CHECKING THE QUALITY OF MATERIAL, SEMI-FINISHED AND FINAL PRODUCTS IN BEVERAGE CAN PRODUCTION PROCESS

FELIKS Jerzy[1], KUREK Magdalena[2], LATOS Tomasz[3]

[1]*AGH University of Science and Technology in Cracow, jfeliks@zarz.agh.edu.pl*
[2] *AGH University of Science and Technology in Cracow, magkurek@agh.edu.pl*
[3]*Can-Pack S.A., tlatos@canpack.eu*

Abstract

The paper presents quality control tests performed to monitor aluminum beverage can making process. The analysis comprises tests performed from the moment when the aluminum stripe is about to be fed into the line, to the moment when cans are packed in a palletizer. What is more, a general idea of a new test that is aimed at verification of formability of aluminum stripes, and results from first research based on both high-efficiency and problematic stripes, are also presented. Introducing the new test is believed to help increase efficiency of the line, but also influence stability of final parameters.

Keywords: Aluminum beverage can, quality control, formability of aluminum stripes

1. INTRODUCTION

The idea of using aluminum as material for packing beverages was first introduced into life in 1959 by Coors. Since that moment, aluminum cans ensure a high level of safety to drinks that are stored in them [1]. What is more, such features of them as: lightweight, ease of handling, cost-effectiveness and the exceptional isolation from air, light and moisture, have made them perfect for an innovative, useful and attractive packaging used also for labelling and product branding.

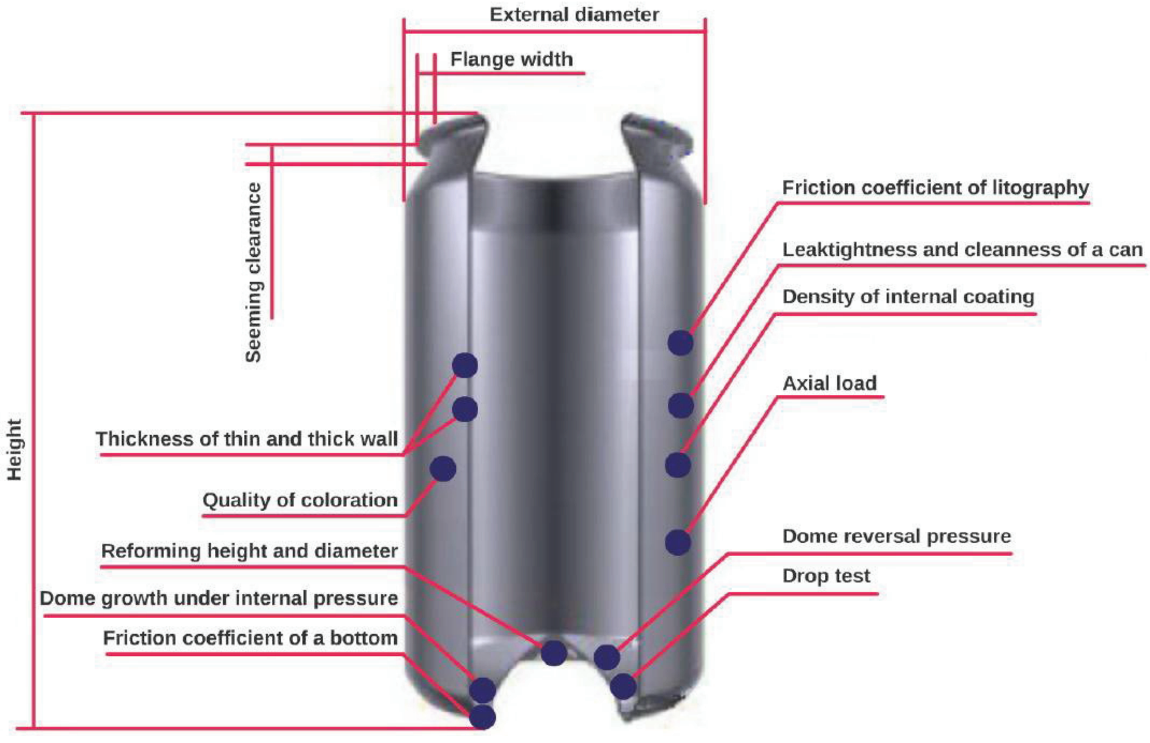

Figure 1 Can body and its most important parameters

Although for many consumers can body does not seem to be a product worth longer consideration, they are a result of a very precise and rapid production process, and meet many requirements. **Figure 1** presents the most important parameters checked during quality control tests performed on final cans.

2. AIM AND SCOPE

The aim of the paper is to present and analyze the complexity of operations and tests involved in quality control of aluminum beverage can production, as well as to introduce the idea of a test for checking formability of aluminum stripes used in can making process, that would become a part of quality assurance system. The paper also presents results of first tests conducted using designed tools.

3. BEVERAGE CAN PRODUCTION PROCESS

Aluminum beverage can production process is well-known as very precise and fast. The speed of the horizontal press shaping a can body is about 350 cans per minute [1]. What is more, the material used in the process is an aluminum stripe of thickness between 0.270 and 0.245 mm while the wall thickness of a final product does not exceed 0.160 mm (for 33 cl cans) [1]. Moreover, the production process consists of several operations in which the quality of a stripe and conditions of shaping tools are crucial.

Aluminum beverage cans are manufactured in a multi-operational production process whose shaping stage is based on drawing and ironing (D&I) [3]. The process starts from loading a stripe on a feeder with lubricator to a vertical press called ‘cupper’, where 2 operations are carried out - cutting blank from an aluminum stripe and drawing a cup from it. The cup, automatically fed into a horizontal press, is centered by the cup locator and held down by the redraw sleeve. Several operations are realized in only one stroke, these are: redrawing, 1st, 2nd and 3rd ironing and dome shaping (in the bottom of a can). Shaping starts from the redraw die sizing the cup to the punch sleeve. Then, the material is forced to flow through the ironing die [4].

After a can body is shaped together with a dome, cans are stripped from the punch by air pressure and held by stripper fingers on the reverse stroke of the ram. Then, cans are trimmed and washed from all dirt, aluminum pulp and lubricants and coolants that are used in presses. After drying operation, cans are externally decorated and lacquered, as well as the internal coating is put on [5]. Later, a neck and a flange are shaped which allows for closing cans with lids after filling them with beverages. **Figure 2** presents the evolution of shape and thickness after each forming operation from a blank to a final shape of a can body. Part a) presents operation carried on the vertical press. Part b) represents shaping a) can in a bodymaker and finally operations held in necker - necking, flanging and reforming, represented in part c).

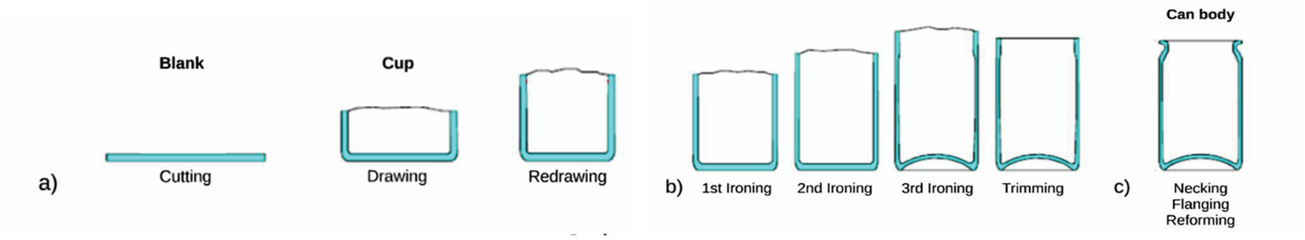

Figure 2 Evolution of shape of a can from a blank to a final product [6]

4. QUALITY OF CANS

In [5], FMEA analysis helped to identify 39 potential failures that may potentially appear in processes realized on Cupper and Bodymaker and 89 of their potential causes. The identified failures are e.g. slight or severe wrinkling in a cup, elliptic shape of a cup or a can, differences in circumferential distribution of thickness in a cup or a can, tearing off a wall or a bottom, “smile mark”, dimensions of the elements that are out of tolerance, and many others. On the other hand in [2] authors present results of an analysis of defects in a can. According to them, the most frequently observed defects were connected to decorating operations, these were: various shades of lithography, roughness of coating lacquer or untightness of internal coating layer and illegible text or bar code. Some mechanical defects also occurred, such as damaged side walls or defects on necking. However, according to [2] the ratio of cans with identified defects to the number of overall monthly production was 0.37, which may suggest that the quality control and process parameters monitoring system work on the highest level.

4.1. Quality control on the production line

The regular control plan starts with a visual control of the stripe used as a body stock. This control is aimed at identification of potential damages during the transport, flooding or worrisome condition of surface or metal stripe itself (scratches, inclusions, streaks, dirt, etc.). The next stage of the quality control plan is visual control of cups and their edges after drawing in the vertical press. The cups are also measured to monitor their thickness and the amount of lubricant.

Visual control carried out after a can body is shaped concerns condition of surface, sidewall and edges. Other measurements check such parameters as thickness of thin and thick wall, depth of a dome and external diameter of a can. Another parameter that has to be monitored after trimming a can body is its height, which is crucial for both customers' requirements, and further production operations, including necking and flanging.

Next sequence of tests is aimed at checking quality of lithography and internal, external and bottom coating. Then certain number of samples is also taken from each board to check the application and distribution of ground lacquer. The same parameters are monitored for lithography and external coating.

The final shape of a can body is obtained after a can leaves a machine called necker. In fact, the machine realizes 3 operations, these are: necking, flanging and reforming. As a result, this moment of production is a start point for final dimensions control. Parameters controlled at this stage are: height of final can, flange width, internal diameter of necking, reforming parameters (diameter and height). The parameters influence final properties of cans, like reforming dimensions, and determine proper proceeding of filling cans at customers' production lines, e.g. width of a flange determines if there are problems with closing a can with a lid. As it was mentioned above, due to its significance, also tightness of internal coating is controlled at this point.

Before cans are transported to a palletizer, all of them are suspected to optical control made by a video tester that scans their interior. It is the last point where any defects, like: untightens of a wall, dirty internal sidewall, etc. may be detected and isolated from flawless products.

During packing operation, as also during all previous operation, it is important to visually check certain number of cans defined in sampling plan of regular quality control. During this operation, the parameters of packing should also be checked including tension of tapes and condition of materials used. It is also a moment when quality control department samples certain number of final cans to check their final condition of coating, appearance, quality of decoration and, especially, mechanical parameters, these are: axial load, dome growth, dome reversal pressure and, required by some customers, drop test. Required values of these parameters are independently defined by individual customers and controlled on certain number of samples taken from each bodymaker.

5. QUALITY CONTROL OF ALUMINUM STRIPES AIMED AT CHECKING THEIR FORMABILITY

As it was discussed above, quality control is conducted throughout the whole can making process involving over 40 tests aimed at monitoring parameters that are important for stability of both the process and quality performance of final cans. However, it is striking that the quality control of a body stock is only limited to visual control, while undoubtedly properties of material influence both final parameters of cans but also efficiency of the process itself. As it was mentioned in [4, 7], the performance of the line is dependent on condition of tools, lubrication condition but also properties of the material. It is known, that all coils of aluminum stripes that are delivered to can producers are attached with a certificate from a supplier which contains values of mechanical parameters of the material, its chemical composition and basic information about the product. Quality control of a coil before it is fed to cupper is mainly aimed at visual identification of any traces of flooding, damage of material that might be caused by improper transportation or at control of the surface.

However, can producers struggle with incidental increase in jams on presses, especially bodymakers, which is believed to be bound up with material parameters. What is more, basic mechanical properties included in a certificate do not always come up with the answer to the problem. This may be explained by changes in the material that take place during shaping in a multi-step process. Since the jams are mainly concentrated in bodymakers, mechanical properties of the material should not be directly correlated with the phenomenon, as the input material of every step of the subsequent operation is a material strengthened and changed by previous forming operations. Thus, it is important to introduce a test that will be a part of quality control plan and which will be able to check formability of aluminum sheets in all operations included in can making process. The idea is presented in **Figure 3**.

The test is a single-stroke test that involves such metal forming operations as: drawing, redrawing and ironing. What is more, the fragment of a sample that will be subjected to ironing is also subjected to drawing and redrawing beforehand. **Figure 3** presents 3 stages of the test that are realized in a single stroke, these are: a blank, drawn cup and the final drawpiece with a fragment after subjection to redrawing and ironing (fragment with a change in thickness). The idea of the test is to deliver information about an aluminum stripe on the basis of its performance during the test expressed by the maximal height of internal part which is drawn and ironed in the bottom (h). This means that the test is conducted until a sample is broken.

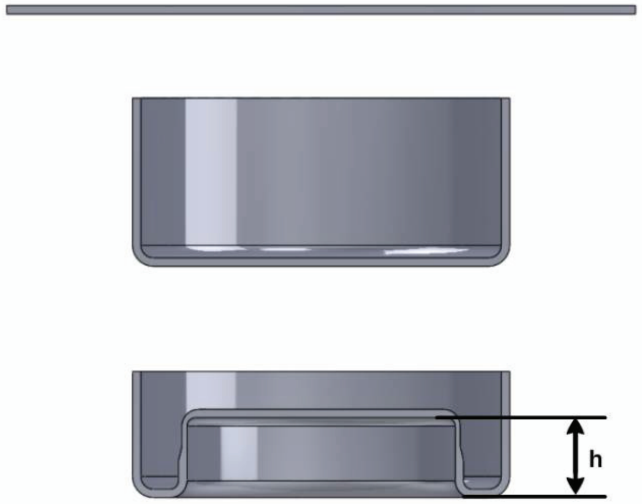

Figure 3 The idea of a quality control test of formability of aluminum stripe

The aim of the experiment was to determine the minimal height (*h*) that may be obtained for materials whose efficiency on the line was high and compare them to results obtained from stripes that were withdrawn from a production line due to increased number of jams. As a result, 16 different aluminum stripes from 3 producers (P, R, S) were tested using the set of tools including the exchangeable punch of diameter 65.97 mm. 4 stripes from producer S were problematic and withdrawn from production (S.P.1, S.P.2, S.P.3 and S.P.4) Thickness of stripes was 0.245 mm. From each material 3 blanks were cut out and tested. During the experiment, maximal force obtained in the test (*F*) as well as the reposition of the upper punch (*s*) were recorded. On the basis of movement of the punch, the height of the bottom part of a sample was calculated. Results are presented in **Table 1**. While *F* indicates maximal force obtained in the test for a given sample, F_a is the average force calculated for 3 samples from a stripe. What is more, *h* indicates height of bottom part of obtained sample (**Figure 3**) calculated on a basis of reposition of the punch, as the bottom part is started being shaped when the punch reaches the lower holder, which was at s = 179.9 mm. Value of h_{av} indicates average height calculated for 3 samples.

Table 1 Results of the experiment obtained for high-efficient stripes from 3 different suppliers

Producer	**P**											
Material	P.1			P.2			P.3			P.4		
No. of a sample	P.1.1	P.1.2	P.1.3	P.2.1	P.2.2	P.2.3	P.3.1	P.3.2	P.3.3	P.4.1	P.4.2	P.4.3
F[kN]	20.2	20.4	20.5	20.5	20.2	20.2	20.7	21	21	20.3	20.6	20.4
F_a[kN]	20.37			20.30			20.90			20.43		
s[mm]	158.2	158.3	158.4	158.3	158.4	158.5	158.5	158.3	158.3	158.4	158.4	158.5
h[mm]	21.5	21.4	21.3	21.4	21.3	21.2	21.2	21.4	21.4	21.3	21.3	21.2
h_{av} [mm]	**21.40**			**21.30**			**21.33**			**21.27**		
Producer	**R**											
Material	R.1			R.2			R.3			R.4		
No. of a sample	R.1.1	R.1.2	R.1.3	R.2.1	R.2.2.	R.2.3.	R.3.1	R.3.2	R.3.3	R.4.1	R.4.2	R.4.3
F[kN]	20.5	20.4	20.5	20.3	20.1	19.9	20.2	20.5	20.1	20.4	20.2	20.3
F_a[kN]	20.47			20.10			20.27			20.30		
s[mm]	158.2	158.1	158.3	158.3	158.4	158.4	158.3	158.4	158.4	158.1	158.3	158.3
h[mm]	21.5	21.6	21.4	21.4	21.3	21.3	21.4	21.3	21.3	21.6	21.4	21.4
h_{av} [mm]	**21.50**			**21.33**			**21.33**			**21.47**		
Producer	**S**											
Material	S.1			S.2			S.3			S.4		
No. of a sample	S.1.1	S.1.2	S.1.3	S.2.1	S.2.2	S.2.3	S.3.1	S.3.2	S.3.3	S.4.1	S.4.2	S.4.3
F[kN]	20.5	20.7	20.7	20.6	20.3	20.7	20.6	21	21	20.7	20.5	20.8
F_a[kN]	20.63			20.53			20.87			20.67		
s[mm]	159	158.9	158.8	158.7	158.9	158.6	158.8	158.8	158.7	158.7	158.8	158.8
h[mm]	20.7	20.8	20.9	21	20.8	21.1	20.9	20.9	21	21	20.9	20.9
h_{av} [mm]	**20.80**			**20.97**			**20.93**			**20.93**		

As it may be seen on the basis of **Table 1**, material from producer S differs in the average value of obtained height (*h*) of the bottom part of a sample. While for producers P and R, values of average height (h_{av}) varied slightly from 21.3 mm to 21.5 mm, the height for producer S only in one sample exceeded 21 mm. The minimal height (*h*) obtained in the tests was 20.7 mm (sample S.1.1). Also a difference may be observed in the maximal force obtained. While for producers P and R, only for one material (P.3) the force exceeded 20.5 kN, for materials from producer S, the average force always exceeds this value.

Those results may suggest that material S is more strengthened after cold rolling and operations taking place during can production process and thus cannot be ironed for the same height as materials from other suppliers.

Table 2 presents results of the experiment obtained for 4 stripes from supplier S whose performance on production line was so ineffective, that they were withdrawn from it. As it may be seen, also for low-efficiency materials F_a exceeds 20.5 kN (as in the case of high-efficient materials from supplier S). A difference may be also observed in the case of height of the bottom part, which varied from 20.7 to 20.77 mm.

Table 2 Results of the experiment obtained for low-efficient stripes from 1 supplier

Producer	**S**											
Material	S.P.1			S.P.2			S.P.3			S.P.4		
No. of a sample	S.P.1.1	S.P.1.2	S.P.1.3	S.P.2.1	S.P.2.2	S.P.2.3	S.P.3.2	S.P.3.3	S.P.3.4	S.P.4.1	S.P.4.2	S.P.4.3
F[kN]	20.6	20.5	20.7	20.9	20.7	20.8	20.6	20.6	20.6	20.7	20.7	20.5
F_a[kN]	20.60			20.80			20.60			20.63		
s[mm]	158.9	158.9	159	158.9	159.1	158.9	159	159	158.9	159.1	158.9	159
h[mm]	20.8	20.8	20.7	20.8	20.6	20.8	20.7	20.7	20.8	20.6	20.8	20.7
h_{av} [mm]	**20.77**			**20.73**			**20.73**			**20.70**		

6. CONCLUSION

With no doubt quality control of material before it is applied to the process may be crucial from the point of view of both performance of efficiency and final parameters of products. The idea of the test proposed in the experiment is to identify problematic materials before they are fed into a line thanks to determination of minimal height (*h*) of a fragment shaped (drawn and ironed) in the bottom of a sample. The aim of the test is to check performance of the material not only in drawing but also in ironing operation.

The first stage of the research involved 16 materials from 3 supplies (12 stripes of high-efficiency and 4 stripes from supplier S of low-efficiency).

Analyzing results of high-efficient materials obtained in the test, a difference between the height (*h*) of samples from materials from supplier S and materials from other 2 suppliers may be seen. A small difference may also be observed in maximal force recorded during the tests, which is higher for producer S. As a result, it may be said that probably materials from supplier S are more strengthened after all plastic working operations (included in production process of a stripe and drawing and ironing) than the other ones.

Comparing these results with values of h_{av} obtained for problematic materials, a slight difference between them may be observed. For all materials of low-efficiency on the line that were withdrawn from it, h_{av} is lower than in case of most of high-efficient material (except for S.1.1 with h = 20.7 mm), and varied from 20.7 to 20.77 mm.

As a result it may be concluded that the idea of the test seems to give hopes for possibility to differentiate low-efficient materials from those of high-efficiency. However, because of small differences between the values of results obtained with the punch of diameter 65.97 mm, it is necessary to conduct more tests using different dimensions of a punch (bigger diameters), which will result in thinner clearance between tools and probably bigger difference in values of force and height of the bottom part.

ACKNOWLEDGEMENTS

The work is being realized within the fund from grants helping out PhD students and young scientists to develop their research, contract no. 15/11.200.334.

REFERENCES

[1] RĘKAS, A., LATOS, T., BUDZYN, R., FIJAŁKOWSKI, M., BRODAWKA, L. The analysis of influence of sheet properties on the ironing process of thin-walled cylindrical shell products from aluminium alloys. *Key Engineering Materials*, 2015. vol. 641, pp. 232-245.

[2] JASNA, G., HEINRICH, M. Structure of quality of a product in a production process. *Problems of exploitation*, 2012, vol. 2, pp. 79-91. (in Polish).

[3] SCHÜNEMANN, M., MUSTAFA, A. et al. Prediction of process conditions in drawing and ironing of cans. *Journal of Materials Processing Technology*, 1996, vol. 59, no. 1-2: pp. 1-9.

[4] KANG, K. Impact of die wear and punch surface textures on aluminum can wall. *Wear*, 2009. vol. 266, Issues 9-10, 24, pp. 1044-1049

[5] RĘKAS, A., KUREK, M., LATOS, T., MILCZANOWSKA, K. Implementation of FMEA into mass production process to identify and eliminate causes of defects. *Key Engineering Materials*, 2015, vol. 641, pp. 266-277.

[6] *Galvanized steel sheet. Two-piece cans*. Available at: http://ecommerce.ibaosteel.com/baosteel_products/galvanizedSteel/en/material/material_02_06.jsp Last access: 15.04.2017.

[7] FOLLE, L. F., EGLAN, S., NETTO, S., SCHAEFFER, L. Analysis of the manufacturing process of beverage cans using aluminum alloy. *Journal of Materials Processing Technology*, 2008, vol. 205, pp. 347-352.