Journal of Advanced Engineering Research
ISSN: 2393-8447
Volume 3, Issue 2, 2016, pp.128-133

A Novel Automated Design Calculating System For Axisymmetric thin-walled structures By Deep drawing process

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ABSTRACT

In this research paper, the various tools used in deep drawing process were designed with a aid of computer-aided design computing system to facilitate the design process and save time. The widely used computer programming language (VISUAL BASIC 8.0) was used to build the computing system, which was linked to Microsoft Excel for retrieving the results. Traditionally, design of deep drawing tools was experience-based, highly complex, and time-consuming task. Selection of suitable size and type of tools plays a vital role in the design process. This research paper exhibits the development of a technique that facilitate in making the design of deep drawing process and computing drawing parameters economical, simple, quicker, and more reliable. The proposed method is capable to automate all major activities of design processes of deep drawing tools such as selection of punch & die components, modeling of die components, and assembly of punch & die.

Keywords - Automated design, Axisymmetric parts, Computer-Aided Design, Deep drawing, Visual Basic.

1. INTRODUCTION

Among the various sheet metal forming processes, Deep drawing is one of the typical process used to create axisymmetric hollow shaped components at very high production rate. The performance of deep drawing process is influenced by many parameters and the choice of these parameters is very essential to achieve high drawability [1]. Design of tools utilized in deep drawing process was a highly specialized task which includes number of significant activities that sequentially start with determination of blank dimensions, manufacturability assessment of drawn parts, selection of various process parameters, determination of process sequences, design of punch & die components, modeling of die components and assembly between punch & die. Traditionally, these activities were performed by skilled process planners and die designers using experience-based trial and error technique [2]. Conventional design procedure of deep drawing tools was manual, highly complex, error-prone and consuming more time which results in long manufacturing lead time of drawn parts and high cost [3]. Therefore automated design process of deep drawing tools has become a challenge for researchers. With the recent advancements in the area of CAD/CAM, researchers started to apply various innovative methods for tools design. In 1978, A CAD/CAM system was recommended for the automation of progressive die design [4]. Potocnik et al [5] proposed an intelligent system for the automatic calculation of stamping parameters to design a stamping die for fabricating a hollow cup with flange. Tsai et al. [6] developed an automated system of die design and process planning for the production of automotive panels using knowledge based engineering approach. The above-mentioned literature review reveals that only very few research works are found in the area of automation of design process of deep drawing tools. The main objective of this research paper is to obtain the best deep drawing parameters with the aid of computer-aided design computing system to reduce wrinkling and tearing during a cylindrical tube deep drawing process.

2. DEEP DRAWING PROCESS PARAMETERS

Deep drawing operation of any sheet metal can be performed with tools such as punch and die. The punch is a widely utilized drawing tool which is the desired profile of the base of the part. The die cavity matches the punch and slightly wider to allow for its passage, called as clearance. The blank, a sheet metal work piece is placed over the opening of the die. A blank holder, that surrounds the punch, applies pressure to the whole surface of the circular blank, holding it in a flat mode against the die. The punch moves towards the blank.

After contacting the work, the punch forces the metal blank into the die cavity, forming its profile. If required percent reduction of sheet metal is above 50%, the part must be made in multi-stage operations. Redrawing is the subsequent drawing of a part that has already undergone a drawing process. Required punch and blank holder forces can be calculated based on geometry of the blank, punch and die profile, die shoulder radius, punch nose radius, material of the blank and friction. Iterations of deep drawing process through method of trial and error can optimize the manufacturing operation over time. Various design constraints as shown in Fig.1 such as geometry of the blank, percentage reduction, Die shoulder radius, punch nose radius, blank holder force may have to be adjusted based on the results of previous stages of design.

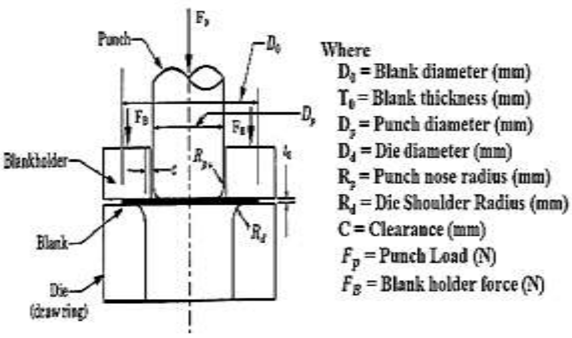


Fig.1 Design Parameters for Multistage deep drawing

3. MATERIAL PROPERTIES

The Aluminium ingots were melted in a furnace and converted into slabs. These slabs were preheated and rolled into intermediate gauge sheets in the hot rolling machine followed by cold rolling to acquire sheets of finally required gauge thickness. After this process, the sheets were cut into Aluminium Circular blanks of required diameter using circle cutting machine. After Aluminium Circle is cut, it was annealed, so that the circle becomes soft and doesn't break in the further processes.

3.1 Chemical Composition of Aluminium

Chemical analysis is a widely used technique to determine chemical composition of various metals and alloys in the engineering sector. The floor standing metal analyzer FOUNDRY-MASTER Pro (OXFORD Instruments, Germany) which is a high-performing optical emission spectrometer (OES) was employed in trace analysis of important elements present in aluminium. The chemical composition of aluminium blank used in this research work is depicted in Table 1.

Table 1 Chemical Composition of aluminium

Elements	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
Weight (in %)	0.204	0.886	0.15	0.065	0.011	0.12	0.032	0.009	98.41

3.2 *Tensile Testing*

Axial tensile test is a universal test to attain various material parameters such as yield strength, ultimate strength, % elongation, and % reduction in area. The sample used for tensile test was machined to comply with ASTM E8 standard as show in Fig. 2 (a) and Fig. 2 (b). The tensile test was carried out by applying longitudinal load at a definite extension rate to a standard tensile specimen with dimensions such as gauge length and cross sectional area perpendicular to the loading direction till fracture of the tested specimen. The engineering stress-strain curve obtained from tensile testing of aluminium flat specimen was illustrated in fig.3.

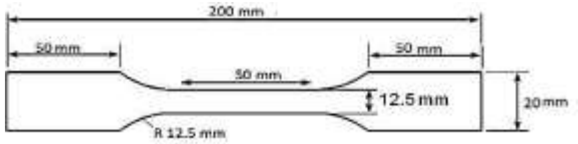


Fig.2 (a) Standard Specimen –ASTM E8 standard

Fig.2 (b) Tensile tested Specimen

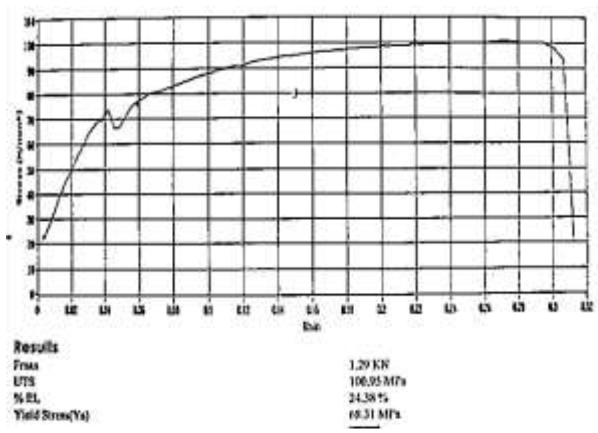
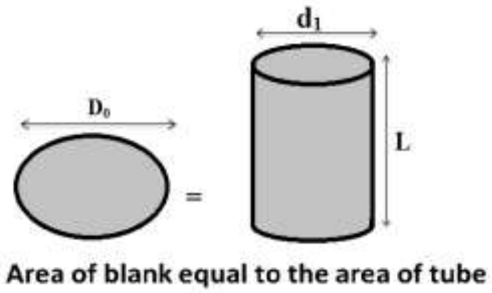


Fig.3 Stress-strain curve

4. DEVELOPMENT OF THE PROPOSED SYSTEM

This research paper exhibits the development of a technique that facilitate in making the design of deep drawing process and computing drawing parameters economical, simple, quicker, and more reliable. The computer – aided computing system requires a database to store the inputs (material properties of the blank) to this algorithm. VISUAL BASIC programming codes were used to develop the computer-aided computing system, if required AutoCAD program can be linked automatically to this developed system to plot the designed punches and dies. Drawing tools consist of the effective parts such as punch, die, and blank holder), and other accessories such as upper plate, lower plate, guides etc. were neglected to simplify the model and to save analysis time.

The first step in design procedure of deep drawing process is to determine the dimensions of the blank. To produce tube- like components, the blank is circular. The blank diameter was determined from the following equation by assuming the area of blank equal to the area of tube.



$$\frac{D_0^2\pi}{4}=\frac{d_1^2\pi}{4}+d_1\pi l$$
$$D_0=\sqrt{d_1^2+4d_1 l} \qquad (1)$$

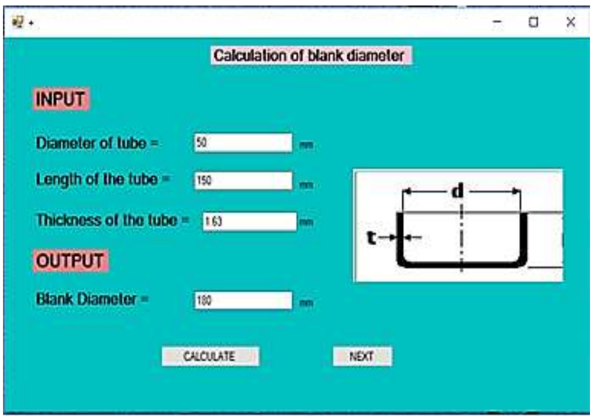


Fig.4 Tube Geometry screen

Then the required number of draws was calculated by taking ratio of original diameter of the blank to the required diameter of the drawn tube which is defined as Limiting Draw Ratio (LDR).

$$\beta=\frac{D_0}{d_1} \qquad (2)$$

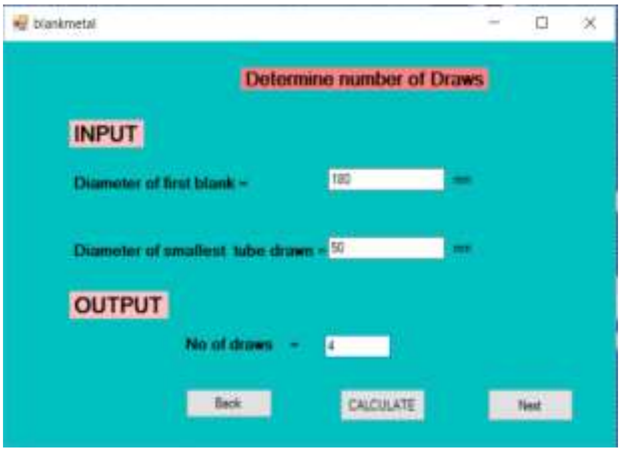


Fig.5 Drawing ratio screen

Based on the calculated number of draws, the suggested percentage reduction was chosen from the Table 2. Then the diameter of the tube for calculated number of stages was determined from the equation 3.

$$P=100\left(1-\frac{d_n}{D_o}\right) \qquad (3)$$

Table 2 Percentage in Reduction

Diameter Ratio	Number of draws	Percentage reduction			
		First draw	Second draw	Third draw	Fourth draw
Up to 0.75	1	50-40	–	–	–
0.75 to 1.50	2	50-40	40-25	–	–
1.50 to 3.00	3	50-40	40-25	25-15	–
3.00 to 4.50	4	50-40	40-25	25-15	15-10

For the initial draw, the diameter of punch was taken as 45% of original diameter of the blank, since the maximum probable reduction for the initial draw is between 40-50% of the original blank diameter. The tubes were successfully drawn in this stage. Based on the method of trial and error, the next draw was performed with two sizes of punch diameter. The first punch diameter was reduced by 35% and second was reduced by 30%. From the results, it was clear that the operation performed with the punch diameter of 35% reduction was failed due to tearing failure whereas the punch diameter 30% has got effective result. The percentage reduction in the further drawn stages was taken as 15% and achieved very good results without causing any failure.

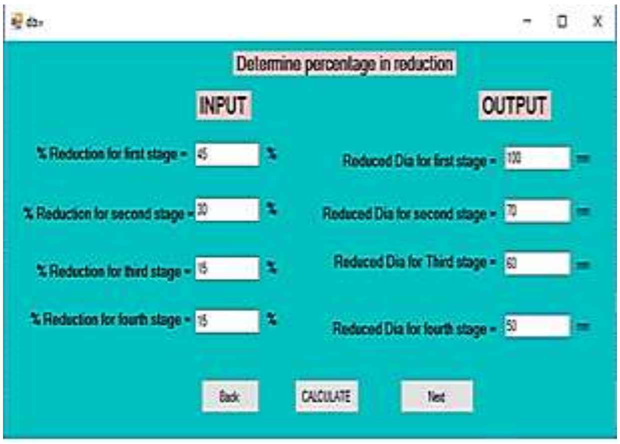


Fig.6 Draw ratio screen

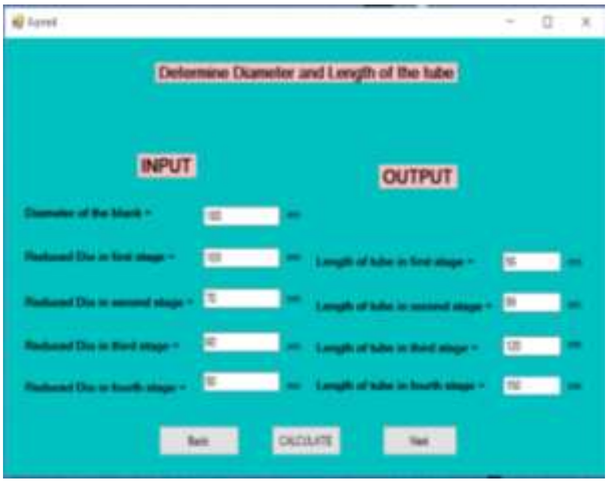


Fig.7 Drawn tube diameter Screen

The diameter and length of the drawn tube in each stage were determined as shown in Fig.7.

Fig.8 Punch design screen

Fig.9 Die design screen

The punches and dies for four stages of deep drawing process were designed as shown in Fig.8 and Fig.9.

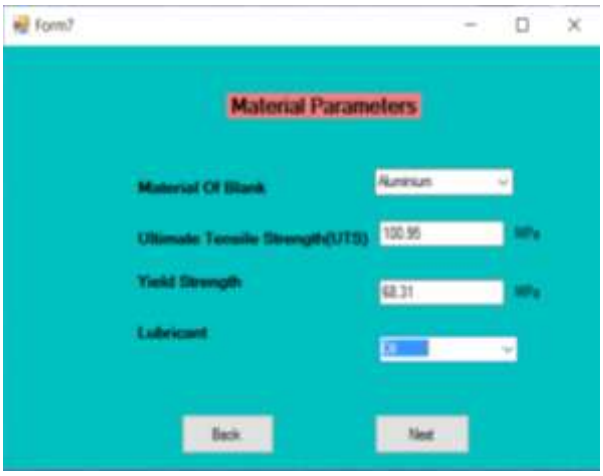


Fig.10 Material parameters screen

The material database was used to store the mechanical properties of frequently used material such as aluminium, steel, brass and the type of lubricant used. The chosen material of the blank in this research paper was aluminium and their mechanical properties were shown in Fig.10.

The various forces involved in every stages of design procedure of the deep drawing process were calculated by the following equations 6, 7 and 8.

$$(F_p)max. = \pi D_p T_0 * \sigma_{ult}\left[\left(\frac{D_0}{D_p}\right) - 0.7\right] \quad (4)$$

$$F_B = \left(\frac{1}{3}\right) * (F_p)max. \quad (5)$$

$$F = (F_p)max. + F_B \quad (6)$$

Fig.11 Load calculation screen

The complete outcomes of the computer aided design computing system are recorded in detail in Fig.13. It can be concluded that, if the tube desires more than one draw to be completely drawn, parameters such as punch load, blank holder load, total load, and LDR will be decreased with subsequent stages. The developed automated system showed the design procedure for deep drawing process which is simple and less time consuming. Also, it is not violated by human errors; these benefits will be reflected on the quality of the manufactured tube.

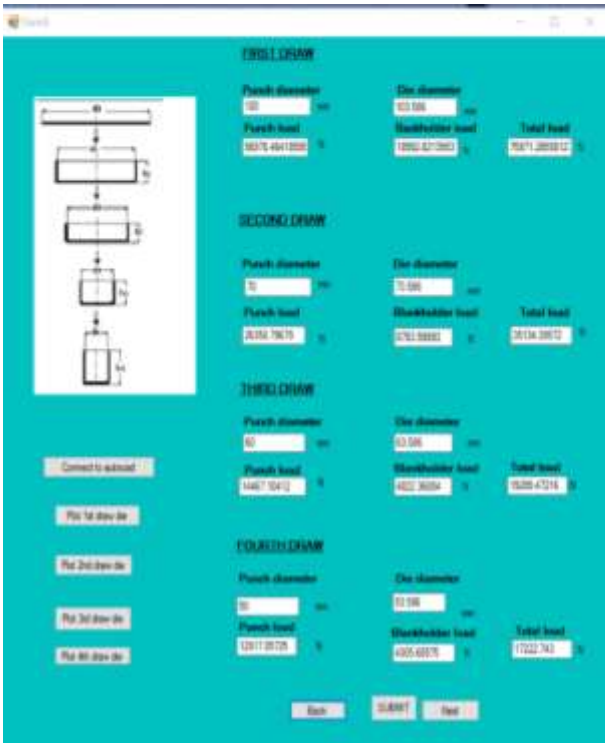


Fig.12 Design parameters screen

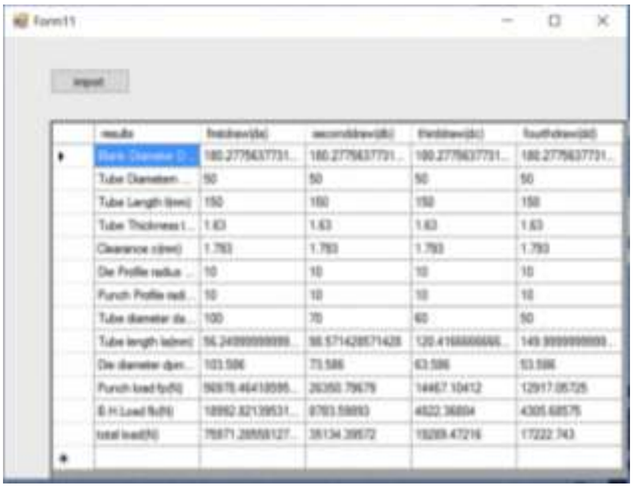


Fig.13 Output screen

5. RESULTS AND DISCUSSIONS

The Draw tools used for multistage deep drawing consists of punch, die and blank holder were successfully designed with using a VISUAL BASIC programming language. The various design constraints such as punch diameter, punch nose radius, die diameter, die shoulder radius, clearance and various forces like punch load,blankholder load and total load were determined for each stage by using computer-aided design calculating system. The blank diameter, thickness of blank and number of draws were given as input to the design.

Table 3: Outcomes of the computer-aided design computing system

Results	First draw	Second draw	Third draw	Fourth draw
Die diameter (mm)	103.58	73.586	63.586	53.586
Die Profile radius (mm)	10	10	10	10
Punch Profile radius (mm)	10	10	10	10
Punch diameter (mm)	100	70	60	50
Tube length (mm)	56	99	120	150
Clearance (mm)	1.793	1.793	1.793	1.793
Tube Thickness (mm)	1.63	1.63	1.63	1.63
Punch load (KN)	56.98	26.35	14.46	12.91
Blank holder Load (KN)	18.99	8.78	4.82	4.31
Total load(KN)	75.97	35.13	19.29	17.22

The punches and dies of required dimensions used in various stages of deep drawing process were machined by CNC lathe machine as shown in Fig.14 and Fig.15. The dimensions of the punches and dies were retrieved from the automated design calculating system. The material used was tool steel.

Fig.14 Machined Punches for Multi-stage Deep drawing process

Fig.15 Machined Dies for Multi-stage Deep drawing process

The defects such as cracks and imperfections occurred during preliminary design of the drawing process as shown in Fig.16. These damages were eliminated by modifying the percentage in reduction ratio of diameter of drawn tubes by trial and error method. The cylindrical tubes were fabricated from aluminum blank using a successfully designed deep drawing process. The various stages of drawn tubes are shown in Fig.17.

Fig.16 Tearing defects

Fig.17 Conversion of Aluminium blank to tube

6. CONCLUSION

From the calculated results, it has been observed that the newly developed computer-aided design computing system supports design engineers in providing an automated design tool for working faster and more accurate; these benefits are reflected on the quality of the manufactured tube. The best deep drawing design parameters were obtained from the novel design system in which the defects such as wrinkling and tearing were reduced completely. The cylindrical tubes were successfully fabricated by multi-stage drawing process.

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