THE EFFECT OF FORMING CONDITION ON IRONING FORMABILITY OF CAN BODY STOCK

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ABSTRACT Formability of aluminum can body stock during drawing and ironing process depends upon material properties, tool conditions, lubrications etc. It is well known that these factors closely relate to 'tear off', however, study on tear off has not been reported much ever. In this study, the effect of forming conditions on ironing formability was investigated on can body stock by using bodymaker installed load cell. It was shown that die angle of third ironing ring and operating speed of bodymaker have influence on the variation of can wall thickness which would cause tear off.

Keywords: *aluminum can body, ironing, forming force, die angle, variation of thickness*

1. INTRODUCTION

The canmakers are proceeding with reduction of the manufacturing cost. As the items for cost down, gauge down of metal thickness and improvement of productivity in their line are effective means, therefore, sheet gauge has been getting thinner and manufacturing line speed has been getting faster. Tear off during ironing at the bodymaker is the large issue in commercial D&I canmaking due to reducing productivity. Both items for cost down cause increasing tear off rate. It would be necessary to improve ironing formability from two aspects of materials and forming conditions. In this study, tests of ironing formability were conducted by using bodymaker installed load cell, and relation of forming force during third ironing step, tear off rate, and thickness variations of thinwall were investigated.

2. EXPERIMENTAL

2.1 Material

The material used in this test is AA3004 alloy sheet with H19 temper. The gauge of sheet is 0.30 mm. Chemical composition and mechanical property are shown in Table 1.

Table 1. Chemical composition and mechanical property of material

Chemical Composition (%)					Mechanical property		
Si	Fe	Cu	Mn	Mg	TS(MPa)	YS(MPa)	El.(%)
0.27	0.41	0.24	1.07	1.28	303	284	5.2

2.2 Apparatus and experimental procedure

Pilot line for manufacturing D&I cans consists of cupping press and bodymaker. The line makes it possible to form D&I cans continuously at the rate of 300 cans per minute as maximum speed. Bodymaker produces 350ml cans with 211 diameter from drawing cup. Load cell is installed behind the ram of bodymaker in order to measure the forming force during the punch passing through redrawing and ironing ring. Table 2 shows forming conditions of cupping press and bodymaker, especially ironing ring. Die angle of third ironing ring was prepared 5, 7, 8 and 10 degrees.

Table 2. Forming conditions

Cupping press		bodymaker	
Blank diameter	140mm	Punch diameter	66.045mm
Cup diameter	90mm	3rd ironing reduction	40 – 47.6%
Press speed	70spm	Die angle of 3rd ironing ring	5, 7, 8, 10 degrees
Cup lube	Synthetic emulsion	Operating speed	200 – 300spm
		Coolant	Synthetic emulsion

To investigate the influence of bodymaker speed and die angle on ironing formability, forming force and tear off rate were measured while the pilot line produced approximately 5000 cans on each forming condition. Two maximum forces were evaluated as forming force of third ironing,. As it is shown in Figure 1, one is the maximum force (Pim) in the beginning of third ironing. The other is the second peak of third ironing force (Pir). Pir corresponds to thinwall region of D&I can where tear off often occurs. In addition, thickness distributions of side wall were measured and can wall surfaces were observed.

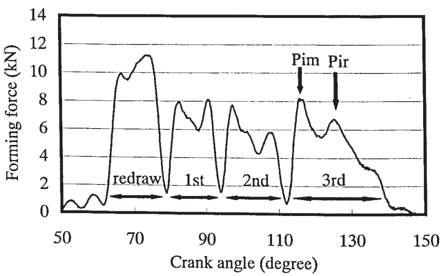


Figure 1. Typical forming force profile

3. RESULTS AND DISCUSSIONS

3.1 The effect of ironing reduction

The test of third ironing with various reduction and two thinwall thickness were conducted at constant speed of bodymaker (250spm). Results of forming force Pir were shown in Figure 2. Forming force increases with higher reduction for both thinwall thickness of 0.110mm and 0.105mm. As shown in Table 3, tear off rate of 0.105mm thickness is higher than that of 0.110mm thickness, although thinner thickness shows lower forming force. The reason is that the side wall tension during ironing process would be increased as thickness is thinner, and tear off is induced due to high tension of side wall[1].

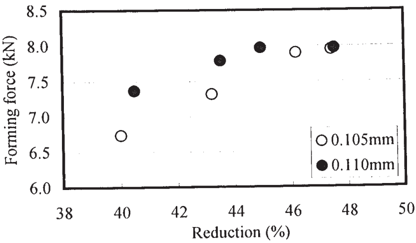


Figure 2. Forming force Pir as a function of third ironing reduction

Table 3. Tear off rate

0.105mm		0.110mm	
Reduction (%)	Tear off rate(%)	Reduction (%)	Tear off rate(%)
40.0	0	40.5	0
43.2	0.02	43.6	0
46.2	0.06	45.0	0.06
47.5	0.40	47.6	0.26

3.2 The effect of die angle

3.2.1 Forming force and tear off rate

Die angle is important factor to dominate the ironing force and tear off rate. Die angle and operating speed of bodymaker were tested. Figure 3 shows the forming force during third ironing as a function of die angle on each bodymaker speed of 200, 250, 300spm. Both Pim and Pir decrease with higher die angle at each speed. The lower angle causes larger contact area between die and material, consequently forming force is increased. The following equation describes theoretical ironing force P calculated from flow model[2].

$$P = \pi d t_1 Y \cdot \frac{1 + \mu_d \cot\alpha}{B} \left\{ 1 - \left(\frac{t_1}{t_0} \right)^B \right\} \qquad (1)$$

$$B = (\mu_p - \mu_d)\cot\alpha$$

where d is punch diameter, Y is yield strength of material, α is die angle, μ_d is friction coefficient between die and material, μ_p is friction coefficient between punch and material, t_0 is thickness before ironing, and t_1 is thickness after ironing. Eqn. (1) indicates that higher die angle would give lower ironing force. As an example of Eqn. (1) as $\mu_p = 0.008$ and $\mu_d = 0.007$ is shown in Figure 3, relationship between measured forming force and die angle would agree with the model for appropriate value of two friction coefficients.

Tear off rate is shown in Table 4. Lower forming force was expected with reduced tear off rate, but as die angle is higher, which is equivalent to lower forming force in this test, tear off occurs more frequently. These results indicate that tear off rate would not depend on ironing force only.

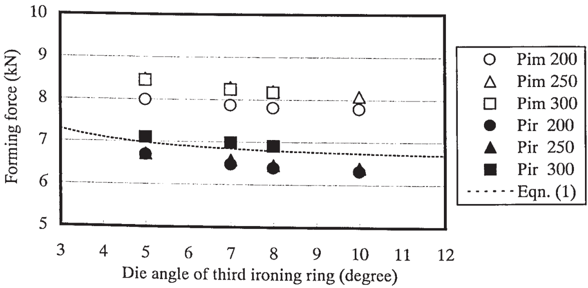


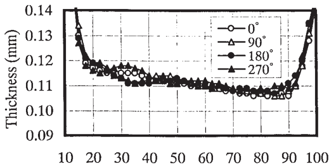
Figure 3. Forming force as a function of die angle of third ironing ring. The dashed line is Eqn. (1) as μ_p=0.008 and μ_d=0.007.

Table 4. Tear off rate (%)

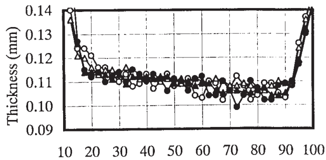
Operating speed (spm)	Die angle of third ironing ring (degree)			
	5	7	8	10
200	0	0	0	0.70
250	0	0	0	2.67
300	0	0.02	0.06	much

3.3.2 Thickness profile of side wall

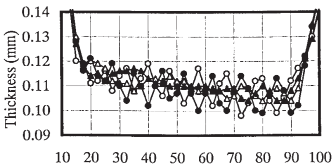
For examination of produced can, thickness profiles of side wall were measured at 4 orientations (0, 90, 180, 270 degrees) to the material rolling direction. Figure 4 (a), (b), (c) show typical examples of thickness profile with each die angle 5, 8 and 10 degrees at operating speed of 250spm. Thickness of thinwall has the periodical variation on some conditions. The thickness profiles show a trend in increasing variation as a function of die angle. As to 10 degrees which has the largest variation in above three die angle, the thickness profiles at operating speed of 200, 300spm were shown in Figure 4 (d), (e). Similarly to die angle, the variation increase with higher speed of bodymaker.



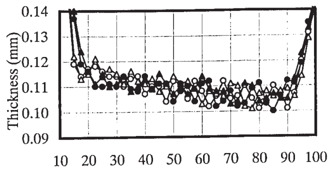
(a) Die angle 5 degrees, Operating speed 250spm



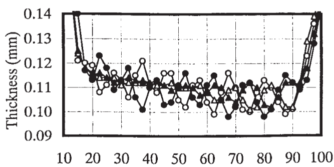
(b) Die angle 8 degrees, Operating speed 250spm



(c) Die angle 10 degrees, Operating speed 250spm



(d) Die angle 10 degrees, Operating speed 200spm



(e) Die angle 10 degrees, Operating speed 300spm

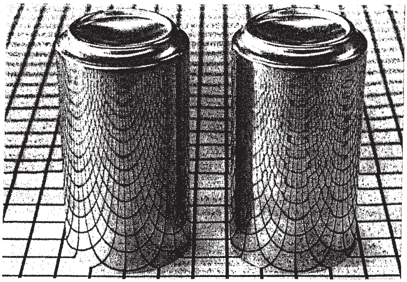
Figure 4. Thickness profiles of thinwall at each conditon

These results show that tear off rate corresponds to thickness variation of thinwall. It can be presumed that stress concentration would occur at thinner part of thinwall caused by variation, consequently tear off would be induced.

As die angle is lower, the force from die to punch is increased and the motion of punch to radial direction is restricted.

3.2.3 Side wall surface

Surface defects of side wall such as bleedthrough are one of the significant issue in the commercial canmaking. It has reported that elevated ironing forming force could cause galling, subsequently less surface quality of side wall[3]. Figure 5 shows appearance of D&I can for die angle of 5 and 10 degrees. Surface defects were not recognized on both samples. The effects of forming force on surface property are little in this test.



die angle 5 degree   die angle 10 degree

Figure 5. Appearance of D&I can

4. CONCLUSIONS

(1) As die angle is higher, forming force during ironing is decreased, the other hand, tear off rate is increased.

(2) Tear off rate corresponds to variation of thinwall thickness rather than forming force.

(3) Lower die angle of third ironing ring can provide decreased variation of thinwall thickness and tear off rate.

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