FORMING OF FOOD CANS - FORMING DEFECTS RELATED TO COMPLEX STRAIN PATHS

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Abstract

A typical can for processed fish is rectangular shaped with conical walls fabricated in a two step drawing operation. Two forming defects associated with the fabrication are studied using the alternative alloys AA5050 and AA3005. First, fractures developed in the upper part of the corners when the corners were stretched in the second operation. The other was a fracture in the flange in the junction between the short side and the corners.

The fracture in the wall was initiated as a typical plastic instability. The one with best work hardening as sheet material (AA5050), gave problems. Small tensile specimens were therefore cut from the walls after the first operation where the fractures could occur. It was revealed that after the strong predeformation (ε=0,7) in the compression of the flange, the work hardening decreased only slightly for AA3005 but more drastically for AA5050. This difference in work hardening curves is the reason for the problem.

The fracture in the flange is essentially caused by a specific assymmetrical flow of the material AA5050 around 20° to the rolling direction. The material on either side has an easier lateral flow. Parts of the flange therefore collides and overlap, giving a shear fracture. ODF texture analysis and calculation of plastic anisotropy, verified the dependency on the initial texture.

Introduction

Cans are demanding products despite the modest and everyday appearance. Strong requirements to surface lacquer/bonding are set by aggressive content on the inside, and environment or handling on the outside. The forming - which will be focussed on here - is complex and involve many aspects of forming technology. For the two-step drawing operation, the material is deep-drawn and blocked out during the second drawing operation to give wrinkle-free corners. There must be no near-fracture, the remaining flange must be narrow with very low buckles and the bending properties must be good. In addition, it is preferable that the lids are made from the same material which means that the formability in the biaxial mode (forming of rivets) must be high and that the score line breaks properly. The general demands for thickness reduction and increase in strength, makes it even more difficult to meet these requirements.

During the development of canbody, problems could be interpreted in terms of low work-hardening, strings of particles, impurities and earing. Two problems were, however, of particular interest.

The first is a fracture or a near-fracture in the wall at the corner (Fig. 1) after the second drawing operation where the corner was stretched to be wrinkle-free. It was surprising that this happened for the apparent most formable material.

The other was a fracture in the flange between the short end and the corner (Fig. 2). This happened only with AA5050 material and only when the rolling direction was along the length of the can.

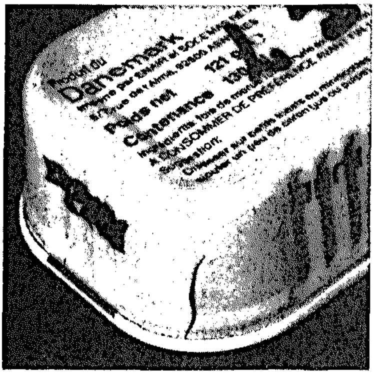

Fig. 1. Optical macro image of a fracture at the corner of a two step drawn club can.

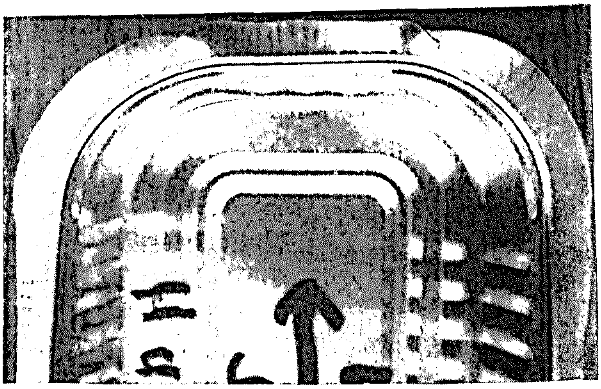

Fig. 2. Optical macro image of a fracture in the flange between the short edge and the corners after the second drawing operation.

Experimental

The materials are conventionally DC-cast, hot-rolled and cold-rolled to 0.24 mm. The sheets were subsequently pretreated, lacquered, baked, decorated, baked and prelubricated. The cans are formed from these sheets by first a deep drawing operation. In the following operation, the cans are drawn to full height and also blocked out to a conical shape which also makes the corners wrinkle-free.

The materials used are AA3005 (Al-1.0wt%Mn-0.3wt%Mg) and AA5050 (Al-1.2wt%Mg-0.3wt%Mn) both in near full hard condition (H48). The mechanical parameters are given below.

Table 1. Mechanical Properties

Alloy	Thickness mm	Rp0.2 MPa	Rm MPa	Au %	A50 %
3005	0.24	209	226	2.2	5.4
5050	0.24	214	245	5.5	6.4

Cans with a varying degree of defects in the corners have been selected from the production line and studied by stereomicroscopy and optical metallography in a Reichert MEF4A microscope. For the second problem, cans from both materials were collected after the first and second operation with the rolling direction pointing along the long and short side, respectively. Some of the cans giving problem were "decorated" with a rectangular grid and a polar grid in the corners.

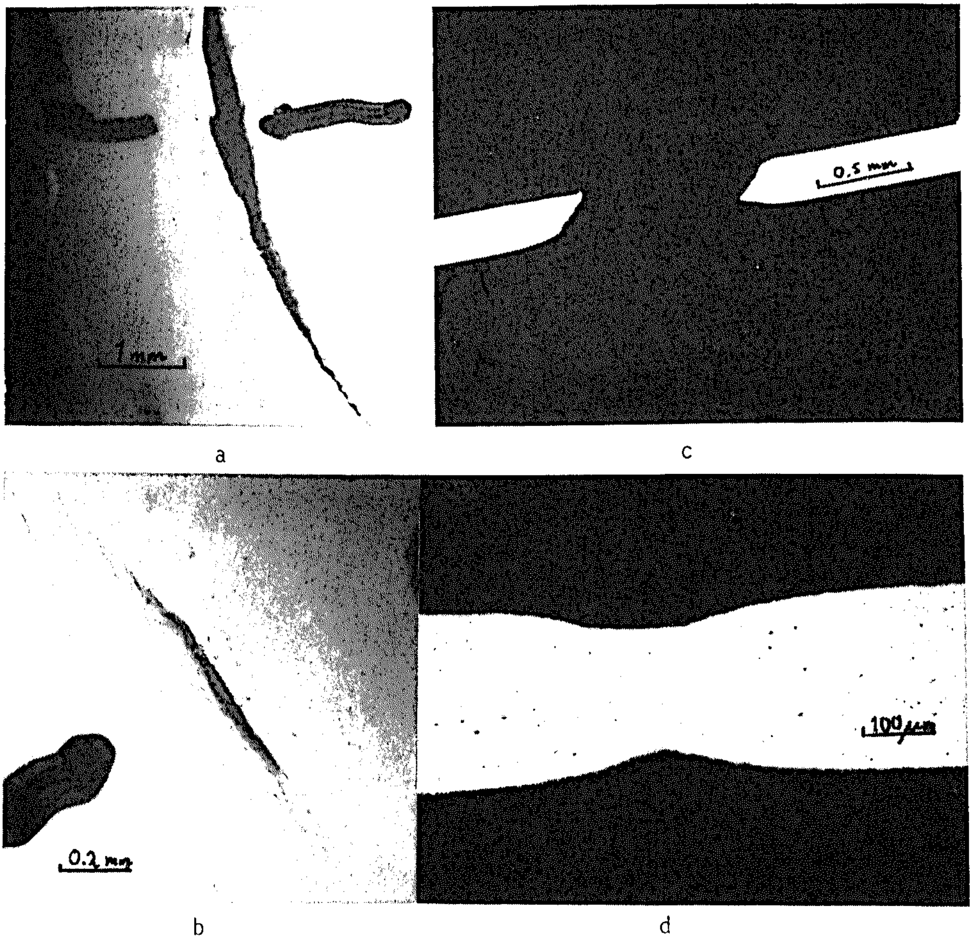

Fig.3. Optical macro image of the corner area showing a) a large defect (upper left) and b) a small defect (lower left) with the corresponding crossection c) and d) between the black marks (right)

Results and Discussion

a) Corner defects.

The surface areas around the defect have been characterized and examples of a severe fracture and a small depression are shown in Fig. 3 together with the corresponding cross sections of the two defects. As seen, the defect starts as a localized instability running in the drawing direction meaning that it is a plane strain condition with components in thickness and transverse drawing direction. At later stage, the fracture runs in a S-shape. The initiation is typical for plastic instability which develops when the work hardening do not compensate for geometrical softening. The instability as seen in Fig 3d is asymmetrical compared to normal tensile testing due to the curved surface. The governing property in such cases is the reduced work hardening capacity i.e. matrix properties. This is underlined by the fact that the instability always starts on the same position and no other factor such as presence of large particles, could be found.

Consequently, it is concluded that a lower work hardening capacity of the AA5050 material is causing the problems. But as seen from table 1, the work hardening as measured by uniform elongation (equal to the n-value in the Holoman expression $\sigma=K\varepsilon^n$) and also ductility measured by total elongation is clearly better for the AA5050.

It was therefore suspected that the predeformation in the flange during drawing along a different strain path could change the ranking. Firstly, by observing the deformation of the polar grid effective strain involved is found to be approximately 0.7 so the predeformation is large. But what are the relevant work hardening ?

For this purpose small tensile specimens were cut from the corners after the first drawing operation. The predeformation is nearly correct (0.6), the deformation mode is close but probably contracts more than in reality. Samples were also taken from circular cans at correct prestrain. The results on these cans confirm that the sligthly lower predeformation did not change the trends found by the corner samples.

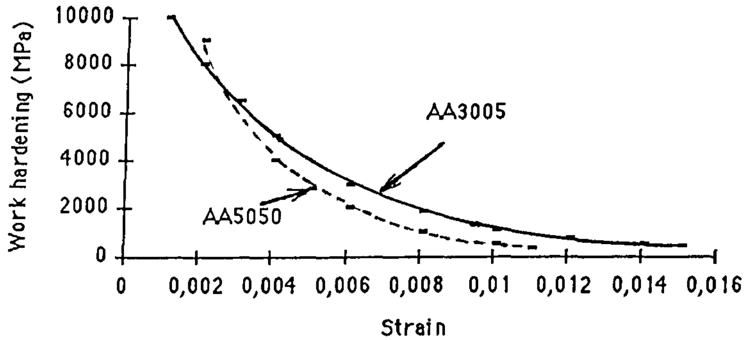

Fig. 4. The work hardening curves of AA3005 (H48) and AA5050 (H48) deep drawn to a compressive strain in the wall of 0.6.

The mechanical properties of the corner samples are presented in Table. 2. From these data, it is observed that the flow stresses have increased only slightly in AA3005 material and the elongations correspondingly a little reduced. On the other hand, AA5050 have increased substantially more in strength and the workhardening and elongations lowered. The work-hardening is characterized by plotting $d\sigma/d\varepsilon$ against the strain (Fig. 4). From these curves, it can be concluded that the AA3005 material has a better overall work hardening characteristics. Therefore, the distribution of strain will be more even and critical instabilities avoided [1].

Table 2. Mechanical properties of material in the corner.

Alloy	Thickness mm	Rp0.2 MPa	Rm MPa	Au %	A50 %
3005	0.24	213	239	1,5	3.1
5050	0.24	242	264	1.2	2.9

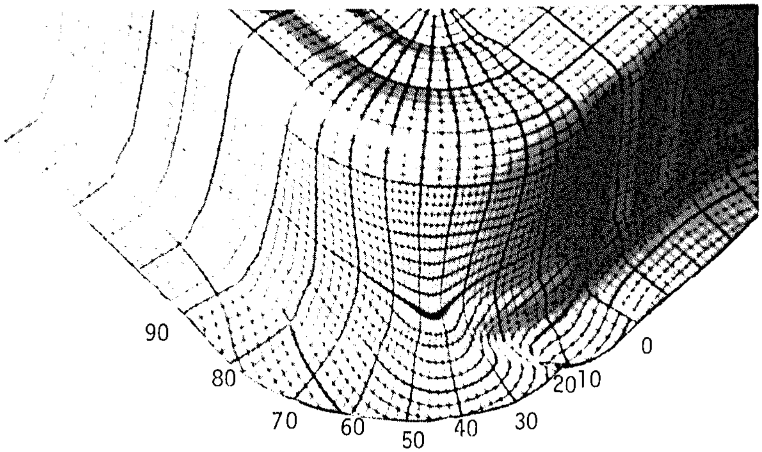

Fig. 5. Optical macro image of a fracture in the flange of AA5050 material. (The small squares are originally 1x1 mm.)

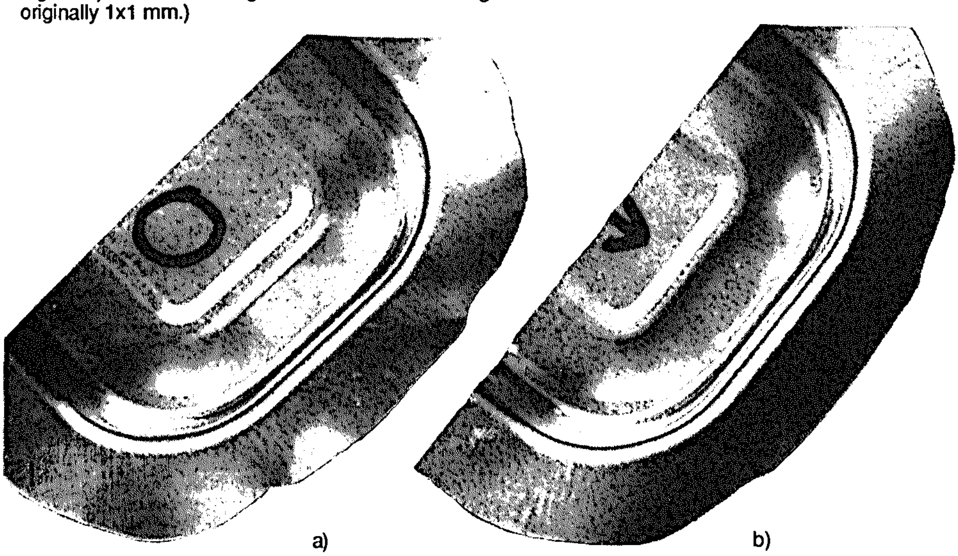

Fig. 6. Optical macroimage of the flange after the first drawing operation. a) AA5050 with rolling direction along the long edge of the can, b) the corresponding image using AA3005 material.

b) Shear fracture in flange

The defect is a shear fracture where the material from the short edge overlap the material from the corner (Fig. 5). The fracture runs into the flange. The early stage in the development is best seen after the first drawing operation (Fig. 6a) where an open V-shape have been formed apparently because the material around 20 ° has relative restricted flow in contrast to AA3005 where the change is gradual. (Fig. 6b). Turning the can of AA5050 material 90°, however, gave the same edge profile as AA3005.

After the second drawing operation, the V must have narrowed and from the grid pattern, it was found that the two legs of the V must have collided resulting in a shear fracture in the notch in this type of metal flow. The cause of the defects are therefore the anisotropic flow of the flange between 10-45°, but what is the underlying reason ?

The differences in flow are obviously inherited from the rolling process. Therefore the texture after rolling has been characterized be means of ODF's. The dominate feature is the range of rolling textures along the skeleton line [2]. This is similar in both materials, but the intensity for AA5050 is higher around ϕ_2=70°. Of particular interest is the presence of fibre components {hk0}<100>. The ODF's are used in a Taylor analysis using the Bishop-Hill method. This shows that the resistance to flow is lower for AA5050 near rolling direction but higher around 30°. This result in inflection points around 10° and 20°.

The shearing in the flange can therefore be explained by the relative easy flow of material outside 20° and the restricted one around 15° resulting in two bulges which collides. In AA3005, however, there is no inflection and there is only one bulge.

It is remarked that if the cans made of AA5050 is turned 90° then the change in Taylor factor is very similar to the AA3005 from 0°- 45° or 90°- 45° and therefore the same deformation of the flange should be expected.

The remaining question is why the AA5050 material gives no defect when turned 90°. A probable reason is that the plastic constraint set up at the short edge, is so strong that the distribution of the strains at the outlet of the corner so not so well as on the long side.

Consequently, differences in texture gives unwanted easy flow close to the rolling direction and this extra bulge interact with the normal 45° ear. The reason for anisotropy is obviously found in the texture. A clear difference is the presence of a cubic fibre component and the intensity variation along the skeleton line. It is known [3] that the fibre texture can result from a deformation of the cube texture. Since Mg-containing alloys recrystallize easy and the cube texture is a natural component, it is expected that the fibre component stems from deformed cube grains during final rolling.

Conclusion

Defects at the corners in the form of localized necking and fracture, are caused by a severe reduction of the work hardening of during the strong deformation of the flange in the first drawing operation. This results in a poor strain distribution and localization of the deformation.

Defects in the flange during the inflow of the flange are due to texture component inherited from the rolling giving an easy flow close to the rolling direction. The resulting inflection, means that there is formed an extra bulge below 15° to the rolling direction when the plastic constraint is large at the short edge. This bulge collides during inflow of the flange with the corner areas around 45 ° a shear fracture develops.

References

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