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Computer – Aided Software for Symmetrical Shells Blank Diameter Determination in Manufacturing Industries

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Abstract: Material waste during symmetrical shells deep drawing process in our manufacturing industries in Nigeria is at increasing rate that need to be control to the minimum since it cannot be fully eliminated. Types of shapes commonly requested by clients were identified in these manufacturing industries as types: A, B, C, D, E, F………L. Each type's mathematical model was identified for the required symmetrical shell's diameter computation. These models where integrated to form the required logic (flow chart). Considerations were given to type of material used for the production based on the client emphasis. Commonly used materials are: copper, aluminum, stainless steel and brass. Manual Computation was carried out based on the requisition of four clients for type D, type A, type G and type J,The total area of material expected for the four jobs was 539666.197 mm^2 but when the models identified were used, the actual area used was 323741014.5 mm^2.This, led to material saving of 215925179.5 mm^2 (215.93m^2) This is 40% of the material expected to be used if former values were used. These models reduced the cost of materials for these four clients' jobs by five hundred and seven thousand, four hundred and thirty five naira fifty kobo (₦507,435:50) only. Thisis equivalent to US$3,252.80 base on current exchange rate of ₦ 161 per US dollar in Nigeria. A computer Software model was developed for implementation of the developed mathematical based logic using Microsoft Visual Studio 2010 Integrated Development Environment (IDM). Because of its versatility for creating, documentary running and debugging programs written in a variety of. NET programming languages.

Index Terms: Blank Diameter, Manufacturing Industries, Material control, Software Model, Symmetrical shells

I. INTRODUCTION

Sheet metal forming is an important manufacturing technology in many forming processes and allows production of thin walled parts with complicated shapes. In particular, knowledge of the deformation mechanisms is important in the design of the drawing operations because deep drawing processes are characterized by non-linearity both in geometry, material behavior and nature of contact. In the wall of the forming part there may be distinguished regions involved stretching, drawing and various combinations of these basic modes of deformation [1]. The deformation mechanism of rectangular cup drawing is very complicated for a theoretical analysis. On the other hand, conventional design processes for sheet metal forming are usually based on an empirical approach. According to [2], shows several attempts have been tried to perform theoretical and numerical analysis of cup drawing. In those studies, the straight and the corner sides' were taken as a whole and its deformation was analyzed theoretically.

Further studies by [3], focused on comparison of experimental and simulation results using Finite Element Methods (FEM) concluded that the discrepancy between the two was large. Various approaches have emerged for developing anisotropic yield criteria. The anisotropic yield criteria proposed by [4] and [5], do not completely represent the general state of anisotropy, even in plane stress conditions. In 1993, Hill proposed a new and user-friendly yield criterion in which the material properties were treated as independent parameters. Hill's criterion is simple to implement, but possesses a certain anomaly. The modified version of his criterion Hill, (1979), reported to be free of this defect but does not contain the shear stress term.

Attention should be paid to the work of[6]. Where isotropic Coulomb's frictional contact law to anisotropic friction conditions with non-associated sliding rule were generalized. Based on a model of rigid anisotropic asperities, a theoretical investigation on friction limit surfaces and sliding rules has been carried out by [7]**.**By virtue of the functional performance required, certain engineering components can be made only from special materials by particular process, stamping or blanks produced from press tools are accurate and uniform, each piece being

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practically identical with hundreds of thousands of others, many components take the form of deep cavity or recess with or without a flange, and with or without a base [8].
Numerous computer measuring and control systems have been developed, often of very complex structure [9], the control actions are performed in two ways: by means of friction control and by means of sliding control, i.e. forming of flange. In the first case the key parameter is blank holding force, and the second case is the height of moving draw beads [10],
Independent steel Industry Limited, is one of the metal process companies located at Plot 5, Block 8, Akilo Road, Ogba Lagos, Nigeria was established in 1996.The blank diameter for production of their deep drawing products is through manual handling which led to errors and some abnormalities in their products. Due to these reasons this industry experience great material waste in their production. Hence, the company was chosen as case study. Some of their products are as shown in Plates 1 and 2.

Plate 1: Case study products

Plate 2: Case study products

II. MODEL DEVELOPMENT

Material properties and their influence on formability

The behavior of materials under plastic flow conditions is usually described by a flow curve. The most commonly used relation is the simple power law hardening relation expressed as;

$$\bar{\sigma} = K\{\bar{\varepsilon} + \varepsilon_o\}^n \quad \text{---(1)}$$

Where $\bar{\sigma}$ = True stress, K = strength coefficient (Swift,2007), n = strain hardening coefficient, ε_o = initial strain, $\bar{\varepsilon}$ = true strain

This law has been proposed by [11].This law is simple yet descriptive enough to be used to analyze the plastic behavior of most materials. Hence, the parameters K and n are seen as material properties.

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The influence of the "n" value on the drawability

In a drawing operation, the metal in the flange must be drawn without causing fracture in the wall. Therefore, a high n value strengthens the wall, which is beneficial, but also, strengthens the flange and makes it harder to draw in, which is detrimental. An analytical and experimental study on the influence of the n value on the deep draw ability; was performed by [12] He has found the following relationship;

$$\ln\left(\frac{d_o}{d_p}\right) = \left(\frac{\eta_{def}}{1.1}\right)^{\frac{1}{(n+1)}} (n+1) \quad (2a)$$

Where:

$$\eta_{def} = \frac{w_{id}}{w_{tot}} \quad (2b)$$

d_o= initial blank diameter, d_p= Punch diameter, η_{def} = Deformation efficiency,

w_{id} = Ideal deformation work and w_{tot} = actual needed deformation work

This equation clearly shows an influence of the strain hardening exponent onthe limiting draw ratio. This result has been verified by about 400 experiments,[12].

The load required for blanking and piercing is:

$$W_b = \Upsilon \lfloor t \quad (3)$$

Where: w_b= load required for blanking, Υ =shear strength of material, τ = shear strength of the material, $\lfloor$ = length of sheared edge and t = thickness of material

Blank holder effect in circular drawn cups

The most basic means of restraining the blank is by friction. Frictional force generated at the binders will result in a restraining force applied to the blank. Using Coulomb's Law, it can be seen that increasing the blank holder force will increase the friction resistance and the forces will be greater.

$$F_R = \mu F_N$$

(4) Where, F_R = Frictional Restraining Force, μ = Coefficient of friction and F_N = Normal force applied by the blank holder [13].

The blank for a cup or tubular part must be of the appropriate thickness and diameter. The diameter is normally determined from the surface area of the formed part with an allowance for trimming if this is necessary. Some typical examples are shown in Table 1.

From the geometry of the blank diameter shown in the Table 1, there must be clearance between punch and die for the product to be accurately produced. The clearance is applied all round, that is when a circular blank is being cut the difference in diameter between punch and die is equal to twice the calculated clearance. When the blank being cut is the product required (blanking).[15]

Clearance between punch and die is (Rd):

$$R_d - R_p = t \quad (5)$$

Where: R_d = die radius, R_p= punch radius and Clearance between punch and die equal to **t**

The maximum load required to draw cylindrical shell (Wd)

$$w_d = \pi t d \sigma \left\{\left({}^{D}/_{d}\right) - k_d\right\} \quad (6)$$

Where: d = the diameter of the cup produce, t = thickness of the blank, σ = true stress.D = diameter of the blank and k_d= constant value for the drawing operation which varies from 0.6 – 0.7 (Sachs2006) Because of the restriction imposed by the limiting draw ratio, it may be possible to achieve the required cup diameter in one drawing operation.

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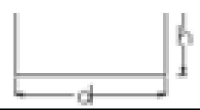
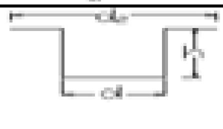
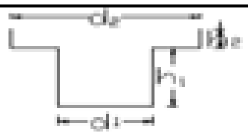
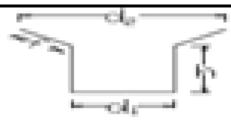
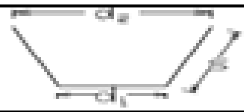
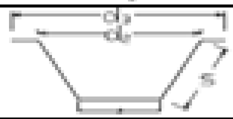
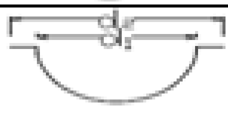
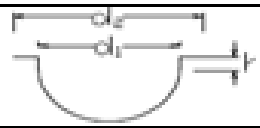
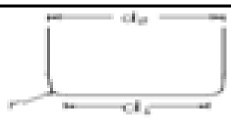
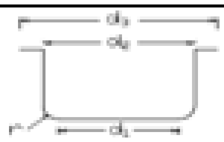
Table 1: Geometry and Blank Diameter Formulae for Symmetrical Shells

Type	Dimensions of Product	Blank Diameter Model (Bd)
A		$(d^2 + 4dh)^{1/2}$
B		$(d_2^2 + 4d_1h)^{1/2}$
C		$\{d_2^2 + 4(d_1h_1 + d_2h_2)\}^{1/2}$
D		$\{d_1^2 + 4d_1h + 2f(d_1 + d_2)\}^{1/2}$
E		$\{d_1^2 + 2S(d_1 + d_2)\}^{1/2}$
F		$\{d_1^2 + 2S(d_1 + d_2) + d_3^2 - d_2^2\}^{1/2}$
G		1.414d
H		$(d_1^2 + d_2^2)^{1/2}$
I		$(d_1^2 + d_2^2 + 4d_1h)^{1/2}$
J		$1.414\{d_1^2 + f(d_1 + d_2)\}^{1/2}$
K		$(d_2^2 + 2.28rd_1 - 0.56r^2 + 4d_2h)^{1/2}$
L		$(d_3^2 + 2.28rd_2 - 0.56r^2)^{1/2}$

Source: (14)

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III. MODEL DEVELOPMENT

The different types of shape that can be processed were identified and named type (A, B, C, D ….L).Mathematical model for each type is identified as shown in Table 1. These mathematical models were integrated for the required logic (flow chart) for determining any required shape blank diameter from the shapes already identified.

IV. MODEL IMPLEMENTATION

The logic will request from the user the type of shape required from types (A, B, C,and D --------L). Base on this type of selection, the logic will select the mathematical model that is appropriate for the blank diameter and perform the computation required to determine the blank diameter, the area of material used and determine the waste by finding the difference between the empirical method initially used and the optimal correct approach.

V. SOFTWARE DEVELOPMENT AND APPLICATION

The application was created using Microsoft Visual Studio 2010 integrated development environment (IDE). *Visual Studio .NET* is Microsoft's integrated development environment(IDE) for creating, documenting, running and debugging programs written in a variety of .NET programming languages. Visual Studio .NET also offers editing tools for manipulating several types of files. Visual Studio .NET is a powerful and sophisticated tool for creating business-critical and mission-critical applications

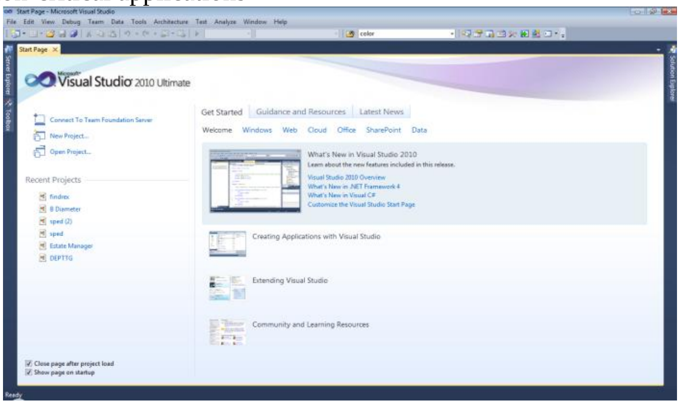

Fig 1:Design environment of the application

The application of the developed software were shown in figure 1-9 and explanation on how each widow performs were written.

Figure 1 shows Microsoft Visual Studio .Net 2010 IDE environment. C# is the ideal language used for the development of the application.

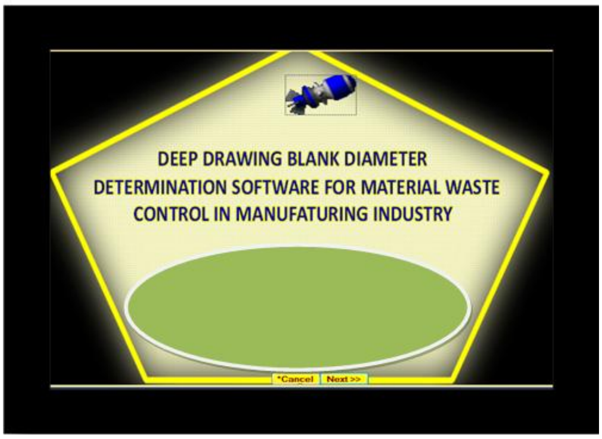

Fig 2: Running Environment of the Application

The first page or form to be launched is been shown in Figure 2 above. Clicking on the "cancel" button will close the entire application, while clicking on the "next" button will take the user of the application to the next form.

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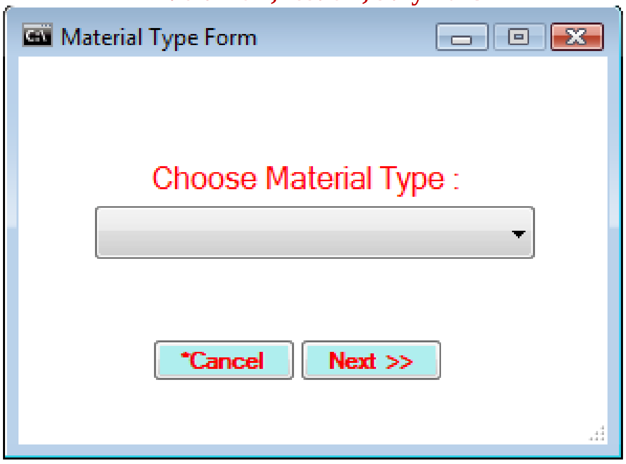

Fig 3: Material Type Form

This form is been shown in Figure 3. Here, the user of the program will asked to choose the material type before moving to the next form.

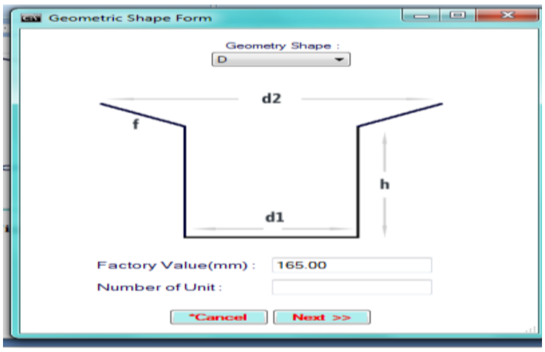

Fig 4: Geometric Shape Form

Figure 4 shows the Factory Value, Number of Unit required and Geometric Shape form. The shape is been represented with letter A to L. User of the application must choose the type of shape he or she want to work with. Clicking on the “next” button on the form shown in Figure 4 will take the user the next form which is called input parameter form.

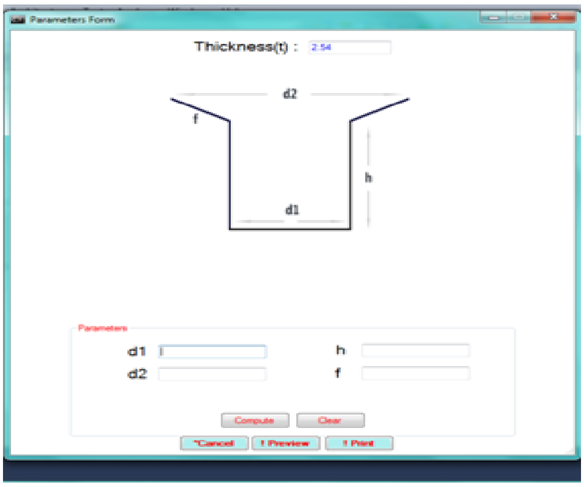

Fig 5 : Input Parameter Form

Here, user will supply the input parameter and then click on “compute” button to compute the blank diameter,area of the blank used and waste material based on the choosen shape. and the computed results will be displaced as shown in figure 6.

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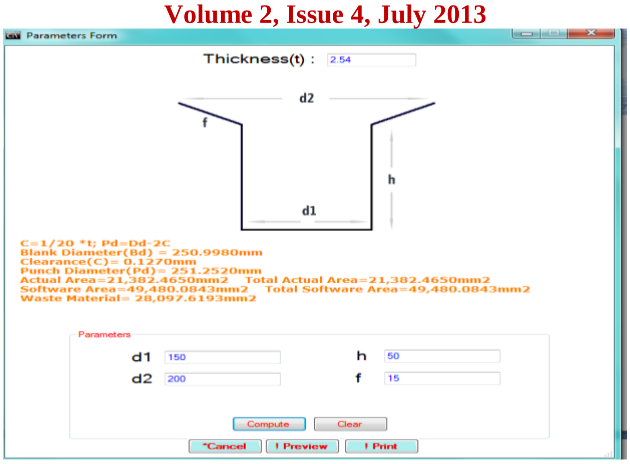

Fig 6: Compute Result

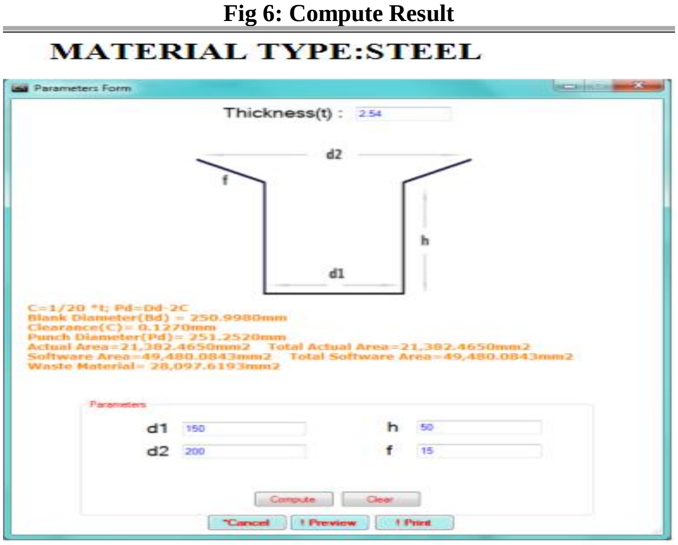

Fig 7: Preview Result

Preview button is been used here to preview the output of the result, while the print button can be used to print the output result

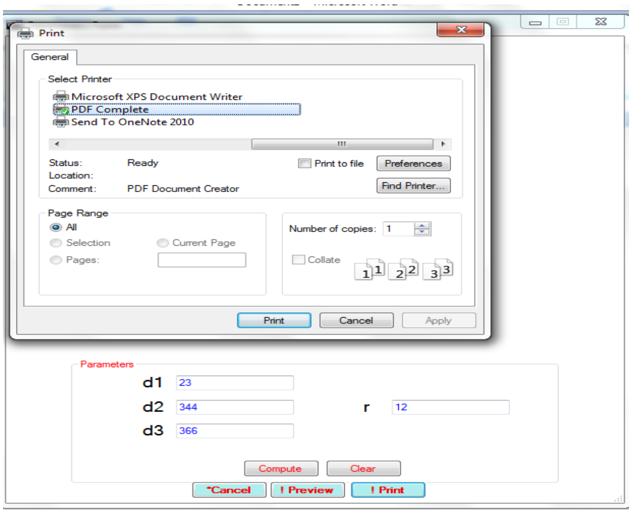

Fig 8: Print Option Form

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Hardware Requirement

In order to implement the computer-aided system, the following minimum hardware requirements are recommended: 512MB RAM , 10 GB HDD, UPS UNIT, SVGA OR GVA monitor (17 inches), an enhanced keyboard ,any types of printer; dot matrix printer (impact, ink-jet printer) or laser printer. These configuration are just at minimum, the higher the configuration the better and faster the solution.

Independent steel Industry limited is the one used here as case study. The Industry is located at plot 5, Block 8, Akilo Road, Ogba, Lagos. This factory faced with the problem of material waste during deep drawing for symmetrical shells products.

The software developed model was used in this industry and the results is shown in Table 2

VI. CASE STUDY

Table 2: The Comparison of Empirical Values with Optimal Values Generated by the Developed Model

S/N	Types (a)	Initial Diameter mm) (b)	Initial Area ( ) $\pi B_d^2/4$ =(c) X_2 ‘m	Software Model Diameter(mm) (d)	Software Model Area( ) $\pi B_d^2/4$ =(e)	Waste Material( ) F = c - e
1	A	225: 00	39,760.782	173.2051	23,561.937	16,198.846
2	B	175: 00	24,052.819	141.4214	15,707.973	8,344.846
3	C	200: 00	31,415.927	158.1139	19,634.958	11,780.969
4	D	165: 00	21,382.465	132.2876	13,744.475	7,637.980
5	E	170: 00	22,698.007	137.8405	14,922.568	7,775.439
6	F	200: 00	31,415.927	160.9348	20,341.820	11,074.107
7	G	190: 00	28,352.874	141.4000	15,703.220	12,649.654
8	H	170: 00	22,698.007	125.0000	12,271.846	10,426.161
9	I	185: 00	22,957.189	147.0544	16,984.233	5,972.956
10	J	105: 00	8,659.015	89.4292	6,281.286	2,377.729
11	K	185: 00	26,880.252	146.3672	16,825.865	10,054.387
12	L	172: 00	23,235.219	138.2896	15,019.965	8,215.255
TOTA L		**303,508.483mm^2**	**191,000.146 mm^2**	**112508.339 mm^2**		

The total initial material used was 303508.483 mm^2, while the optimum material utilization generated from the developed model is191000.146mm^2.The difference between the initial total area used and optimum area generated by the model used is 112508.339mm^2.This shows that the models used in these computations improved material utilization by (112508.339 /303508.483) × 100 = 37%

This model was used to control material utilization for four (4) clients that made requisition for types; A, D, G and J respectively. Number of units for each type for manufacturing is (A, 5000), (D, 5500)' (G, 6500) and (J, 4500).Total material utilized is as shown in table 4.

Table 3: Computation Table for the Clients' Request

S/N	Type	Initial Area (mm^2) (a)	Number of Unit Required (b)	Total Initial Material Used (mm^2) c = a x b	Models Values (mm^2) d	Optimum Models Value (mm^2) e = b x d	Waste Material of Actual Used (mm^2) d = c-e
1	A	39,760,782	5000	198,803,391.0	23,561.937	117,809,685	80,993,703
2	D	21,382,465	5500	117,603,557.5	13,744.475	755,946,12.5	42,008,945
3	G	28,352,874	6500	184,293,681.0	15,703.220	102,070,930	82,222,751
4	J	8,659.015	4500	389,655,67.5	6,281.286	28,2657,87	10,699,780.5
TOTAL				**539,666,197** mm^2 = = (539.66 m^2)		**323,741,014.5**mm^2 = (323.74 m^2)	**215,925,179.5**mm^2=(215.93m^2)

Concerning these jobs from four clients, total material saved by implementing these models is as shown in Table 3,this is 215,925,179.5mm^2=215.93m^2.This is 40% of the actual material expected to be used if former actual values were used. The cost of 1m^{2}is ₦2,350:00 this will bring to the company saving of (₦215.93×2,350) = ₦507,435:50. This is equivalent to US$3,352.80 on these four jobs used as case study base on the current exchange rate as at the time of this research.

VII. RESULT AND DISCUSSION

This study has identified some type of shapes available in deep drawing manufacturing process, as well as their appropriate mathematical models for determining their blank diameters. These models when used on symmetrical shells helps to determines not only the blank diameter but also the area of material used for the product and waste preserved. And calculate looses to the industries. When these models were tested in all the types, considering all the empirical values with the optimal values. There is an improvement of material utilization of 37%. When these models were tested on four clients. The total material waste that was controlled is 215.93m^{2}saving an amount of ₦507,435:50 of which is US$3,352.80 equivalent base on exchange rate as at the time this research was conducted.

VIII. CONCLUSION AND RECOMMENDATION

Conclusion

The objective s of this research has been achieved. The geometric parameters identified are: diameter (d), height (h), slanting height (s), flange (f) and radius of the shell (r). Thus, appropriate mathematical model required for type (A, B, C, D, E …….L) were well selected as shown on page (7) with the required shapes. Yielding strength of the materials for the deep drawing, also the corresponding software algorithm for the software was developed as well as the software for implementing the models selected which finally determine the optimum blank diameter and material waste control through calculation of actual blank area to be used.

Recommendations

Further research work on this model and its software, the following area can be carried out in modification of the model software should also include the force required for the plate to be drawn for each type considering the materials to be used; this resulting software will find its application in small, medium and large scale industries as well as institutions and research centers that deep drawing manufacturing process affects their products. It will be used as teaching aid to impact knowledge on deep drawing design computations to learners.

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