved.

The final finishing of the die has been done by using a smooth emery stone. This has been completely prepared for extrusion.

5.7 RESULTS:

The cross-sectional measurements of the graphite electrode for the rough and the finishing cuts have been given in Table 5.2. The electrodes used were found to have worn to a certain extent both axially and circumferentially. The dimension for the electrode was found to be more than the designed dimension, implying that the electrode was worn axially. The electrode used for the finishing cut was found to be less than the designed dimension, implying that the electrode was worn circumferentially.

The die was then measured and its dimension was found to be 0.515 X 0.515 inch. Due to the electrode wear the dimension of the die has been increased by 3.0 percent compared to designed
FOR SQUARE SECTION ELECTRODE:

<table>
<thead>
<tr>
<th>GRAPHITE ELECTRODE</th>
<th>ORIGINAL DIMENSION (IN.)</th>
<th>MEASURED AFTER EDM (IN.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROUGH CUT</td>
<td>0.5 x 0.5</td>
<td>0.505 x 0.505</td>
</tr>
<tr>
<td>FINISH CUT</td>
<td>0.5 x 0.5</td>
<td>0.490 x 0.490</td>
</tr>
</tbody>
</table>

FOR TOOL STEEL DIE:

<table>
<thead>
<tr>
<th>CROSS-SECTION MEASURED AT SQUARE END (IN.)</th>
<th>0.515 x 0.515</th>
</tr>
</thead>
<tbody>
<tr>
<td>BILLET DIAMETER (IN.)</td>
<td>1.00</td>
</tr>
</tbody>
</table>

TABLE 5.2 TABLE OF RESULTS
dimension of 0.5 X 0.5 inch. The billet diameter of the die was found to be accurate (1.0 dia. inch.).
6.1 SUMMARY:

The technology of designing and manufacturing extrusion dies is increasingly based on the application of Computer-Aided Design and Manufacturing [34]. The use of CAD/CAM reduces lead time, improves quality and reproducibility and also improves the communications between design and manufacturing.

The technological advances in extrusion during the past thirty years have greatly increased the economic importance of extrusion [7]. The development of extrusion dies is one of the significant areas for advancement in extrusion. There are two main types of dies: a square die and a shaped die (streamlined die). The streamlined die has been considered in this study. The advantage of lubricated extrusion through streamlined dies compared to non-lubricated extrusion with flat-faced dies are as follows [5]:

- Smooth and streamlined flow;
- High extrusion speed;
- Lower extrusion force;
- Lower energy for deformation;
- Less local adiabatic heating;
- Prevention of hot shortness.

Die design is one of the important fields in the extrusion industry. The efforts of Gunasekera [17,18,21] have resulted in a complete die design package called "STREAM". This package was
modified by Mehta [22] and again further modified by Gunasekera, Mehta, and Walters to design part-conical and part-streamlined dies. STREAM is a fully interactive and user friendly package and can be used without prior knowledge of computer programming or advance die design technology. It has a capacity to design straight, convex, parabolic, cubic streamlined, streamlined, part conical-part streamlined and constant strain rate dies. In this study the cubic streamlined type has been selected to design extrusion dies. The square, L, and H section product geometries with round billet shape were used in this study. The "STREAM" package creates the APT die design file which is used to draw the die.

Curves and surfaces are essential requirements for modeling and displaying the subject. The B-spline curve has been used to draw the die drawing. The B-spline is smoother than any other form. In the B-spline, the control points affect the curve shape in a natural way. The curve has the following advantages: (a) variation-diminishing, and (b) independent axes and (c) multivalues. The DFPI interface subroutines are used to draw the die design into the Intergraph IGDS/MEDS design file. The required subroutines must be called in the DFPI program to place the B-spline curve correctly in the design file as per the following order.

BSPBGN, BHDFPI, PODFPI, AND BSPEND.

The curve has been connected to form a B-spline surface by using the MEDS menu. The design file has been prepared for CNC programming to manufacture the extrusion dies.
Computer Numerical Control (CNC) programming is one of the important fields in manufacturing. The computer is incorporated with a NC controller and that technique is called the CNC. In this study the NCPS has been used to interactively generate the NC program based on the design drawing [43]. The NC programming of streamlined dies of different shapes has been created by using this software. All the factors such as tolerencing, tool-offset, and simulation have been taken care of by this package. Before using this software the user must have some knowledge of the IGDS (Interactive Graphics Design System) [42] or MEDS (Mechanical Engineering Design System) [41] package and one should be familiar with different machining techniques. The NCPS gives the CL-file (Cutter Location File) which can be postprocessed to generate the Bridgeport NC program.

The Bridgeport R2E4 control with BOSS 9 operating software and an internal hardware architectural uses four micro processors [29]. The system provides 3-axes linear and 2-axes switchable plane circular interpolation [30]. The NC program of square section die has been transferred to the Bridgeport machine by using the PROCOMM software. A graphite electrode has been used for EDM due to its better surface finish, high melting point and less electrode wear. The graphite electrode machining has been done. The tool steel die has been prepared for EDM. The type D2 tool steel, which is air hardened, is used for this die. The Premachining has been done before the hardening. The hardening has been done according to the ALRO specifications.
The next step is to do the EDM by using the graphite electrode (KK8). The fixture has been prepared from the aluminum to flush the eroded metal. In the EDM process the die is the cathode and the electrode is the anode. Petroleum (Vectra oil No. 2) has been used as a dielectric medium. The rough and finishing cut was done. Appropriate amperes, frequency, flushing rate and gap have been maintained during the EDM operation. The ram is already available in the extrusion lab. The tool steel die was then completely ready for extrusion.

6.2 CONCLUSION:

Based on this study the following conclusions are drawn:
- The NCPS package has been successfully used to manufacture the complex shape of a streamlined extrusion die.
- The DFPI program has been used to draw the B-spline shape for the streamlined dies.
- In this study, it was found that, there is a small problem in the Bridgeport postprocessor. The postprocessor doesn't give the speed and feedrate, which are defined in the NCPS package, in the generated NC program
- By using the B-spline surface, the extrusion die can obtain a more accurate shape. So more advantages of streamlined shape can be achieved.
- In this study, the simplified manual for NCPS package has been prepared so that a new user can learn the package quickly.
- The graphite electrode wear was found to be small in the Electrical Discharge Machining (EDM).
6.3 RECOMMENDATIONS:

Based on the review of the literature and from this study, the following recommendations are made:

- The feature based programming of 3-axis complex surface can be done so that the generation of NC programs can be more accurate and quick.
- The improvement of Bridgeport postprocessor has to be done to obtain the speed and the feedrate in the NC program.
- The interactive editing of the Bridgeport machine program needs to be done on the computer i.e. Direct Numerical Control (DNC).
REFERENCES
REFERENCES


[29] Programming Manual, “Bridgeport R2E4 Control System for a Bridgeport Series I Vertical Machining Center”


APPENDIX-A

NUMERICAL CONTROL PROGRAMMING SYSTEM (NCPS)

USER'S MANUAL
NUMERICAL CONTROL PROGRAMMING
SYSTEM
(NCPS)
USER'S MANUAL
BEGINNERS GUIDE

PREPARED
BY
HASMUHK K. PATEL
GRADUATE STUDENT
MECHANICAL ENGG.

NOVEMBER 1990
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1:   INTRODUCTION-----------------------------</td>
<td>74</td>
</tr>
<tr>
<td>2:   CREATING MACHINE LIBRARIES---------------</td>
<td>77</td>
</tr>
<tr>
<td>3:   CREATING TOOL LIBRARIES------------------</td>
<td>79</td>
</tr>
<tr>
<td>4:   PREPARING A DESIGN FILE-------------------</td>
<td>81</td>
</tr>
<tr>
<td>5:   SETTING UP A PROGRAM----------------------</td>
<td>83</td>
</tr>
<tr>
<td>6:   GENERATING A TOOLPATH---------------------</td>
<td>97</td>
</tr>
<tr>
<td>7:   PROCESSING THE TOOLPATH-------------------</td>
<td>119</td>
</tr>
<tr>
<td>8:   EXITING THE NCPS-------------------------</td>
<td>124</td>
</tr>
<tr>
<td>9:   REFERENCES-------------------------------</td>
<td>125</td>
</tr>
</tbody>
</table>
1 INTRODUCTION:

The main aim of this users manual is to getting started with Numerical Control Programming System (NCPS) [1]. NCPS is an Interactive software package that uses graphic design files generated with the Mechanical Engineering Design System (MEDS) [2] or Interactive Graphics Design System (IGDS) [3] to generate the Numerical control programs. IGDS & MEDS are software packages written by Intergraph Corporation to design mechanical components. This manual contains step by step procedure and an example on how to go through the minimum requirements for generating the NC output.

To create a numerical control toolpath, the user has to give various information to the NCPS, such as machine name, tool name, and method of machining. Then the system uses this information for processing and generating the actual toolpath graphics. The user can verify the generated toolpath before he/she starts the actual machining. If one finds any mistake during verification, he/she can edit the toolpath description and verify it again. All of the larger tasks have been divided into many small, self-contained tasks to make programming very simple. In this package different options are available, so that the user can try any combination.

Before using this software the user must have some knowledge of the IGDS or MEDS packages and one should be familiar with different machining techniques. This manual does
not attempt to teach how to generate three dimensional designs, but it just provides a reference guide to the NCPS software. The user should know how to generate the wireframe models in three dimensions, and B-spline surface models for multi-axis machining.

The user has to go through two main screen tutorials with ten icons per tutorial. Each icon is a pictorial symbol which relates to a set of commands in the Numerical Control environment. The first tutorial is called Numerical Control Programming (NCP) and the second is called Mill Toolpath Creation (MTC). For more information see NCPS mill users guide where sections 1-10 describes NCP tutorial and sections 11-19 describes MTC tutorial. Each tutorial consists of four rectangular blocks. The first top little box contains, from left to right, program level or toolpath level, tutorial title, and three command blocks. The command blocks contain stop light to terminate a particular process, question mark for help and a cursor to exit the tutorial.

The second largest box contains the active data and subcommand selection area. Data in the area includes the key-in change, toggles, pull-down lists, a turn page function, command selections, and active informational text data. To key-in the field, place a data point on the field and key-in the new information. In the toggle field, the user can change available option by placing the data point over the field. Only one option can be chosen at a time. The user can also review the
pull-down list option by selecting a field with a data point and can change the option by placing a data point over it. If the data is too long to be displayed on one screen, the system offers "the turn page" option to change the page. The user can page forward or backward by placing data point over it. All the commands can be selected by putting a data point over it. The system displays some informative data on the top that cannot be changed by using the data point.

The third box contains the command, error, and prompt area. This area has three lines of display, the first line contains command, the second line contains warning, error or completion message and the third line contains prompt message that tells the user what the system expects him to do next. The fourth box contains the ten icons numbered one to ten which can be activated by placing a data point over it.
2  CREATING MACHINE LIBRARIES:

Creating a machine library is the first important step before starting the programming. Following steps are required to create a machine library:

Step 1:
At the $ prompt activate the NC Library Generator command by keying:

@PRO_DD_NC:NCDBS.COM

Step 2:
MACHINE OR TOOL LIBRARY?
Key in MACHINE

Step 3:
NAME OF LIBRARY TO BE CREATED?
Key in the name of the library and extension of .DBS is automatically assigned to the defined name. The name of the machine library in the example is 'XBRIDGE'.

Step 4:
MAXIMUM NUMBER OF ENTRIES?
Key in the number of machine descriptions required for programming. The system creates a file for each machine with a same name but the extension of file is different, such as .E01, .E02, E03, etc.

Step 5:
DO YOU WANT TO PRINT THE LIBRARY SCHEMA? (Y or N)
Key in Y to print schema (machine library format) but it
is not necessary to print when you create a machine library.

The system generates a machine library, prints the schema and exits the NC Library Generator.

CR

Key in N to exit the NC Library Generator Without printing Schema.

The system generate a machine library and exits the NC Library Generator.
3 CREATING TOOL LIBRARIES:

Following steps are required to create a tool library:

Step 1:
At the $ prompt activate the NC Library Generator command by keying:

@PRO_DD_NC:NCDBS.COM

Step 2:
MACHINE OR TOOL LIBRARY?
Key in TOOL

Step 3:
MILL, LATHE OR PUNCH LIBRARY?
Key in MILL

Step 4:
NAME OF LIBRARY TO BE CREATED?
Key in the name of the library and extension of .DBS is automatically assigned to the defined name. The name of the tool library in the example is 'XBRIDGET'.

Step 5:
MAXIMUM NUMBER OF ENTRIES?
Key in the number of tool description required for programming.
The system creates a file for each tool with the same name but the extension of file is different, such as .E01, .E02, E03, etc.

Step 6:
DO YOU WANT TO PRINT THE LIBRARY SCHEMA? (Y or N)
Key in Y to print schema (tool library format) but it is not
necessary to print when you create a tool library.

The system generate a tool library, prints the schema and exits the NC Library Generator.

CR

Key in N to exit the NC Library Generator Without printing Schema.

The system generate a tool library and exits the NC Library Generator.
4 PREPARING A DESIGN FILE:

A B-spline surface cone (as shown in fig-1) has been drawn in the three dimensional design file to demonstrate the NCPS software. For this example at least 200 blocks are required to run NCPS. The maximum design file size to create the program and toolpath are 32768 blocks. Use the MEDS menu to draw this cone. Turn on the views one to four for this example. Define the fifth view as a tutorial view and turn off the views numbered six to eight.
5: SETTING UP A PROGRAM

Activate the NCPS in the design file where a cone has been created by keying:

```
UC = PRO_DD_NC:NC.UCM
```

Select the NC option from the MEDS menu [2]. Use the command button on the mouse for table menu and data button for screen menu. The Numerical Control Programming (NCP) tutorial comes up in the tutorial view.

Select Icon 1 (Program Manipulations) from the first tutorial as shown in fig. 2. Then the system displays several commands in tutorial. (see fig.-3)

Step 1:

Select NCP 1.1 PROGRAM MANIPULATIONS -- CREATE PROGRAM AND MAKE ACTIVE.

by placing a data point over it.

Step 2:

"KEY IN PROGRAM NAME" In the example "TRIAL" has been used as the program name.

The system creates the program.

Step 3:

Select NCP 1.3 REVIEW/MODIFY ACTIVE PROGRAM

Enter the Program Description, Machine and Tool Library name, Macro file name as shown in fig. 3. The output file name has a toggle option. One of them is the program name.
### NUMERICAL CONTROL PROGRAMMING

**ACTIVE PROGRAM = TRIAL, MILLING**
**ACTIVE MACHINE = MILL 1, VERTICAL MILL 3 AXIS**

- [ PROGRAM NAME = TRIAL ]
- [ M Milling ]
- [ ACTIVE MACHINE LIBRARY = QS1:[051,240]XBRIDGE.DBS;1 ]
- [ ACTIVE TOOL LIBRARY = QS1:[051,240]XBRIDGET.DBS;1 ]
- [ USER MACRO FILE = QSA0:[IGR.POST.PRO]NCBAPT.MAC ]
- [ MATERIAL TYPE = 1 ]
  - (OUTPUT FILE NAMES = PRGNAM)
- [ PROGRAM NUMBER = 0 ]
  - (PROGRAM COORDINATE SYSTEM OUTPUT)

### FIGURE 3: PROGRAM MANIPULATIONS

1. **CREATE PROGRAM AND MAKE ACTIVE**
2. **SELECT ACTIVE PROGRAM**
3. **DELETE PROGRAM**
4. **LIST PROGRAMS**
5. **REPORT PROGRAM**

**1.3 PROGRAM MANIPULATIONS -- REVIEW/MODIFY ACTIVE PROGRAM**

(< SELECT OPTION >)

**FIGURE 3: PROGRAM MANIPULATIONS**

85
NUMERICAL CONTROL PROGRAMMING

ACTIVE PROGRAM = TRIAL, MILLING
ACTIVE MACHINE = MILL1, VERTICAL MILL 3AXIS

(INCH MACHINE)

[MACHINE DESCRIPTION = 3-AXIS]
[MACHINE MANUFACTURER = BRIDGEPORT]
(CONTROL DESCRIPTION = BOSS 9]
(CONTROL MANUFACTURER = none defined]

(APT CLFILE OUTPUT)
[POSTPROCESSOR COMMAND FILENAME = PRO_DD_POST:NCBPOST.COM]
[POSTPROCESSOR TABLE FILENAME = none defined]
[MACRO FILENAME = PRO_DD_POST:NCBAPT.MAC]

1- REVIEW AXIS DATA
2- REVIEW SPINDLE DATA
3- REVIEW TOOLING DATA

2.3 MACHINE LIBRARY MANIPULATIONS -- REVIEW/MODIFY ACTIVE MACHINE

< SELECT OPTION >

FIGURE 4: MACHINE LIBRARY MANIPULATIONS
(PRGNAM) and the other is the program name with a design file name (PRGNAM_DGN). There is also another toggle option where Program Coordinate System Output (PCSO) and Machine Coordinate System Output (MCSO) are available. In the example PCSO has been selected.

Step 4:

Select NCP 2.1: MACHINE LIBRARY MANIPULATIONS -- CREATE MACHINE AND MAKE ACTIVE

Key in the machine name and select the 3-axis Milling machine. In the example Mill1 has been used as the machine name.

Step 5:

Select NCP 2.3: REVIEW/MODIFY ACTIVE MACHINE

Now key in the machine data as shown in fig. 4; X, Y and Z axis data as shown in fig. 5(a), 5(b) and 5(c) respectively, spindle data as shown in fig. 6, and tooling data as shown in fig. 7.

Step 6: (OPTIONAL)

Select NCP 3.1: TOOL LIBRARY MANIPULATIONS -- CREATE TOOL

Key in the tool name. The tool library can be used to store the tool data and can be recalled when ever necessary. (see fig. 8)

Step 7:

Select NCP 4.2: ACTIVE COORDINATE SYSTEM -- CREATE BY 3 POINTS

Define the program zero position by using the 3-D data point in the design file as shown in the fig. 9. In the example,
NUMERICAL CONTROL PROGRAMMING

ACTIVE PROGRAM = TRIAL, MILLING
ACTIVE MACHINE = MILL1, VERTICAL MILL 3AXIS

(X AXIS)

[ MINIMUM TRAVEL = 0.0001 INCHES ]
[ MAXIMUM TRAVEL = 18.0000 INCHES ]

[ ZERO POSITION = 0.0000 INCHES ]
[ HOME POSITION = -9.0000 INCHES ]
[ TOOL CHANGE POSITION = -5.0000 INCHES ]

[ RESOLUTION = 0.001000 INCHES ]
[ MINIMUM FEEDRATE = 0.1000 IPM ]
[ MAXIMUM FEEDRATE = 200.0000 IPM ]
[ RAPID FEEDRATE = 200.0000 IPM ]

1- REVIEW MACHINE DATA
2- REVIEW AXIS DATA FOR NEXT AXIS
3- REVIEW SPINDLE DATA
4- REVIEW TOOLING DATA

2.3 MACHINE LIBRARY MANIPULATIONS -- REVIEW/MODIFY ACTIVE MACHINE

< SELECT OPTION >

FIGURE 5(a): REVIEW X AXIS DATA
NUMERICAL CONTROL PROGRAMMING

ACTIVE PROGRAM = TRIAL, MILLING
ACTIVE MACHINE = MILL1, VERTICAL MILL 3 AXIS

(Y AXIS)

[ MINIMUM TRAVEL = 0.0001 INCHES ]
[ MAXIMUM TRAVEL = 12.0000 INCHES ]

[ ZERO POSITION = 0.0000 INCHES ]
[ HOME POSITION = -5.5000 INCHES ]
[ TOOL CHANGE POSITION = -5.5000 INCHES ]

[ RESOLUTION = 0.001000 INCHES ]
[ MINIMUM FEEDRATE = 0.1000 IPM ]
[ MAXIMUM FEEDRATE = 200.0000 IPM ]
[ RAPID FEEDRATE = 200.0000 IPM ]

1- REVIEW MACHINE DATA
2- REVIEW AXIS DATA FOR NEXT AXIS
3- REVIEW SPINDLE DATA
4- REVIEW TOOLING DATA

2.3 MACHINE LIBRARY MANIPULATIONS -- REVIEW/MODIFY ACTIVE MACHINE

< SELECT OPTION >

FIGURE 5(b): REVIEW Y AXIS DATA
NUMERICAL CONTROL PROGRAMMING

ACTIVE PROGRAM = TRIAL, MILLING
ACTIVE MACHINE = MILLI, VERTICAL MILL 3 AXIS

( 2 AXIS )

[ MINIMUM TRAVEL = 0.0001 INCHES ]
[ MAXIMUM TRAVEL = 5.0000 INCHES ]

[ ZERO POSITION = 0.0000 INCHES ]
[ HOME POSITION = 3.0000 INCHES ]
[ TOOL CHANGE POSITION = 3.0000 INCHES ]

[ RESOLUTION = 0.001000 INCHES ]
[ MINIMUM FEEDRATE = 0.1000 IPM ]
[ MAXIMUM FEEDRATE = 200.0000 IPM ]
[ RAPID FEEDRATE = 200.0000 IPM ]

1- REVIEW MACHINE DATA
2- REVIEW AXIS DATA FOR NEXT AXIS
3- REVIEW SPINDLE DATA
4- REVIEW TOOLING DATA

2.3 MACHINE LIBRARY MANIPULATIONS -- REVIEW/MODIFY ACTIVE MACHINE

< SELECT OPTION >

FIGURE 5(c): REVIEW Z AXIS DATA
NUMERICAL CONTROL PROGRAMMING

ACTIVE PROGRAM = TRIAL, MILLING
ACTIVE MACHINE = MILL1, VERTICAL MILL 3AXIS

( 1 CUTTING SPEED RANGES )
[ MIN RPM RANGE 1 = 55 ]
[ MAX RPM RANGE 1 = 4200 ]

( 1 TAPPING SPEED RANGES )
[ MIN TAP RPM RANGE 1 = 0 ]
[ MAX TAP RPM RANGE 1 = 0 ]

[ 5.0000 HORSEPOWER SPINDLE ]
[ SPINDLE START TIME = 11.0000 SECS ]
[ SPINDLE STOP TIME = 15.0000 SECS ]
[ SPINDLE REVERSE TIME = 16.0000 SECS ]

1- REVIEW MACHINE DATA
2- REVIEW AXIS DATA
3- REVIEW TOOLING DATA

2.3 MACHINE LIBRARY MANIPULATIONS -- REVIEW/MODIFY ACTIVE MACHINE

< SELECT OPTION >

FIGURE 6: REVIEW SPINDLE DATA
**NUMERICAL CONTROL PROGRAMMING**

ACTIVE PROGRAM = TRIAL, MILLING  
ACTIVE MACHINE = MILL1, VERTICAL MILL 3AXIS

[ 5 PRIMARY TOOL POSITIONS ]  
[ 5 SECONDARY TOOL POSITIONS ]  

[ 5 TOOL LENGTH OFFSETS ]  
[ 5 TOOL RADIUS OFFSETS ]  
[ 5 FIXTURE OFFSETS ]  
[ 65.0000 SECOND TOOL CHANGE TIME ]

1- REVIEW MACHINE DATA  
2- REVIEW AXIS DATA  
3- REVIEW SPINDLE DATA

2.3 MACHINE LIBRARY MANIPULATIONS -- REVIEW/MODIFY ACTIVE MACHINE

< SELECT OPTION >

**FIGURE 7: REVIEW TOOLING DATA**
### NUMERICAL CONTROL PROGRAMMING

**ACTIVE PROGRAM** = TRIAL, MILLING  
**ACTIVE MACHINE** = MILL1, VERTICAL MILL 3AXIS

<table>
<thead>
<tr>
<th>NAME</th>
<th>DESCRIPTION</th>
<th>SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOOL1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOOL2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOOL3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOOL4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOOL5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOOL6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.1 CREATE TOOL  
3.3 DELETE TOOL  
3.4 LIST TOOLS  
3.5 REPORT TOOL  
3.2 REVIEW/MODIFY TOOL
3.2.2 TOOL LIBRARY MANIPULATIONS -- REVIEW/MODIFY TOOL FROM LIST

**SELECT TOOL**

**FIGURE 8: TOOL LIBRARY MANIPULATIONS**
program zero position has been defined on the center of the top surface because of symmetry of the part.

**Step 8:**

**Select NCP 6.1:** PROGRAM HOME/TOOLCHANGE -- DEFINE HOME BY DATA BUTTON/KEYIN

Define the program home by using the 3-D point as shown in the fig. 10. Similarly define the position for toolchange (NCP 6.3).
FIGURE 10: PROGRAM HOME/TOOLCHANGE
6 GENERATING A TOOLPATH:

Step 1:

Now select NCP 9: MILL TOOLPATH CREATION

This command gives the second NCPS tutorial as shown in the fig. 11. This tutorial is called the Mill Toolpath Creation (MTC) tutorial.

Step 2:

Select MTC 1.1 TOOL MANIPULATIONS -- CREATE TOOL

Key in the name of the tool to be used. TOOL1 has been used in the example as shown in the fig. 12.

OR

Select MTC 1.2 TOOL MANIPULATIONS -- SELECT ACTIVE TOOL

If the tool has been created and stored in the tool library initially by using NCP 3.1, retrieve the tool data by selecting this command.

Note: Please enter the cell library name which you have created.

Step 3:

Select MTC 2.1: TOOLPATH MANIPULATION -- CREATE TOOL

The user can key in the toolpath name as he/she wants. In the example PATH1 has been used. (fig. 13)

Step 4:

Select MTC 2.3: TOOLPATH MANIPULATION -- REVIEW/MODIFY ACTIVE TOOLPATH

Define all the parameter as shown in the fig. 13.
MILL TOOLPATH CREATION

ACTIVE TOOL = #0, TOOL1, 0.50000, 0.2500CR, 0.0000SA
ACTIVE TOOLPATH = PATH1, LV=2

X1.0000 Y1.0000 Z1.0000

< SELECT OPTION >

FIGURE 11:  SECOND NCPS TUTORIAL
MILL TOOLPATH CREATION

ACTIVE TOOL = #0, TOOL1, 0.50000, 0.25000CR, 0.00000SA
ACTIVE TOOLPATH = PATH1, LV=2
X1.0000 Y1.0000 Z1.0000

[ CELL LIBRARY = OS1:[OS1, 240]HKP. CEL:1 ]
[ CELL NAME = none defined ]
[ GAGE LENGTH = 2.0000 ]
[ RIGHT HAND ]
[ CUTTING EDGES = 4 ]
[ CUTTING HEIGHT = 2.0000 ]
[ INCH ]
[ MATERIAL TYPE = 1 ]

[ TOOL DESCRIPTION = none defined ]
[ TOOL NAME = TOOL1 ]

1.3 TOOL MANIPULATIONS -- REVIEW/MODIFY ACTIVE TOOL

< SELECT OPTION >

FIGURE 12: TOOL MANIPULATIONS
MILL TOOLPATH CREATION

ACTIVE TOOL = #0, TOOL1, 0.5000D, 0.2500CR, 0.0000SA
ACTIVE TOOLPATH = PATH1, LV=2
X1.0000 Y1.0000 Z1.0000

[ LEVEL = 2 ]
[ TOOL NUMBER = 0 ]
[ LENGTH OFFSET REGISTER = 0 ]
[ TOLERANCE = 0.00050 ]

[ FEED XY = 17.0000 IPM ]
[ FINISH FEED XY = 15.0000 IPM ]
[ RETRACT FEED = 20.0000 IPM ]
[ FIRST FEED = 17.0000 IPM ]

[ FEED Z = 17.0000 IPM ]
[ FINISH FEED Z = 15.0000 IPM ]
[ RAPID FEED = 21.0000 IPM ]

[ RPM = 2100 ]
[ RANGE 1 ]
[ VARIABLE 1 = 0.0000 ]
[ VARIABLE 2 = 0.0000 ]
[ VARIABLE 3 = 0.0000 ]
[ VARIABLE 4 = 0.0000 ]

[ STRING = none defined ]

[ TOOLPATH NAME = PATH1 ]

2.3 TOOLPATH MANIPULATIONS -- REVIEW/MODIFY ACTIVE TOOLPATH

< SELECT OPTION >

FIGURE 13: TOOLPATH MANIPULATIONS
Step 5:

Select **MTC 3.2**: CURRENT POSITION MANIPULATIONS -- SET TO DATA BUTTON/KEYIN

Define the current position of the tool by using the 3-D data button as shown in the fig. 14.

Step 6:

This icon is very important for generating the toolpath. From this icon one should accurately define the stock surface, retract plane, flat Z plane, and complex surfaces. (In the example stock surface, retract plane, and complex surface are necessary to be defined.) (Make sure that the grid lock is on.)

Select **MTC 4.1** SURFACE MANIPULATIONS -- DEFINE STOCK SURFACE

Select surface type as the 'STOCK' by using the pull down menu. Define the stock surface by placing a the 3-D data point as shown in the fig. 15.

Step 7:

Select surface type as the 'RETRACT' by using the pull down menu. Define the stock surface by using the 3-D data button as shown in the fig. 16.

Step 8:

Select surface type as the 'COMPLEX GROUP' by using the pull down menu. Following are the steps to define the 'COMPLEX SURFACE':

1. Before defining the surface the part should have proper B-spline surface.
2. Make sure that grid lock is off.
3. Define the surface by using the 3-D data button.
FIGURE 14: CURRENT POSITION MANIPULATIONS
FIGURE 15: DEFINING STOCK SURFACE
FIGURE 16: DEFINING RETRACT PLANE
(4) Accept the dashed triangle by using data button as shown in fig. 17.

(5) Place the data button over the 'TERMINATE DEFINITION' option to complete the complex surface definition.

**Step 9: (DO NOT USE FOR GIVEN EXAMPLE)**

Select MTC 5: INTERACTIVE TOOL MOTION

This command can generate the tool motion manually (fig. 18).

**Step 10: (DO NOT USE FOR GIVEN EXAMPLE)**

Select MTC 6: BOUNDARY MANIPULATION -- AUTOMATIC BOUNDARY CREATION

This command can define the part boundary which can be used to perform different operations such as, facing, profiling, and pocketing (fig. 19).

**Step 11:**

Select MTC 7.5: AUTOMATIC TOOL MOTION -- 3-AXIS

Following steps are to be followed to generate the automatic motion:

1. Key in all data which are shown in fig. 20.
2. Select the 'ENTRY AND EXIT TYPE' option to define the approach point (fig. 21).

**Note:** In this tutorial the user cannot use any IGDS or MEDS command.

3. Define the XYZ approach.
4. Press the reset button to return to the main menu.
5. Place the data button over the 'PROCESS' (7.5.1) to generate the toolpath.
6. Accept the toolpath by pressing the data button.
FIGURE 17: DEFINING COMPLEX SURFACE
MILL TOOLPATH CREATION

ACTIVE TOOL = #0, TOOL1, 0.5000D, 0.2500CR, 0.0000SA
ACTIVE TOOLPATH = PATH1, LV=2
ACTIVE PART SURFACE
ACTIVE RETRACT PLANE = 0.2000
ACTIVE STOCK SURFACE = 0.0000

5.1 ONE ELEMENT STARTUP
5.2 TWO ELEMENT STARTUP
5.3 THREE ELEMENT STARTUP
5.4 NEXT DRIVE ELEMENT
5.5 NEXT CHECK ELEMENT
5.6 DISPLAY DRIVE ELEMENT
5.7 MOVE TO POSITION
5.8 REJECT LAST MOTION
5.9 MACHINE COMMANDS

5. INTERACTIVE TOOL MOTION

< SELECT OPTION >

FIGURE 18: INTERACTIVE TOOL MOTION
MILL TOOLPATH CREATION

ACTIVE TOOL = #0, TOOL1, 0.50000, 0.2500CR, 0.00005A
ACTIVE TOOLPATH = PATH1, LV=2

X1.0000 Y1.0000 Z1.0000

( AUTOMATIC ) ( BOUNDARY TYPE = PART )

[ TOLERANCE = 0.00050 ] ( CLOSED BOUNDARY )

6.1 BOUNDARY MANIPULATIONS -- AUTOMATIC BOUNDARY CREATION

< POINT TO START ELEMENT >

FIGURE 19: AUTOMATIC BOUNDARY CREATION
MILL TOOLTIP PATH CREATION

ACTIVE TOOL = #0, TOOL 1, 0.50000, 0.25000CR, 0.00000SA
ACTIVE TOOLPATH = PATH 1, LV=2
ACTIVE PART SURFACE
ACTIVE RETRACT PLANE = 0.2000

X1.0000 Y1.0000 Z1.0000
ACTIVE STOCK SURFACE = 0.0000
(ENTRY AND EXIT TYPE)

CLEARANCE = 0.1000
NUMBER OF XY PASSES = 10
(ENTRY AND EXIT TYPE)

(USE NUMBER OF XY PASSES)

SURFACE STOCK = 0.0000
REVERSE XY CLEARANCE = 0
(FOLLOW SURFACE BOUNDARY)

(SINGLE Z PASS)
(MACHINE SURFACE)

NUMBER OF STROKE POINTS = 100
(PROCESS INTERACTIVE)

7. 1 POCKET
7. 2 PROFILE
7. 3 FACE
7. 4 POINT TO POINT

7. 5. 1 PROCESS
7. 5. 2 MODIFY SURFACE CUT DIRECTION
7. 5. 3 GENERATE INTERSECTIONS

7. 5 AUTOMATIC TOOL MOTION -- 3-AXIS

SELECT OPTION

FIGURE 20: 3-AXIS MILLING
### MILL TOOLPATH CREATION

<table>
<thead>
<tr>
<th>ACTIVE TOOL PATH = PATH1, LV=2</th>
<th>X=1.0000 Y=1.0000 Z=1.0000</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTIVE PART SURFACE</td>
<td>ACTIVE STOCK SURFACE = 0.0000</td>
</tr>
<tr>
<td>ACTIVE RETRACT PLANE = 0.2000</td>
<td>ENTRY AND EXIT TYPE (</td>
</tr>
<tr>
<td>) APPROACH = XYZ (</td>
<td></td>
</tr>
<tr>
<td>1- XYZ</td>
<td></td>
</tr>
<tr>
<td>2- XY FIRST</td>
<td></td>
</tr>
<tr>
<td>3- Z FIRST</td>
<td></td>
</tr>
<tr>
<td>4-</td>
<td></td>
</tr>
<tr>
<td>5- XYZ FEED</td>
<td></td>
</tr>
<tr>
<td>6- VECTORED</td>
<td></td>
</tr>
<tr>
<td>7-</td>
<td></td>
</tr>
<tr>
<td>( NON-PLUNGING ENTRY )</td>
<td></td>
</tr>
<tr>
<td>) RETRACT = NONE (</td>
<td></td>
</tr>
<tr>
<td>1- ALONG TOOL AXIS</td>
<td></td>
</tr>
<tr>
<td>2- DELTA ALONG TOOL AXIS</td>
<td></td>
</tr>
<tr>
<td>3- NONE</td>
<td></td>
</tr>
<tr>
<td>.1 DEFINE APPROACH POINT</td>
<td></td>
</tr>
<tr>
<td>.2 DEFINE RETRACT POINT</td>
<td></td>
</tr>
</tbody>
</table>

#### 7.5 AUTOMATIC TOOL MOTION -- 3-AXIS

*(SELECT ENTRY/EXIT TYPE)*

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

**FIGURE 21: SELECTION OF TOOL ENTRY/EXIT TYPE**
(7) Again put the data button on the ‘ENTRY AND EXIT TYPE’ to define the retract point (fig. 21). (Make sure that the grid lock is on.)

(8) Place the data point over ‘DEFINE RETRACT POINT’.

(9) Define the home position as a retract point by using the 3-D button.

(10) Exit the tutorial by pressing the reset button.

(11) Now, the complete toolpath is ready for milling.

**Step 12:**

Select MTC 8.2: TOOLPATH VERIFICATION -- TOOL IMAGE

Select the option which is shown in the fig. 22. Place the data button over in view to see the toolpath verification in that view or at the center of the design file to see the verification in all four views (fig. 23).

**Step 13:** (DO NOT USE FOR GIVEN EXAMPLE)

Select MTC 7.3, 7.1, & 7.4: FACING, POCKETING, AND DRILLING

Automatic generation of toolpath for FACING, POCKETING, and DRILLING are shown in fig. 24, 25, and 26 respectively.

**Step 14:**

Select MTC 9: TOOLPATH EDITING

If the toolpath created is wrong, then by using the MTC 9.3 Delete command, (fig. 27) delete the toolpath and generate the new toolpath again. There are some other manipulation commands such as Move, Copy, Change, Rotate, Scale, Mirror, Modify, Convert, Resequence, and Element Editing which can be used if necessary. For more information on these commands see the NCPS MILL USER GUIDE.
FIGURE 25: POCKETING
Now toolpath is ready to process.
FIGURE 27: TOOLPATH EDITING
7 PROCESSING THE TOOLPATH:

(This is the last procedure to process the toolpath.)

Step 1:
Exit the MTC tutorial by placing a data point over the CRUSHER command which is located at upper right corner of the menu.

The NCP tutorial will appear on the screen.

Step 2:
Select NCP 8: PROGRAM EDITING
The program editing menu will appear on the screen as shown in fig. 28.

Step 3:
Select NCP 8.5: PROGRAM EDITING -- PROCESS INTERACTIVE
By selecting this command the system will interactively process the program (fig. 28).

Step 4:
'TOGGLE OR DATA BUTTON TO PROCESS'
Press the data button to start the process.

Step 5:
'DATA BUTTON TO VIEW ERROR FILE, RESET IF NO'
To view the errors on the screen press the data button.

Press reset.

Step 6:
'DATA BUTTON TO RUN POSTPROCESSOR, RESET IF NO'
Press data button to run the postprocessor. The
ACTIVE PROGRAM = TRIAL, MILLING
ACTIVE MACHINE = MILL1, VERTICAL MILL 3AXIS

1) TOOLPATH = PATH1, LEVEL 2, TOOL = #0, TOOL1
2) ** EOP **

<----- TURN PAGE ------>

8. 1 MOVE ENTRY
8. 2 DELETE ENTRY
8. 3 MODIFY MACHINE COMMAND
8. 4 INSERT MACHINE COMMAND
8. 5 PROCESS INTERACTIVE
8. 6 PROCESS BATCH
8. 7 ENABLE/DISABLE ENTRY

< SELECT OPTION OR KEYIN COMMAND LINE >

FIGURE 28: PROGRAM EDITING
postprocessor generates a file containing the G codes for the BOSS 9 (R2E4) Bridgeport Milling Machine. The file has an extension of .PUN.

Press the reset button to exit without running the postprocessor.

**Step 7:**

The following files will be generated at the end of the process.

1. A CL-file with a .CLF extension.
2. An error file with a .ERR extension.

If the postprocessor is used then:

3. A print file with a .PRN extension.
5. A punch file with a .PUN extension.

**Step 8: (OPTIONAL)**

Select NCP 7.2: PROGRAM VERIFICATION -- TOOL IMAGE

This command allows the user to verify toolpath in the active program with three tool display techniques: tool image, tool diameter, and tool cell image and toolpath elements to show the tool direction (fig. 29).

**Step 9: (DO NOT USE FOR GIVEN EXAMPLE)**

Select NCP 10: LABELED GEOMETRY

This command allows the user to label the geometry within the design file and create an ASCII file of geometry definitions corresponding to each label (fig. 30).
NUMERICAL CONTROL PROGRAMMING

ACTIVE PROGRAM = TRIAL, MILLING
ACTIVE MACHINE = MILL, VERTICAL MILL 3AXIS

[ LABEL DEFINITION FILE = PRO_DD:NCAPT:NCAPT.DEF ]
[ LABEL OUTPUT FILE = 051:[051,240]TRIAL.LBL:0 ]
(CREATE OUTPUT FILE)  NO FENCE DEFINED
(INCH OUTPUT)
[ LABEL INCREMENT = 1 ]  (DRILL CIRCLE OFF)

(ELEMENT NUMBERING ACTIVE)
[ STARTING POINT NUMBER = 1 ]  [ OUTPUT LEVEL = 1 ]
[ STARTING PLANE NUMBER = 1 ]  [ STARTING LINE NUMBER = 1 ]
[ STARTING CIR_ARC NUMBER = 1 ]  [ STARTING CIRCLE NUMBER = 1 ]
[ STARTING ELL_ARC NUMBER = 1 ]  [ STARTING ELLIPSE NUMBER = 1 ]

10.1 PROCESS AUTOMATIC
10.2 PROCESS SEMI-AUTOMATIC
10.3 PROCESS INTERACTIVE

10. Labeled geometry

(SELECT OPTION)

FIGURE 30: LABELED GEOMETRY
8 EXITING NCPS:

Place a data button over the upper right corner of the NCP tutorial to exit from the NCP tutorial.
9 REFERENCES:


APPENDIX-B

PROCEDURE TO RUN THE STREAM
PROCEDURE TO RUN THE STREAM:

Following are the procedures to design the round to square die by using the STREAM package in the intergraph $ environment. To activate the STREAM package enter the following command in $ environment.

$QSA1:[51,16]NST53.EXE

The STREAM package will activate and follow the steps:
- Do you want to choose units? (Y/N)
  ---- > N
- Number of section along die length?
  ---- > 10
- Length of die?
  ---- > 1 Inch
- Diameter of billet?
  ---- > 1 Inch
- Die surface definition?
  ---- > 5 (cubic streamlined)
- Coordinates of product geometry.
  ---- > 2 (from product geometry data file)
- Name of data file with product geometry coordinates.
  ---- > SQR.DAT
- Option for design output.
  ----> 1 (movie for textronix/compatible)
- Do you want view product geometry? (Y/N)

(If you want to view the product geometry, then make sure that you are in TEX mode)
  ---- > N
- Modify / correct any node?  
  == > 2 (no)

- Type 1 to file the product geometry coordinates.  
  2 otherwise  
  == > 2

- Do you want radii calculation? Type (Y/N)  
  == > N

- Modify/correct any node?  
  == > 3 (no)

- Type 1 to file product geometry coordinates.  
  2 otherwise  
  == > 2

- Do you need radii calculation? Type (Y/N)  
  == > N

- Transferring product centroid to billet center.  
  == > 0,0

- Mapping of billet to product  
  == > 0.02, 0.02

- To view mapping  
  == > 3 (no)

- Do you want to print product coordinates and angle type? (Y/N)  
  == > N

- Please input the fineness factor for interpolation of billet geometries.  
  == > 1 (every 10 degree)

- Type 1 if force calculation required  
  2 otherwise  
  == > 2
- Title of movie compatible output file - start with 'M' type 0 for null specification.
  ===== > MSQR
- Title of APT compatible output file - start with 'A' type 0 for null specification.
  ===== > ASQR
- Do you want run movie (Y/N)?
  ===== > N
  The the package will then terminate after creating the MOVIE and APT file.

In a similar way the L-section and H-section have been designed. The billet diameter is 2 Inch for L and H section. The mapping parameter are 0.47, 0.47 and 0.03 ,0.03 for L and H section respectively. The other parameters for both section are same as the square section.
APPENDIX-C

DATA FILES
[1] DATA FILE FOR SQUARE SECTION: (PSQR.DAT)

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<table>
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<th></th>
</tr>
</thead>
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<td>0.2500</td>
<td>0.0000</td>
<td>0</td>
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</tr>
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<td>-0.2500</td>
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[2] DATA FILE FOR L-SECTION: (PLDIE.DAT)

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DATA FILE FOR H-SECTION: (PHDIE.DAT)

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<td></td>
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</table>

[4] **APT FILE FOR SQUARE SECTION:** (ASQ1.DAT)

| 32 |
| 11 |

| 0.0000  | 0.0000  | 0.5000  |
| -0.0975 | 0.0000  | 0.4904  |
| -0.1913 | 0.0000  | 0.4619  |
| -0.2778 | 0.0000  | 0.4157  |
| -0.3536 | 0.0000  | 0.3536  |
| -0.4157 | 0.0000  | 0.2778  |
| -0.4619 | 0.0000  | 0.1913  |
| -0.4904 | 0.0000  | 0.0975  |
| -0.5000 | 0.0000  | 0.0000  |
| -0.4904 | 0.0000  | -0.0975 |
| -0.4619 | 0.0000  | -0.1913 |

| ===== | ===== | ===== |
| ===== | ===== | ===== |

| 0.2500 | 1.0000 | -0.1875 |
| 0.2500 | 1.0000 | -0.1250 |
| 0.2500 | 1.0000 | -0.0625 |
| 0.2500 | 1.0000 | 0.0000  |
| 0.2500 | 1.0000 | 0.0625  |
| 0.2500 | 1.0000 | 0.1250  |
| 0.2500 | 1.0000 | 0.1875  |
| 0.2500 | 1.0000 | 0.2500  |
| 0.1875 | 1.0000 | 0.2500  |
| 0.1250 | 1.0000 | 0.2500  |
| 0.0625 | 1.0000 | 0.2500  |
APT FILE FOR L-SECTION: (ALDIE.DAT)

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| ====== | ====== | ====== |
| ====== | ====== | ====== |
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| 0.7600 | 1.0000 | -0.2400 |
| 0.7600 | 1.0000 | -0.1400 |
| 0.7600 | 1.0000 | -0.0400 |
| 0.5600 | 1.0000 | -0.0400 |
| 0.3600 | 1.0000 | -0.0400 |
| 0.1600 | 1.0000 | -0.3400 |
| -0.0400 | 1.0000 | -0.0400 |
| -0.0400 | 1.0000 | 0.1600 |
| -0.0400 | 1.0000 | 0.3600 |
| -0.0400 | 1.0000 | 0.5600 |
### APT FILE FOR H-SECTION: (AHDIE.DAT)

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| 0.5000 | 1.0000 | 0.0667 |
| 0.5000 | 1.0000 | 0.2000 |
| 0.5000 | 1.0000 | 0.3333 |
| 0.5000 | 1.0000 | 0.4667 |
| 0.5000 | 1.0000 | 0.6000 |
| 0.4000 | 1.0000 | 0.6000 |
| 0.3000 | 1.0000 | 0.6000 |
| 0.2000 | 1.0000 | 0.6000 |
| 0.2000 | 1.0000 | 0.3500 |
| 0.2000 | 1.0000 | 0.1500 |
APPENDIX-D

NC FILES
NC FILE FOR SQUARE SECTION: (SQDIE.PUN)

R
:777
N10G70G90G0T1S2100M26
N20X.0017Y.5001Z-.2358F15.
N40X-.0718Z-.2368
N50X-.1181Y.5002Z-.2379
N60X-.1539Z-.2392
N70X-.1858Z-.2405
N80X-.2512Y.4964Z-.2413
N90X-.3303Y.4741Z-.2410
N100X-.4149Y.4165Z-.2408
N110X-.4725Y.3319Z-.2410
N120X-.4946Y.2544Z-.2413
N130X-.4948Y.2528
N140X-.4986Y.1874Z-.2405
N150Y.1561Z-.2392
N160Y.1249Z-.2381
N170X.4985Y.0936Z-.2372
N180Y.0624Z-.2366
N190Y.0311Z-.2362
N200Y-.0313
N210Y-.0626Z-.2366
N220Y-.0938Z-.2372
N230X-.4986Y-.1251Z-.2381
N240Y-.1563Z-.2392
N250Y-.1876Z-.2405
N260X-.4948Y-.2530Z-.2413
N6130X-.6884Y.2856Z1.2358
N6140X-.6848Y.2941Z1.2359
N6150X-.6571Y.3519Z1.2366
N6160X-.6527Y.3600Z1.2367
N6170X-.6195Y.4148Z1.2375
N6180X-.6144Y.4224Z1.2376
N6190X-.5759Y.4737Z1.2384
N6200X-.5700Y.4808Z1.2385
N6210X-.5266Y.5282Z1.2389
N6220X-.5200Y.5346Z1.2388
N6230X-.4721Y.5775Z1.2384
N6240X-.4650Y.5833Z1.2383
N6250X-.4132Y.6211Z1.2375
N6260X-.4055Y.6262Z1.2374
N6270X-.3468Y.6603Z1.2366
N6280X-.3333Y.6672-1.2364
N6290X-.2717Y.6942Z1.2357
N6390X-.2319Y.7085Z1.2354
N6310X-.1680Y.7262Z1.2349
N6320X-.1011Y.7390Z1.2345
N6330X-.0228Y.7488Z1.2341
N6340X1.0945Y.8875Z0.F21
N6360M30
^D^T
NC FILE FOR L-SECTION: (LDIE.PUN)

R
:715
N10G70G90G0T1S2100M26
N20X-.0423Y.8874Z.1
N30G1X-.0423Y.8874Z-.0064F15.
N40X-.1601
N50X-.2340
N60X-.2913
N70X-.3423
N80X-.3953Y.8853
N90X-.4115Y.8831
N100X-.4564Y.8702
N110X-.4987Y.8452
N120X-.5221Y.8222
N130X-.5480Y.7800
N140X-.5616Y.7354
N150X-.5649Y.7142
N160X-.5678Y.6618
N170X-.5679Y.6419
N180Y.5819
N190Y.5219
N200Y.4619
N210Y.4019
N220Y.3419
N230Y.2818
N240Y.2218
N250Y.1618
N260Y.1018
N270Y.0418

N5230X-.8488Y.7465
N5240X-.8332Y.7540
N5250X-.7842Y.8049
N5260X-.7671Y.8211
N5270X-.7135Y.8679
N5280X-.6948Y.8828
N5290X-.6371Y.9253
N5300X-.6172Y.9386
N5310X-.5556Y.9763
N5320X-.5389Y.9909
N5330X-.4669Y1.0212
N5340X-.4367Y1.0341
5350X-.3646Y1.0610
N5360X-.3611Y1.0622
N5370X-.2943Y1.0824
N5380-.2270Y1.0981
N5390X-.2053Y1.022
N5400X-.1190Y1.1156
N5410X-.0132Y1.1268
N5420X.9958Y1.0632Z0.F21.
N5440M30
^D^T
NC FILE FOR H-SECTION: (HDIE.PUN)

R
:716
N10G70G90G0T1S2100M26
N20X.0056Y.2779Z.1
N30G1X.0056Y.2779Z-.006F15.
N40X-.0267Y.2792
N50X-.0496Y.2823
N60X-.0634Y.2860
N70X-.0662Y.2872
N80X-.0678Y.2961
N90X-.0693Y.3246
N100X-.0688Y.3445
N110X-.0702Y.4583
N120X-.0711Y.4785
N130X-.0762Y.5340
N140X-.0851Y.5794
N150X-.0945Y.6078Z-.0059
N160X-.1154Y.6472
N170X-.1463Y.6820
180X-.1888Y.7095
N190X-.2042Y.7158
N200X-.2477Y.7260
N210X-.2928Y.7283
N220X-.2944
N230X-.3444
N240X-.3944
N250X-.4462Y.7262
N260X-.4658Y.7233
" " " 
" " " 
N5240X-.8662Y.7044
N5250X-.8447Y.7304
N5260X-.7951Y.7848
N5270X-.7718Y.8082
N5280X-.7193Y.8564
N5290X-.6949Y.8767
N5300X-.6406Y.9181
N5310X-.6205Y.9320
N5320X-.5591Y.9706
N5330X-.5383Y.9825
N5340X-.4743Y1.0153
N5350X-.4525Y1.0254
N5360X-.3860Y1.0526
N5370X-.3748Y1.0567
N5380X-.2999Y1.0814
N5390X-.2307Y1.1006
N5400X-.1852Y1.1112
N5410X-.1534Y1.1166
N5420X-.1097Y1.1212
N5430X-.0012Y1.1279Z-1.0044
N5440X1.0016Y1.0638Z0.F21.
N5460M30
\^D\^T
APPENDIX-E

PHOTOGRAPHS
FIGURE 1  CNC BRIDGEPORT (R2E4) MILLING MACHINE
FIGURE 2 GRAPHITE ELECTRODES
FIGURE 3 EDM (EASCO SPARCATRON)
FIGURE 4 EDM PROCESS
FIGURE 5  EXTRUSION DIE
APPENDIX-F

DFPI PROGRAM TO DRAW THE DIE
DFPI PROGRAM TO DRAW THE DIE:

TO DRAW THE EXTRUSION DIE BY USING THE B-SPLINE CURVE.

PROGRAM DIEDGN
IMPLICIT INTEGER*2 (A-Z)
DIMENSION IGG(2), IATLK(4), IFILE(7), INBUF(15)
INTEGER*2 IOBUFF(256), ISPEC(5)
BYTE IBUFF(32)
CHARACTER*20 FNAME
INTEGER*4 REGN50, IPOLE(210)
REAL*4 XPOLE(70), YPOLE(70), ZPOLE(70)
DATA IGG/2*0/, ISPEC/5*0/, IEX/'EX1/', IATLK/4*0/
DATA REGN50/6RREGION/
DATA ILUN/1/

C*** ENTER VALID FILE NAME ***
WRITE(6,1)
1 FORMAT(' ENTER NAME.EXT')

C*** READ DESIGN FILE SPECIFICATION ***
READ(5,2) ICHA, INBUF
2 FORMAT(Q,15A2)
3 WRITE(6,3)
FORMAT(' HOW MANY BLOCKS?')

C*** READ NUMBER OF BLOCKS ALLOCATED ***
READ(5,4) IBLOCKS
4 FORMAT(I5)
C *** CREATE DESIGN FILE ***
    CALL FILALO(ILUN,INBUF,ICHA,IBLOCKS,IRC)
    IF (IRC.NE.0) STOP 'FILALO --- ERROR'
    CLOSE (UNIT = ILUN)
C *** OPEN DESIGN FILE FOR WRITING ***
    OPEN (UNIT=ILUN,FILE=INBUF,ACCESS='DIRECT',
         1 RECORDTYPE='FIXED',RECL=128,STATUS='OLD',
         1 IOSTAT=IST)
C *** WRITE ERROR CONDITION ***
    WRITE(6,44) IST
    44 FORMAT(' IST=',15)
C *** OPEN SEED FILE FOR READING ***
    OPEN(UNIT=2,,FILE='SEEDZ.DGN',ACCESS='DIRECT',
         1 RECORDTYPE='FIXED',RECL=128,STATUS='OLD',
         1 IOSTAT=IST)
C *** WRITE ERROR CONDITION ***
    WRITE(6,44) IST
C *** READ FROM UNIT=2 AND WRITE TO UNIT =1, 1 SECTOR AT A
    TIME.  ***************
    DO 5 I=1,8
         READ(2) IOBUFF
         WRITE(1) IOBUFF
    5 CONTINUE
C *** CLOSE DESIGN FILE AND WORD FILE ***
    CLOSE (UNIT=ILUN)
    CLOSE(UNIT=2)
    WRITE(6,7)
    7 FORMAT (' VALID DESIGN FILE CREATED')
C *** GENERATE LKTRAN FORMAT FILE SPECIFICATION BLOCK ***
CALL LKTCSI(INBUF,IFILE,ICHA,0,IRC)
IF (IRC.NE.0)STOP 'LKTCSI CONVERSION ERROR'

C *** INITIALIZATION FOR DFPI ***
CALL INDFPI (REGN50,IFILE,0,0,0,1,IRC,IEX)
IF (IRC.NE.0) GO TO 1010
WRITE(6,25)
25 FORMAT(' INDFPI COMPLETED')

C *** ENTER THE DATA ***
WRITE(6,*) 'ENTER THE DATA FILE NAME '
READ(5,55) FNAME
55 FORMAT(A20)
OPEN(UNIT=10,FILE=FNAME,STATUS='OLD')
LVL = 1
READ(10,*) NPOINT
READ(10,*) NFILE
DO 11 KK=1,NFILE
   DO 12 I=1,NPOINT
      READ(10,*) XPOLE(I),YPOLE(I),ZPOLE(I)
   12 CONTINUE
XPOLE(NPOINT+1) = XPOLE(1)
YPOLE(NPOINT+1) = YPOLE(1)
ZPOLE(NPOINT+1) = ZPOLE(1)
FAC = 10*1000
J = 1
DO 15 I=1,NPOINT+1
   IPOLE(J) = XPOLE(I)*FAC
   IPOLE(J+1) = ZPOLE(I)*FAC
IPOLE(J+2) = YPOLE(I) * FAC

J = J + 3

15 CONTINUE

ORDER = 4

NPOINT = NPOINT + 1

NKNOT = 0

CALL BSPBGN(0, IRC)

IF (IRC .NE. 0) GO TO 900

WRITE(6, 300)

300 FORMAT(' BSPBGN COMPLETED')

CALL BHDFPI(IGG, LVL, ISPEC, 0, ORDER, 0, 0, 01,
$     NKNOT, IATLK, IRC)

IF (IRC .NE. 0) GO TO 905

WRITE(6, 310)

310 FORMAT(' BHDFPI COMPLETED')

CALL PODFPI(NPOLE, IPOLE, IRC)

IF (IRC .NE. 0) GO TO 910

WRITE(6, 320)

320 FORMAT(' PODFPI COMPLETED')

CALL BSPEND(0, IRC)

IF (IRC .NE. 0) GO TO 920

WRITE(6, 330)

330 FORMAT(' BSPEND COMPLETED')

GO TO 1100

900 WRITE(6, 901) IRC

901 FORMAT(' ERROR IN BSPBGN IRC = ', I3)

GO TO 1010

905 WRITE(6, 906) IRC
906 FORMAT(' ERROR IN BHDFPI IRC =',I3)
910 WRITE(6,911) IRC
911 FORMAT(' ERROR IN PODFPI IRC =',I3)
920 WRITE(6,921) IRC
921 FORMAT(' ERROR IN BSPEND IRC =',I3)
1010 CONTINUE
   IF (IRC.GE.900) CALL ERROR9 (IRC)
   CALL ERROR
1100 CONTINUE
11    CONTINUE
   CLOSE(10)
C**** TERMINATE DFPI(1) ****
   CALL DEDFPI(1)
   STOP 'DIEDGN COMPLETED'
END
APPENDIX-G

PROCEDURE TO DOWNLOAD A NC-FILE INTO THE
BRIDGEPORT CNC MACHINE
PROCEDURE TO DOWNLOAD A NC-FILE INTO THE BRIDGEPORT CNC MACHINE:

The steps have been divided into two major groups:

(A) Editing the NC-file by using the WORDPERFECT.
(B) Downloading the NC-file into Bridgeport by using the PROCOMM.

(A) TO EDIT THE NC-FILE:

1. Boot up the computer and place the diskette in drive A.
2. Change to WordPerfect directory by keying ‘CD\WP’.
   Type ‘WP’ and press ‘RETURN’ in WordPerfect directory.
3. Retrieve the ‘FN.PUN’ file by using ‘Ctrl F5’ and select option 1:— Retrieve Dos Text.
4. Edit the file as per given example:
   ^R (Ctrl R)
   :101
   N10G70G90G0T1S1800M26
   ----------------------
   N****M30 } (At the end)
   ^D^T (Ctrl D & Ctrl T) }

(B) TO DOWNLOAD FN.PUN FILE INTO THE BRIDGEPORT BY USING PROCOMM:

1. Before turning on the Milling Machine make sure that the PC is on and the cable (which is located near switch) is connected to ‘B’ port.
3. Wait until Bridgeport goes through a series of checks.
   The ‘BRIDGEPORT’ logo will then appear on the CRT.
(4) Press ‘ACCESS ENABLE KEY’ which is on the front panel of the machine.

(5) Press ‘ENTER’ key and then by pressing the ‘EXECUTE’ key the machine will go to home position.

(6) Activate the BOSS 9 control by pressing ‘LOAD/CLEAR/EDIT/’ key.

(7) Then select the Load option and select remote option by pressing ‘0’ and ‘EXECUTE’. Then select the ‘Load from Remote’ by pressing ‘0’ and ‘EXECUTE’.

(8) Press ‘EXECUTE’ one more time and ‘LOADING’ will appear on the CRT. CNC control is waiting to receive the file.

(9) Go to the PC and change the directory by typing ‘CD\PROCOMM’.

(10) Activate PROCOMM by typing ‘PCPLUSSTD’.

(11) Press the ‘PAGE UP’ key and select 4.

(12) Type NC-file name (‘A:FN.PUN’).

(13) Now press ‘RETURN’ and the program will be transferred to the Bridgeport (For more information press ‘ALT-F10’ for help menu.).

(14) Type ‘ALT- X’ to exit from the procomm program.