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Seasoning Funnels Die Design for Autopacking Machine Distributors Using SUS 316 Material

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Abstract

This article discussed the design of dies and punched using SUS 316 material for seasoning funnel (SF) applications in the food industry. Cracks in the welding zone in the seasoning funnel (SF) result in leakage of seasonings and result in product mass, which is one of the main parameters in the food industry and a minimum. The damage location on the SF is identical, on the sides of the SF around the bolt holes. The movement of the spice powder, which rotates at high speed, produces a centrifugal force and is then transferred through the SF. The metal structure is becoming increasingly coarser in the area adjacent to the weld melting line. An additional punch with a knocking arm delivers to the SF to expedite the transfer. The knocking arm caused the SF fracture on the SF. SUS 316 sheet metal material for SF without welding is thought to reduce weld damage and speed up the procurement process. The input design for attempting to make dies has been correctly selected as SUS 316 material thickness of 1.0 mm. The two main processes required to form SF from sheet metal were blanking and bending. The SKD-11 material was selected carefully for the main components of the dies and punch. Supporting components such as shank, shaft, top plate, and bottom plate are determined using St 60 material. St 37 material determines the stripper, punch holder, and stopper components. Based on theoretical calculations, the blanking force should be about 225.5 kN. To minimize the burr in the blanking process, dies and punch allowances of 0.1 mm were chosen. The minimum required bending force calculation was 39 kN. A material factor springback value of 0.98 was selected correctly to achieve the desired bending angle. The simultaneous blanking and bending processes necessitated using a 72.96-tonne power press machine.

Keywords:
Dies, damage of the funnel, sheet metal

1 Introduction

Cracks in the welding zone of the seasoning funnel (SF) cause seasoning leakage and result in product mass, which is one of major parameters in the food industry and must be kept. SF was producing from SUS 316 food grade material. The initial material of SF provided into two components, namely the body funnel and flange funnel. These two parts are put together through the GTAW welding process or TIG welding. Damage in SF flange often occurs at the location of Heat Affected Zone (HAZ). A HAZ is a part of the base metal located adjacent to the weld metal that undergoes a thermal cycle of heating and cooling rapidly during the welding process [1]. The HAZ is the most critical area of the welded joint. The metal structure is becoming increasingly coarser in the area adjacent to the weld melting line [2]. A HAZ is a part of the base metal located adjacent to the weld metal that undergoes a thermal cycle of heating and cooling rapidly during the welding process. The HAZ is the most critical area of the welded joint. The metal structure is becoming increasingly coarser in the area adjacent to the weld melting line. This damage in the welding zone in the seasoning funnel (SF) resulted in leakage of seasonings [3]. It affected product mass, one of the main parameters in the food industry and beverage. The damage location on the SF is identical, on the sides of the SF around the bolt holes. The movement of the spice powder, which rotates at high speed, produces a centrifugal force and is then transferred through the SF. An additional punch with a knocking arm is applied to the SF to speed up the transfer process. The knocking arm on the SF continuously resulted in the SF fracture [4].

The metal structure is becoming increasingly coarser in the area adjacent to the weld melting line. An additional punch with a knocking arm delivers to the SF to expedite the transfer. The knocking arm caused the SF fracture on the SF. SUS 316 sheet metal material for SF without welding was thought to reduce weld damage and speed up the procurement process. These could be processed by punch and die metal forming processing [5]. Sheet metal forming is a combination of elastic-plastic bending and workpiece strain deformation [6][7].

Punches and Dies are top and bottom cutting knives used for cutting or cutting procedures, forming processes, or formation. One of the critical goals in many manufacturing companies is to fabricate high-precision sheet metal [8]. Sheet metal V-bending is commonly used to create curved portions in the fabrication of various components. Two essential quality indicators are the bending angle and the bending component's dimensions [9].

Some research on the design of dies has been conducted by [10] [11] [12][13]. Syah conducted research in the design of punches and dies to manufacture the mainframe of ITS bicycles using AL 6061 ASTM B 221 = 42.16 mm. The result of the design was to obtain punches and dies designed to withstand the forming force where the maximum yield strength in the punch and die. The lower plate is smaller than the maximum melt strength shown by the S45C material, which is 4.8 x 106 N/m2 with each punch, die, and lower plate value. 3.11 x 106 N/m2, 9.02 x 106 N/m2, and 3.57 x 106 N/m2 are the values. The result showed that the punch, die, and lower plate design can be said to be safe. Punching for the formation of punches includes CNC milling and drilling. Then, quality includes CNC milling, drilling, and tapping to form dies. While forming a lower plate, quality includes CNC milling, drilling, and counterboring. [10].

Soleman and Jumadi investigated the production of gasket cylinder heads TVS N54 made of SUS 304 material with a material thickness of 0.25 mm. Machine power press capacity of 102.23 kN for blanking force 48.61 kN, piercing 36.62 kN N, and stripping 17.01 kN. The compounds of the blanking process and piercing have a clearance size of 0.01 mm. The burry was formed during the blanking and piercing process due to the less-than-ideal clearance chosen and the selection process not correctly considered [11].

Ginting et al. conducted design research and designed press tool aids to increase the productivity of metal furniture SMEs. The product results of this press tool are relatively faster. However, there are uniform size deviations due to the shift in plate laying in the first and second stages. The test results of ten treatments were observed three times against length, width, and height variables. The percentage of deviations was relatively small, namely 0.36 %, 0.48 %, and 1.75 %. These indicated greater precision and efficiency. The required load and force necessitated greater operator power because the product work process was completed in a single stage [12].

Kumbarasari et al. designed and manufactured a combination of wall bracket products for towel bars. The result of this design is the manufacture of wall bracket products on towel bars using the die combination method that is able to shorten the time in the machining process, and each product produced is capable of more than one product, adjusted to the capacity of the stamping machine. Wall bracket products with external dimensions of 33 mm, height of 9 mm, and a hole diameter of 3.5 mm in the product weld as much as 3 pieces of bowl curvature angle of 820 and a product thickness of 2 mm can be produced by using the combination dies workmanship method on the Nagao 110 Ton machine. The die height required to reach the size of the wall bracket in the drawing process is 360.4 mm.[13].

Unlike previous research, this study focused on SF punches and dies production. This study aimed to reverse engineer SF by eliminating the TIG welding process. The existing SF process will be replaced by bending and blanking simultaneously. Design punches and dies were selected for the processing development. The experimental method was chosen to calculate the bending force, the allowance dimension between the punch and the dies, and the required power press machine capacity. SUS 316 material with a thickness of 1.0 mm was chosen for the dies and punch design research.

2 Research Methods

2.1 Material and dimensional

The plate material SUS 316 sheet 1.0 mm thickness was selected in this study. The mechanical properties were listed in Table 1. The dimensions of the SF stretch are as in Fig. 1. The blank design was determined while determining the geometry of the SF. The dimensional accuracy was required to produce a profile according to the dimensions of the SF. The angle of the SF can be used as a reference during the bending process.

Table 1. Mechanical strength of SUS 316

type	Tensile Strength		Yield strength (to 0.2% offset)		Elongation in 2" (50.80 mm)	Hardness (Rockwell)
	ksi	MPa	ksi	MPa		
316	84	579	42	290	50	B79

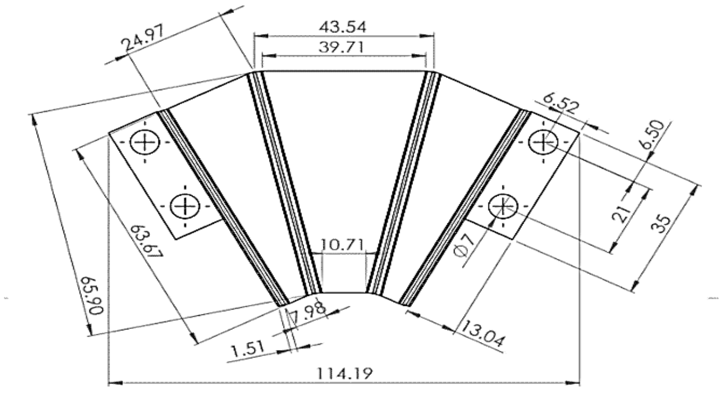


Fig. 1. SF stretch dimensions

The three-dimensional SF modelling was ready for analysis and study using Cad-cam software. The geometry was altered by the shape produced and presented in fig. 2. The bevel protractor was selected to determine the angle according to the design. The angular dimension of SF was listed in Table 2. The analysis determined the specifications of the press tool, which included press tool material, linear dimensions, angular dimensions, cutting forces, and bending work. The determination of the dies and punch allowances in the blanking and bending processes is determined by the value of the spring back factor material used for the SF after the blanking and bending processes. The SF geometry in the analysis refers to the SF geometry on the available machines.

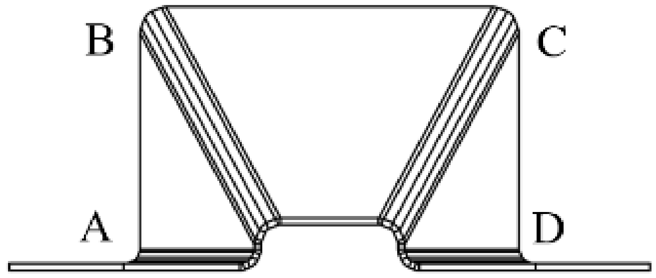


Fig. 2. SF bending geometry

Table 2 Angular and liner dimension of SF

No	Post	Linear [mm]	Angular (o)
1	A	63,67	90°±3°
2	B	65,90	90°±3°
3	C	65,90	90°±3°
4	D	63,67	90°±3°

2.2 Determination of blanking and bending

The calculation was concerned with dimensions relating to the force or pressure that the metal plate can withstand; the most common types of loading are tensile strength, tensile shear strength, compression, torsion, or a combination of them [14]. The top plate and bottom plate will receive a compressive load from the force source. Therefore, the equipment used must be able to withstand the given force [15].

The top and bottom plates must be able to withstand the given pressure because they will be subjected to a compressive force [16]. To ensure that the material can withstand the load from the blanking and bending forces, the allowable strain must be greater than the actual strain. Eq.s 1 and 2 were used to calculate the allowable strain and actual strain [8].

Allowable strain

$$\sigma_{ti} = \frac{\sigma_t}{v} \quad (1)$$

Actual strain

$$\sigma_t = \frac{F}{A} \quad (2)$$

The punch is used to press the workpiece against the dies when forming. The formula 4 can be used to calculate the maximum length of the punch *(L_p)* that will not break when used [14].

$$L_p = \sqrt{\frac{\pi^2 \times E \times I}{F_s}} \quad (3)$$

Where I is the moment of inertia (mm4), Fs is the blanking force (N), and E is the modulus of elasticity of the material (N/mm2).

The clamping force charged on each spring is the same, then the total load set on the spring in the divide corresponds to the number of springs used. Stripping pressure is the force needed to grip the material during the blanking process, and the allowable clamping force is 3%–8% [14]. The minimum force, F_m obtained is based on the total force acting in the cutting process, expressed by eq. 4.

$$F_m = 4\%.F_s \quad (4)$$

The clearance resulting from the sheet metal cutting process is expressed as the side distance between the punch and die in eq. 5 [8].

$$c = \frac{k.s\sqrt{0.7UTS}}{2} \quad (5)$$

The eq. 6 is used to calculate the minimum die thickness H [14].

$$H = (10 + 5t + 0{,}7(\sqrt{a + b}))c \tag{6}$$

Where t is the material thickness (mm); a and b are workpiece dimensions (mm); *c* is constants that are provided in Table 3. A and B are the dimensions of the dies (mm) and expressed by eq. 7 and 8.

Table 3 Material Constant Value

UTS (MPa)	117	245	392	784
Constants, c	0,6	0,8	1,0	1,3

$$A = a + 2e \text{ and } B = b + 2e \tag{7}$$

$$e = \left(\frac{10}{12}\right) + 0.8\text{H} \tag{8}$$

The blanking force (F_s) was calculated using the fracture limit of the material, which can be observed in eq. 9.

$$F_s = l_s S k_s \tag{9}$$

Where ls is the circumference of the workpiece (mm), s is the thickness of the material (mm), and ks is the shear stress material (N/mm2).

The amount of blanking work (*Ws*) determines the size of the press machine capacity used. As a result, the pressing machine's force must be greater than the style of the blanking process. The blanking work process can be calculated using Eq. 10.

$$W_s = \frac{2}{3} . F_s . s \tag{10}$$

Where *S* is material thickness of the workpiece (mm).

The bending moment (Mb) can be expressed as a calculation of the bending moment in the elastic and plastic zones on the same axis. The bending moment can be calculated by using eq. 11 [17].

$$M_b = n\,(UTS)\,\frac{b.s^2}{4} \tag{11}$$

Where, *n* is the coefficient of hardening material (1,6–1,8), *b* is the bending length (mm).

Bending force (F_b) during processing of bending can be calculated by using eq. 12.

$$F_b = \frac{K.L_b.UTM.S^2}{W} \tag{12}$$

Where K is the die correction factor (1.33), Lb is the length of the workpiece (mm), W is the die opening width (mm).

Excessive stretching of the outer radius during the bending process can cause thinning of the wall thickness and excessive shrinkage of the inner radius. The initial length (L_n) required for the bending operation can be calculated using eq. 13 [14].

$$L_n = \frac{\theta\pi}{180}(\mathcal{E}s + r) \tag{13}$$

Where, θ is Bending angle(^{o}), Ɛ is the cconstant value as listed in Table 4, and r is the internal radius (mm).

Table 4. Constant value of band allowance

R_i/t	0.1	0.2	0.3	0.4	0.5	0.8	1	1.5	2
Ɛ	0.23	0.29	0.32	0.35	0.37	0.4	0.41	0.44	0.45

The minimum bending radius measures how much strain can be accepted. Wrinkles on the inner bending surface may be of concern if they occur prior to fracture on the outer surface. Like most mechanical properties, fracture strain can be obtained from tensile testing [18]. If the strain is at which cracks on the outside appearance, then the minimum bend radius causes this strain. Determining the minimum radius for the material using tensile strengths up to 640 N/m2, as shown Table 5.

Table 5. Minimum bending radius (mm) for angles below 120°

Tensile strength [N/mm2]	Bending Direction	Material thickness (s), mm				
		1,0	> 1 - 1,5	> 1,5 - 2,5	> 2,5 – 3,0	> 3,0 – 4,0
Up to 390	transverse	1,0	1,6	2,5	3,0	5,0
	longitudinal	1,0	1,6	2,5	3,0	6,0
>390 - 490	transverse	1,2	2,0	3,0	4,0	5,0
	longitudinal	1,2	2,0	3,0	4,0	6,0
400 – 640	transverse	1,6	2,5	4,0	5,0	6,0
	longitudinal	1,6	2,5	4,0	5,0	8,0

According to Table 5, SUS 316 has a tensile strength of 579 MPa and a thickness of 1.0 mm. The bending was done longitudinally, resulting in a minimum radius of 1.6 mm. Based on this information, a Ri value of 2.0 mm was regarded as safe because it meets the bending radius requirements [19].

3. Results and Discussion.

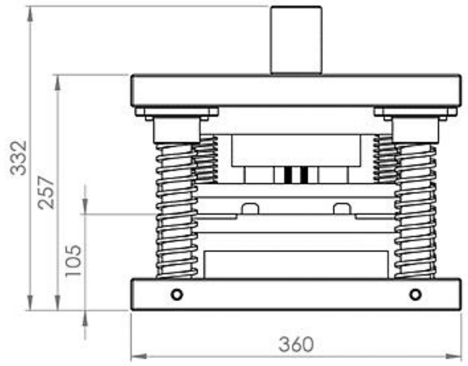
The final dimensions of SF are 62.17 mm long, 74.01 mm wide, and 36.71 mm high. According to the previous analysis and calculations, the material obtained for each press tool component is the shank, top plate, bottom plate, guide bosh using St. 60, stripper, punch holder, stopper using St. 37, and punch and dies using SKD 11. SKD 11 was chosen for die and punch due to its higher mechanical properties than the workpiece material. Wire cut electro-discharge machining (WC-EDM) was used to create SKD 11, then hardened [5]. The hardness of the SKD material after heat treatment was around 55-58 HRC.

Fig. 3 (a) depicts the details of the press tool blanking and (b) bending design. It indicates the dimensions to be created in the dies. The calculation results of the design of blanking and bending SF dies have been listed in Table 6.

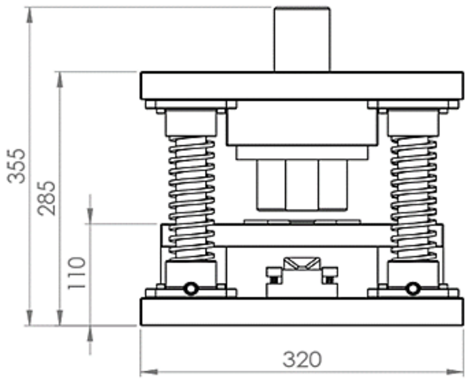
The dies have a minimum die thickness of 32 mm and a maximum punch length of 37.18 mm. The minimum thickness of the dies and the maximum length of the dies are required so that the deflection in the dies can withstand the blanking force (Fs) and bedding force (Fb) that occur during the SF formation process [8]. This condition also followed the die design theory presented by [17] The length of the dies is inversely proportional to the magnitude of the force applied during the material forming process. This condition is described in eq. 3. If the die length exceeds the provisions in eq. 3, there will be excessive die deflection [16]. This condition will affect the quality of the product and the service life of the dies used. The minimum thickness of the dies is directly proportional to the ultimate tensile strength value shown in eq. 8. The higher the ultimate tensile strength value, the thicker the required die thickness [5].

The stripping spring was selected for the FIBRO Din/ISO: 241.14.40.064. The clearance between die and punch during the blanking process has been calculated by eq. 5 and provides a result of about 0.1 mm.

The force that occurs during the blanking process is 225.5 kN, and the force for the bending process is 39 kN, with each press blanking machine having a capacity of 79.1 tons and bending 8.1 tons.



(a)



(b)

Fig. 3. Press tool (a) depicts the details of the press tool blanking and (b) bending design

Table 6 The design calculations of blanking and bending SF dies

Description	Results	Unit
Blanking force	225.5	kN
Stripping pressure	9020	N
Max force of each spring	4510	N
Clearance Punch and Die	0.1	mm
Bending allowance	3.85	mm
U-shape moment	14.74	Nm
Wiping moment	15.26	Nm
U-shape force	11.79	kN
Wiping force	12.2	kN
Capacity of press blanking machine	79.1	ton
Capacity of press bending machine	8.1	ton

4. Conclusions.

This study was successful in creating dies for seasoning funnels (SF), allowing them to replace old SF designs with new models without welding. Some of the research's findings can be explained as follows:

a. Based on the analysis and calculations in this study, the obtained clearance on punch and dies is 0.1 mm to avoid burrs when using sheet metal SUS 316 with a thickness of 1.0 mm. The minimum radius required for the bending process is 2 [mm].
b. According to Table 3, the actual magnitude of the spring back factor is 0.96. The thickness and width of the dies for both the blanking and bending processes must be designed to prevent deflection. The finished product must meet quality standards, and the dies used must have a long service life.

Furthermore, additional research will be conducted by optimizing the die design parameters to obtain the optimum die thickness and width values.

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