Design and Implementation of Asymmetric Extrusion Die Using Bezier Technique

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**Abstract:** Extrusion is a process that used to create objects of a fixed cross-sectional profile. A material is pushed through a die of the desired cross-section. The main advantage of this process with respect to other manufacturing processes is its ability to create very complex cross-sections, while the limitation of extrusion process is used to produced just a symmetric profile so this paper proposed an adopted algorithm that used to design and implementation the Asymmetric extrusion die that used to prevent the twisting that caused in metal when used to produce the Asymmetric product, and in other wise reduce the total extrusion power and die pressure distribution on metal during extrusion process. This adopted design was implemented in this work using Teflon material in both symmetric and asymmetric profile using CNC milling machine to demonstration the success of this algorithm.

**1. Introduction**

A die is the tool shape that the material is pushed through to create the profile, and to form a substantially limitless of sizes and shapes can be made using Extrusion dies [1]. Dies are broadly grouped as solid (or flat) dies that which produce hollow dies or semi hollow shapes and solid shapes. Combinations of semi hollow, solid, and/or a single die may be produced using incorporated hollow shapes. A solid die may have one or more orifices through which the softened material is forced (extruded), figure (1) illustrated the extrusion die [2].

![Figure 1. Hollow profile extrusion uses a mandrel to produce the cavity](image-url)
A semi hollow extrudes die shape that is nearly hollow, enclosing a void partially; the area of the die cape is larger than the gap where the cape is connected with the die body. Hollow dies used to produces a variety of shapes, such as porthole, Bridge and spider dies, that include a fixed shock mandrel as an integral part of the die [3]. These types of hollow extrusion die have a various function with respect to their limitation and advantage of this process. The cost of this process is vary widely with respect to manufacturing methods and the selection of design and manufacturing process depended on extrusion profile, container size, press types and production requirements. [4]

There are several issues that need separate discussion as peoples around the world are trying to study the theories and algorithms which relate of design extrusion die by using bezier curve technique and other method. Pongalagusamy et al developed a Bezier curve model for streamlined extrusion dies. The design of stream line extrusion dies by using different methods like the polynomial equation-based die, line and area mapping technique and analytical method. The theoretical calculation on the extrusion pressure according to various friction factors is done. It is concluded that the design of extrusion stream line dies using the Bezier technique is better than the design of dies based on the polynomial equation [5]. Thilo kielmann studied computer graphics curves and surface using curve mathematical representation (parametric implicit and explicit) the parametric surface representation for quadratic and cubic polynomial and the cubic interpolation was studied and the segments was interpolating joining. This study was applied to B-spline, Bezier and Hermit curves and surfaces [6].

Young-Kenn choi et al developed the tool path generation and analysis the tolerance of free-form surfaces. They focus on improving the mathematical algorithms to generate the tool paths for free-form surfaces based on the desired manufactured accuracy of the part and by using mathematical curves and surfaces, the manufacturing part is performed.[7]

From the above literature survey it concluded that the little researches have focused on the design the profile of extrusion die and the mechanism of Asymmetric extrusion process, so, the aim of this work is to design Asymmetric extrusion die that used to prevent the twisting that caused in metal when used to produce the Asymmetric product and reduce the total extrusion power and die pressure distribution on metal during extrusion process.

2. Theoretical Consideration and Simulation

2.1 Surface Modeling:

The surface modeling process includes a collection of operations that aimed to representing a 3D surface and transforming a spatial data from one form to another. Any variable can be present and analyzed as a 3D surface with respect to it varies relatively smoothly at the chosen map scale and has only a single value at each location [8]. A 3D surface can be approximated in a number of control points, including irregularly-spaced point observations, contour lines of equal value (isolines) or a regular grid of values; Surface interpolates a regular grid of values from data in the input object and outputs the grid as a meshed object [9].

The input data can be formed as a vector object or in a form that has X, Y and Z coordinate fields for each record. The input object used in this work is a 3-D vector object regularly spaced sample elevation points from a complex surface. The elevation is stored as a Z value for each point. The adopted approximation method can be used in a variety of CAD-CAM.

Approximation is a first step in numerical analysis, which used to construction a given set of data points to form the required shape. In some applications, these data points are obtained by sampling a process or function; on otherwise, the values of the function can be used to construct an approximate, which the data points must agree with the interpolated function. The best type of approximation is Bezier method.

The steps of mathematical solution of the adopted method can be illustrated as follows:

**Step-1-** Considering the input data set points (a sequence of planar points) defined by:-

\[(x_1, y_1, z_1), \ (x_2, y_2, z_2), \ldots, \ (x_n, y_n, z_n)\]
Step-2- use the approximation method (Bezier curve) in \( (n^{th}) \) degree can be formulated as:

\[
B(t) = \sum_{i=0}^{n} b_{i,n}(t) p_i, \quad 0 \leq t \leq 1
\]

\[
b_{i,n}(t) = \binom{n}{i} t^i (1 - t)^{n-i}, \quad i = 0, \ldots, n
\]

Step-3- find the centroid of the close shapes that required in proposal shape (complex shape) by using the mid-point for the line that intersection between the irregular shapes. Figure (2) and (3) present the sequence that used to find the centroid.

Step-4- move and contribute the center point between the input shape and the output irregular shape that desired in extrusion dies.

Step-5- represent Bezier curve in third degree between the input shape and the output desired shape to represent the stream profile for extrusion die, figure (4) illustrated the stream profile for extrusion die.
2.2 Tool Path Generation and Development

The significant step of this work is determination of the tool path in the process of designing the product for part machining. This work aimed achieving a satisfying quality of the machined surface and an optimal machining time when selected the optimal tool path and must be observed various specific constraints. the machining time needs to be minimized when using rough cutting, while the machined surface quality is not that much important. In surface finishing, the scallop height does not skip the allowable tolerance but time of machining does not perform an important role in the machining process. The uniform distributed scallops high that used in this work when select the tool path. smaller scallop high caused the high machining time and best surface quality. Thereby, the cost of the part is high. a bicubic Bezier surface most frequently represented by a sculptured surface, which are represent using Cartesian coordinates specified in control points. Each point on the surface is calculated using the corresponding formulas as a function of two parameters, u and v. Specifying one parametric value enables the construction of a curve as a function of the other parameter, whereby a surface grid is generated. Three methods for complex surface machining have been developed so far, i.e., isoparametric, iso-planar and iso-scallop. In this work used the NX program to generate the tool path for the semi-extrusion die for two types of extrusion die and in roughing and finishing machining, which illustrated in figures (5) and (6).

**Figure 4.** Illustrated the stream profile for extrusion die four three model used in this work.

**Figure 5.** Present the tool path and G-code in rough machining using NX program (model -1-)

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G-code of model 1(Roughing)
%
N1 G17 S1000 M03 F500
G01 G54 X-29.5417 Y59.8967 Z25
Z4.2726
G01 X-31.7053 Y59.5713 Z3.6861 F500.
X-33.4327 Y58.1994 Z3.0996
X-34.3184 Y56.1792 Z2.5131
X-34.157 Y53.9792 Z1.9266
.X
X-2829 Y56.5517 I-269.0387 J-13.7377
G01 X-.45 Y58.3378
X-.5606 Y59.4714
X.5.9211 Y60.1039
Z-.32.9723
G00 Z102.2726
M02
```
Figure 6. Present the tool path and G-code in finish machining using NX program (model -1-)

3. Experimental work

The NC program for free-form machining was generate using the above-described algorithm with the following machining parameters that created, with rotational speed 1000 R.P.M and available feed rate of 500 mm/min using flat-end cutting tool in rough machining diameter of 10 mm and ball-end mill in finish machining of diameter 8 mm. In the experiments the same workpiece materials and vertical machine center were used. Table (1) illustrated the specification of CNC machine (UM-85) that used in this work. While figure (7) present the CNC milling machine.

| Table 1. CNC milling machine specification |
|-------------------------------------------|
| Item | Model  | Fanuc UM-85 |
| Spindle speed (rpm) | 8000(6000\(10000\(12000) | 850 |
| x-axis travel (mm) | 550 |
| y-axis travel (mm) | 550 |
| z-axis travel (mm) | 550 |
| Rapid feed rate (x,y,z) (m/min) | 30/30/30 |
| Cutting feed rate (m/min) | 12 |
Figure 7. Present the CNC milling machine used in this work.

3.1 Simulation Experimental Work steps

The implementation work is divided into two groups, as shown in figure (8), while figures (9), (10), and (11) present the presider of this work.

![Implementation Work Diagram]

Figure 8. The sequence of the implementation work.
Figure 9. Present the presider of this work (model -1-)

Figure 10. Present the presider of this work (model -2-)
Matlab design | UG design
---|---

G-code
N1 G17 S1000 M03 F500
G01 G54 X-32.1639 Y63.6763 Z25
Z5.7517
G01 X-33.871 Y64.7679 Z5.2088 F500.
N248 X.1315 Y68.9156
X.03 Y68.9091
G03 X-11.5943 Y65.9549 I-0.0085 J-24.3136
X-12.9494 Y55.715 Z.0487 J-5.6131
X.1157 Y51.1128 I12.1221 J13.5669
G01 X.275 Y51.1028
X.2948 Y52.3775
G03 X.1235 Y60.3471 I-86.7967 J2.1206
G01 X4.6133 Y60.6503
Z-41.7959
G00 Z113.7517
N249 M02

Figure 11. Present the presider of this work (model -2-)

4. Results and Discussions:
In order to enhance the streamlined of extrusion die, several product has been take for symmetric extrusion process and design the die using NX package, after that applied this design by manufacturing using CNC milling machine, this design applied on round and polygon product using Teflon material as a prototypes shape. And to demonstration the proposal work, the design was applied on the Asymmetric product and find the solution of different of product centroid by shafting the centroid to a new position to achieve the symmetry of metal. These shafting of product centroid prevent the twisting that happened during squeezing of metal and reduce the total power that need to complete this process, and in otherwise, prevent the failure that happened in the internal surface of die due to metal twisting and high power that needed to complete this process.

5. Conclusions:
It has been established that Bezier technique is an effective technique used to find irregular shape for all engineering application. The conclusion remark illustrated below:
- Bezier technique is the good method to present the profile in extrusion die to give the smoothness of flow of the metal.
− Find the centroid of the irregular shape is very important to avoid the twist of the metal that give the high pressure at the die and take the failure in the extrusion process.
− The adopted method aimed to prevent the failure that happened in internal face of die due to high pressure in extrusion die.
− Using of NX program to generate the tool path for extrusion die and part program to minimum roughness and machining time.

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