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Experimental Study and Analysis of the Influence of Drawbead against Restriction and Deep Drawing Force of Rectangular Cup-Cans with Tin Plate Material

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Abstract. Drawbead are often used to control the flow of material, stress and deep drawing force in the flange area. This paper discussed the drawbead (fully, not fully and without drawbead) that combined with variations in the blank holder force against restriction of material flow and drawbead restriction force of deep drawing with palm oil lubrication. In this paper, analytical and experiments are used to predict the drawbead restraining and deep drawing force. The tin steel sheet with a thickness of 0.2 mm is used as speciment. The results obtained, that the application fully drawbead be very effective in controlling the flow of materials in the flange, as compared to not fully and without drawbead. In the beginning of the process (punch stroke < 4 mm), the magnitude of restraining force and deep drawing force can be increased. And, the magnitude of Radial Stress increases, conversely the magnitude of tangential stress decreased. This can prevent the occurrence optimum blank holder force is recommended in range 4394-8788 N. Comparisons of results between the analysis and experiments show the phenomenon is similar.

Introduction

Drawbead is one of component in the die set, which is used to control the flow of materials during the process of drawing takes place by controlling the drawbead restraining force (DBRF) [1-5]. And the value DBRF depend on shape and position of the draw-bead. Actual die design depends mostly on the trial-and-error method without calculating the optimum DBRF. And the value DBRF dependent on shape and position of the draw-bead. The value of DBRF obtained from each design case, can be approximated by formula DBRF (N/mm) = *26.93-+ h-24.87 Rs 15.98 + t-boned 159.09 v3.14 hRs + 23.75 ht-29.89 Rs t-2.95 h2 = 4.18 Rs2 85.95 + t2*. where the dimensions are as follows: height of drawbead (h) 2-6 mm, the shoulder radius (Rs) = 3-5 mm and the thickness of the sheet material (t) = 0.6-1.2 mm. Mathematical Formula above are still relevant, but that the equation is not considered the blank holder force and lubrication, so not suitable to solve the influence of the blank holder force and lubrication effect. Drawbead inklinasi on die, with an angle quite effective in restraining the flow of material with a blank holder force that is not high [2]. This application is suitable for die with large die radius. Besides the form of drawbead, the position of drawbead intensely affecting of the drag the flow of material in the process of deep drawing. Research conducted by mujic 4 inform, that the position drawbead is a good enough with the effect of thinning a small, is in the position of 63 up to 65 mm from a central point die (where the diameter of die = 102 mm). This paper will study the combined effect drawbead and blank holder force to produce products rectangular cup with application fully drawbead and not-fully drawbead, against DBRF and deep drawing force. This research using methode in an analytical manner and experiment.

Deep drawing

The theory that is used for this analysis is a method using the balance of forces in all parts of the material is formed. On the process of deep drawing of rectangular products, the creation of the product is divided into two parts, namely: formation in the corner and the straight sides of the

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product. In order to obtain a mathematical formula of deep drawing force, based on model blank and flow stress of material as shown in Figure 1.

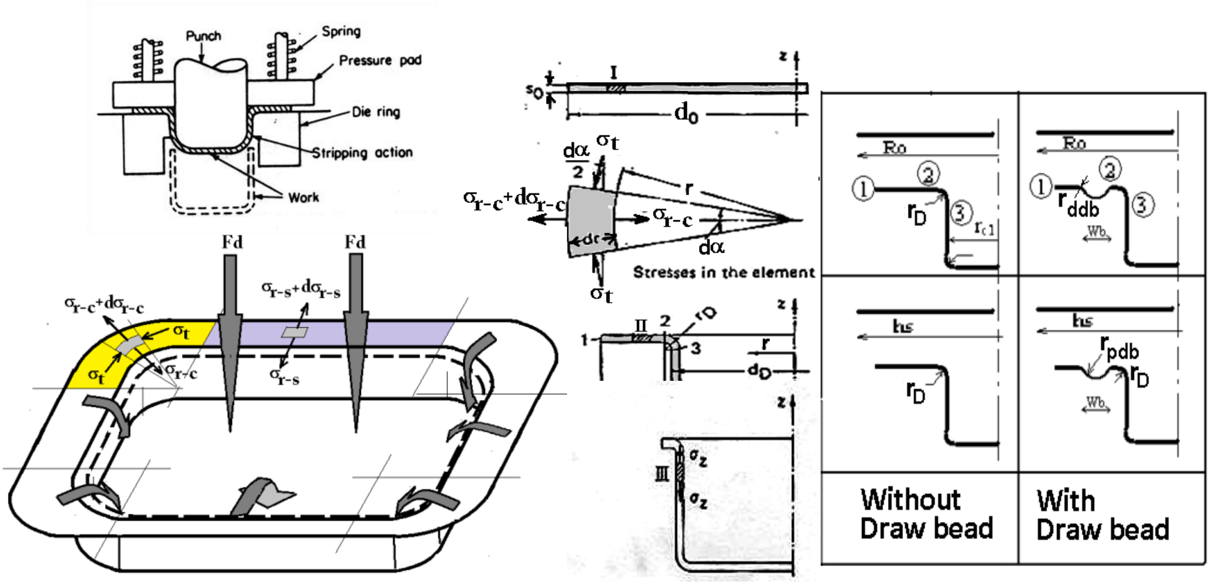


Figure 1. A. Flow of Material, B. Stress of state, C. Point of material flow

Neglecting friction, the equilibrium condition force in the radial direction can be writen as (no application of drawbead)

$$(\sigma_{r\text{-}c}+d\sigma_{r\text{-}c})\,(r+dr)\,d\alpha\, s_o - \sigma_{r\text{-}c}\, r\, d\alpha\, s_o + 2\,[\sigma_t]\, s_o\, dr \sin(d\alpha/2) = 0 \qquad (1)$$

(see Figure 1A, B and 1 C)

where: $\sigma_{r\text{-}c}$ = radial stress, r = radius blank corner, $d\alpha$ = a small segment angle in corner area, s_o = thickness of sheet metal, σ_t = tangential stress dr = a small segment of the radius. Since the material used is sheet material, the approach used is based upon the characteristics of the material destroyed on the conditions of plain strain according to Von Misses. The total radial stress at the corner and straight sides of rectangular products are as follows.

Without drawbead) [6]. The radial stress in radial direction is follow:

$$\sigma_{r\text{-}c} = e^{\mu\alpha}\,\{1.15\sigma_I \ln(\frac{d_1}{d_m})+(\frac{2\,(F_{BhC}}{\pi d_1 s_o}\,)\}+\frac{\sigma_{II} s_o}{2r_D} \qquad (2)$$

and

$$\sigma_{r\text{-}S} = e^{\mu\,\pi/2}\,\{\frac{2\mu F_{BhS}}{(l_1+l_2)s_o}\,\}+\frac{\sigma_b s_o}{2r_D} \qquad (3)$$

where F_{BhC} = blank holder-corner side, σ_I = mean flow stress in the flange (point 1-2, R and d_1 respectively are the radius flange (corner blank size) or a diameter from point 1-2, dm= average diameter $=d_1+s_0$, μ = coefficient of friction, s_o = thickess of sheet metal (mm), r_D =die radius, α = bending angle. σ_{II} = mean flow stress after material subjected to bending on the die radius, $\sigma_I = [K/(\varepsilon_2-\varepsilon_1)][\varepsilon_2^{n+1}-\ \varepsilon_1^{n+1}/(n+1)]$ and $\sigma_{II} = [0{,}5\ K][\varepsilon_2^{n}+\ \varepsilon_3^{n}]$, $\varepsilon_1=\varepsilon_{1c}$ = strain due to the change in diameter of the start to the point 1, and $\varepsilon_2=\varepsilon_{2c}$ = strain from point 1 to point 2 in the corner.

Fully drawbead [7]. If apply fully drawbead, an equation of radial stress is follow

$$\sigma_{r\text{-}C\text{-}FDB}=e^{\mu\,\pi/2}\{e^{\mu\,\alpha}1.15\sigma_I \ln(\frac{d_1}{d_m})+\frac{2\,\mu\, F_{BhC}}{\mu d_1 s_o}+\frac{\sigma_I s_o}{2r_{db}}\}+\frac{\sigma_{II} s_o}{2r_D} \qquad (4)$$

$$\sigma_{r\text{-}S\text{-}FDB} = e^{\mu\pi/2}\left\{e^{\mu\alpha}\left(\frac{2\,\mu\,F_{BhS}}{2(l_1+l_2)s_o} + \frac{\sigma_{fdb}\,s_o}{2r_{db}}\right)\right\} + \frac{\sigma_{fdr}\,s_o}{2r_D} \tag{5}$$

where F_{BhS} = blank holder force- side of perpendicular, l_1 and l_2 = length and width datum line in flange area. ; F_{BhC}: blank holder force-corner area; σ_{fdr} : bending stress in straight sides = $K(\varepsilon_b)^n$

Not fully drawbead. For not fully drawbead, radial stress on the corner ($\sigma_{r\text{-}C\text{-}NFDB}$)=$\sigma_{r\text{-}c}$ and straight side radial stress ($\sigma_{r\text{-}S\text{-}NFDB}$)= $\sigma_{r\text{-}S\text{-}FDB}$. Strain in a point 1, the 2nd and 3rd determined based on change the diameter or radius in every those points, for a moment either on the side of a corner and straight sides of a material flow which enters into a die. To get the dimensions of the diameter on each point of the trigonometric calculations are used, by following the rule of constant volume and no depletion of sheet material. Total Deep drawing force (Fd) to produce rectangular cup can be obtain from a summation drawing force on the corner and die straight sides, described as follows:

$$F_d = F_{d\text{-corner die}} + F_{d\text{-straight side die}} = \pi.d_m.s_o\,\{\sigma_{r\text{-}c}\} + 2\,(l_1+l_2)\,s_o\,\{\sigma_{r\text{-}s}\} \tag{6}$$

While the draw-bead restraining force (DBRF) derived from the multiplication between the of deep drawing force (F_d) at each corner and at the straight side of the product with a long transverse which is perpendicular to the direction of flow of the material, as with the equation:

$$DBRF_{Corner\ die} = F_{d\text{-corner die}} / \pi\,d1 \quad \text{dan} \quad DBRF_{Straight\ Side\ Die} = F_{d\text{-straight side die}} / \pi\,d1 \tag{7}$$

Cracking failure criterion equation approach to follow is as follows [7]:

$$F_{crack} \geq F_d\ ;\ F_{crack} = \pi\,.\,d_m\,.\,s_o\,.\,UTS\ \ a_c \tag{8}$$

where: F_{crack} = cracking material force ; F_d = deep drawing force, UTS = Ultimate Tensile Strength of material ; and a_c = multiplier factor.

Experiment Set Up

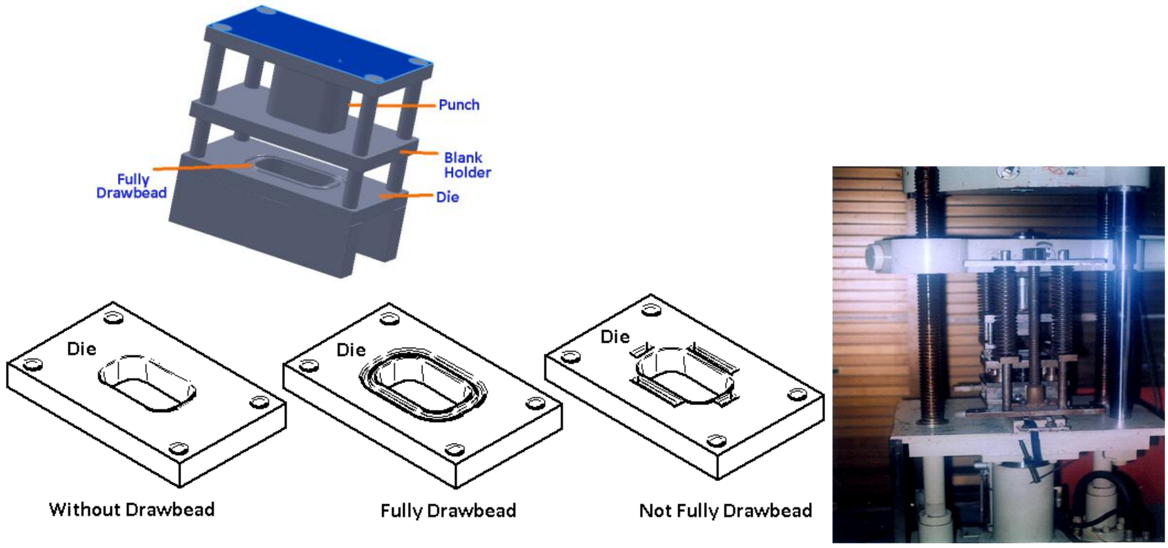
The material used in this study is a tin steel sheet T4 CA-B, where their characteristics can be seen in table 1. While the dimensions of punch die used as indicated by table 2 and Figure 2.

Tabel 1. Characteristics of tin Steel T4 CA-B

No	Karakteristik	Value
1	Ultimate Tensile Strenght; N/mm^2	391
2	Yield Stress (σ_o atau σ_y); N/mm^2	309
3	Strain Hardening Exponensial (n)	0.12
4	Strength coefficient (K); N/mm^2	573
5	Elongation; %	15%
6	r_{value}	0,43

Tabel 2. The main dimensions of punch die

No	Uraian	Dimensi
1	Die lenght	100 mm
2	Die width	60 mm
3	Radius of Die corner	20 mm
4	Punch length	99,3 mm
5	Punch width	59,36 mm
6	Die Clearance	0,35 mm
7	Radius of Punch corner	19,65 mm
8	Die Radius	1 mm
9	Punch Radius	2 mm
10	Spring contatats	37 N/mm
11	Drawbead position	22.5 mm
12	Palm Oil lubrication (μ) [9,6]	0.12



A. B

Figure 2. A. Punch and Die Set (without, fully dan not fully drawbead), B. Susunan Punch and Die on press machine.

Dimensions of blank size are set to follow the rule of constant volume, where the volume of blank size = the volume of the finished product = instantaneous volume of each condition punch stokes. Beside that, in the process of drawing is assumed to be not the case thickness depletion [6.7]. Detailed dimensions of blank size can be seen in table 3, while its shape can be seen in Figure 3.

Tabel 3. Dimensions of Blank Size [7]

No	Description	l_1 (mm)	l_2 (mm)	H or h (mm)	S (hs) (mm)	r_o (Do) (mm)	Remark
1	Specimen	± 60	± 20	± 10	± 33	± 29	l_1 and l_2 : length and width - straight side., H: depth of rectangular cup, hs = distance of the straight edge blank side of neutral axis.

Result and discussion

Results of calculation equation DBRF (7) with a blank holder force variation on the conditions of the process of formation of drawbead fully, without drawbead and not fully knowable drawbead as in table 4.

Table 4. Draw-bead restraining force (DBRF) and Restraining force (RF) maximum

Fbh dan Punch Stroke	μ	Fully Drawbead				Without Drawbead				Not Fully Drawbead			
		DBRF Corner Die	DBRF Straight Side Die	DBRF Avg.	DBRF Reff. Journal [1]	RF Corner Die	RF Straight Side Die	RF Avg.	RF Reff. Journal [1]	DBRF Corner Die	DBRF Straight Side Die	DBRF Avg.	DBRF Reff. Journal [1]
(N)	-	N/mm	N/mm	N/mm	N/mm	N/mm	N/mm	N/mm	N/mm	N/mm	N/mm	N/mm	N/mm
4394, Punch Stroke=4.41 mm	0.12	40	16	28	44.5	31	10	21	N.a	31	16	24	26.4
8788 Punch Stroke=4.41 mm	0.12	42	18	30	44.5	33	12	22	N.a	33	18	26	26.4

As shown in table 4, fully drawbead will get the most high value DBRF, compared to the drawing process by not fully and without drawbead. An increase in blank holder force will cause the enhancement of value DBRF. It is caused by a flow of material is obstructed during pass drawbead, therefore the deep drawing force will be increase. Figure 3 shows that based on the deep drawing experiment, the magnitude of deep drawing force varies with the blank holder force in each the punch stroke.

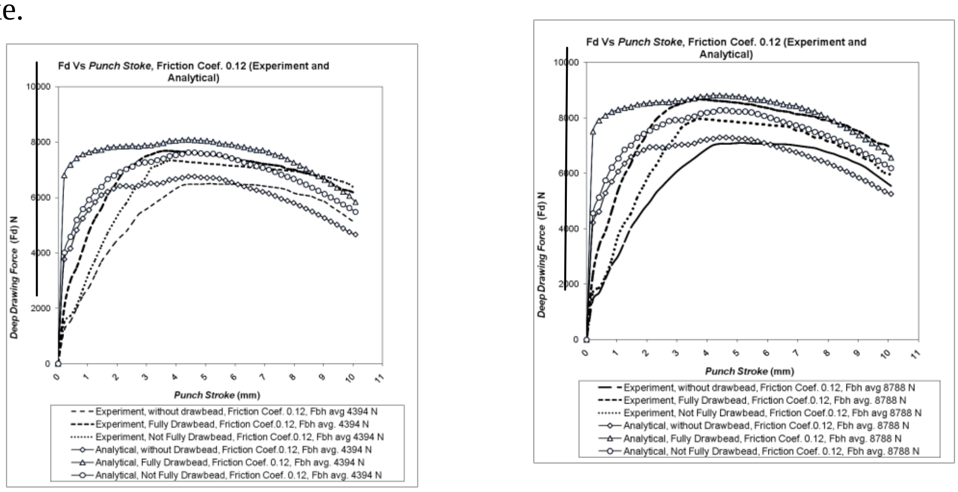


Figure 3. Deep Drawing force Vs punch stroke, using die set-without drawbead, fully drawbead, not fully drawbead (straight side only), with lubrication (palm oil), Fbh (Pbh) = 4394 - 8788 N.

Calculation analysis and experiment gave the similar phenomena, although its value is slightly different. With lubrication on the surface of the die without drawbead, restraining and deep drawing force will be dropped, compared to dies with the fully drawbead. These caused by the value of radial stress is very low, other side these effect to increase value of tangential stress.

A. Without Drawbead B. Not Fully Drawbead C. Fully Drawbead

Figure 4. Products experiment

On the process of formation with lubrication, the blank holder force is raised from 4394-8788 N, resulting in a distribution of deep drawing force will increases. Symptoms may wrinkle from the phenomenon of flow radial stress, and deep drawing force on the punch strokes under 4 mm. In the early punch stroke by using fully drawbead, the magnitude of radial stress increase, and conversely the magnitude of tangential stress decrease. It is effective to avoid wrinkle and cracking. This leads to the pull of material in the flange rise so that the probable occurrence of wringkle can be avoided. It shows that the application fully drawbead produce products with cracking and wringkle minimal. Through the experiment with the blank holder force parameter between 4394 N-8788 N, the application fully drawbead obtain product without defects with deep drawing limit maximum 13430 N, as shown in Figure 4.

Summary

Application of drawbead in combination with fully blank holder force is capable in providing maximum resistance (DBRF maximum) in the early punch stroke, compared with non fully drawbead and without drawbead. On punch stroke under 4 mm with fully drawbead, obtain a deep

drawing force is relatively higher than the others, that is quite effective to avoid the occurrence of wrinkle and cracking at the beginning of the process of drawing in the flange. Application of fully drawbead with blank holder force between 4394 N up to 8788 N as well as lubrication palm oil is recommended for this process.

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