An Analysis of The Drawing with Aluminum Brazed Sheets

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Abstract. This paper analyzes drawing of aluminum sheets joined by brazing. Drawing is the transformation of a plan workpiece into the drawn part or workpiece, transformation with decreasing of depth corresponding transverse dimensions. The brazing process is based on the difference by the melting points of the base materials and filler metal. During the brazing process, the aluminum sheets to be assembled are heated to a temperature between the melting temperatures of the two alloys, this process tends to modify the geometry and the microstructure of the brazed sheets. In various industries such as automotive, aerospace, electronics, machine building industry etc., aluminum alloys can be used to replace the steel parts of carcasses (car body). Brazed sheets are widely used in the manufacture of heat exchangers by using an aluminum alloy. These sheets have different thicknesses and are generally made by hot rolling. Aluminum in natural form is very soft and ductile, slightly used due to its mechanical properties. The brazing process is based on the difference in the melting points of the base materials and filler metal. During the brazing process, the sheets to be assembled are heated at a temperature between the melting temperatures of the alloy, this process tends to modify the geometry and the microstructure of the brazed sheets.

1. Introduction
As shown in the specialized drawing processes in the literature, consisting of a combination of deep drawing and stretching, it is necessary to control how the material is deformed. The drawing methods are varied, but mainly they can be obtained individually or in complex combinations: empty form, using lubricants, crimping grips and influencing frictional forces. These are best prepared when it is necessary for the embossing of large and complex surfaces with large drawing forces required [1,2].

Part drawing in general can be defined as the process of cold or hot plastic deformation of an aluminum alloy workpiece that becomes the drawn part, whether or not intentional modification are made to the wall's thickness. Part drawing is now widely used in various industries such as automotive, aerospace, electronics, machine building industry etc. [3,4].

In these industries, aluminum alloys can be used to replace steel parts of carcasses. Folded plates are widely used in various industrial processes. These sheets are of different thicknesses and are generally made by hot rolling. Aluminum is soft and ductile, being easy to form due to its mechanical properties. Because their structure is quite complex, aluminum sheets are also used by brazing, using a base material and another aluminum alloy as a filler material having similar properties [5].

An accepted method is to use a sheet of sheet for embossing, using a non-uniform layer of lubricant depending on the area that requires additional lubrication, this is done before the deformation process.

In this paper I have studied how bimetallic brazed parts can be drawn by cold procedure, by a normal procedure of drawing with aluminum-based materials and mainly by studying the response of the brazing cord after the deformation is performed.
The analysis of the brazability of the materials requires the following considerations: the characteristics of the joining process; the chemical composition of the base metal; cleaning before and after the joining process; the chemical composition of the adder metal; protecting the joint against oxidation; temperature and duration of the joint; the appearance of the joint, figure 1 [6,7].

![Figure 1. Brazed joint design: (a) Lap Joint; (b) Butt Joint; (c) Scarfed Joint; (d) Butt-Lap Joint; (e) Capillary Attraction Base Metal.](image)

Each of these considerations influences the wetting and dispersion behavior, the mechanical properties of the joint, the corrosion resistance and the residual stress levels.

2. Drawing part procedure

This paper aims to determine the deformation capacity by drawing of the brazed sheets with different thicknesses of the material up to 1 mm and with a length of 100 mm (figure 2). A wide range of elements can be stamped by this method from pieces with simple shapes and with small heights and ending with complex asymmetrical shapes.

The deformability of the aluminum alloy sheets expresses their ability of plastic deformation to take a certain shape, without showing defects of the part. The amount of deformability is the degree of deformation supported by a material that begins to appear until the first crack in the material.

![Figure 2. Dimensions of the Drawing Part.](image)

The schematic diagram of the drawing process is shown in figure 3, the brazed aluminum alloy boards are cut with sides of \(L = 100\) mm and are fixed in the blank holder, and the drawing punch exerts an \(F\) force on the initial plate until it reaches its final shape \(H = 40\) mm.
Schematically the drawing process is composed of: drawing punch and the gap, that limits the outer contour of the retaining ring of the piece (the drawing ring) that presses the metal to the gap between them, prevents wrinkles and controls its flow into blankholder.

The drawing punch delimits the inner contour of the workpiece, achieving the force required to deform the sheet (pulling force). The deformation method depends on the mode of action of the drawing ring. When stretching the aluminum sheet, the board is locked between the ring and the drawing punch.

If we analyze the strain distribution of stresses and deformations, we study an element of material located at the outer edge of the sheet at the beginning of the drawing operation, this element shortens the transverse direction due to the compression efforts $\sigma_1$ and extends to the radial direction due to the tension stretching $\sigma_2$, figure 4 [8].

![Figure 3. Schematic drawing procedure.](Image)

![Figure 4. Strain distribution of stresses and deformations.](Image)

Once the volume of the advance of the drawing punch moves inward (towards the edge of the blankholder), the compression stresses $\sigma_1$ decrease and the tensile stresses $\sigma_2$ increase, giving rise to a large deformation which extend in the radial direction.

The materials used for the tests were: the base material AA6016-T4 type and for filler metal brazing rode type4043 and 4104 alloy. The chemical compositions for this material are presented in table 1 and 2.

**Table 1. Chemical composition (%) of aluminium alloy, type AA6016-T4 [9].**

|          | Mg | Si  | Fe  | Cu  | Cr  | Ti  | Mn  | Zn  | Others | Al   |
|----------|----|-----|-----|-----|-----|-----|-----|-----|--------|------|
|          | 0.25-0.6 | 1.0-1.5 | 0.5 | 0.2 | 0.10 | 0.15 | 0.20 | 0.20 | ≤0.15  | Balanced |

Alloy 4043 and 4104 are most widely used for filler metal brazing alloys. The silicon additions result in improved fluidity (wetting action) to make the alloy a preferred choice by braziers. Those alloys are less sensitive to weld cracking and produces resistant brazing cords.

**Table 2. Chemical composition (%) of the filler alloys [10].**

| Alloy  | Si  | Fe  | Cu  | Bi  | Mg  | Zn  | Ti  | Be  | Others | Al   |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|--------|------|
| 4043  | 4.5-6 | 0.8 | 0.3 | ≤0.1 | 0.05 | 0.1 | 0.2 | 0.003 | ≤0.1  | Balanced |
| 4104  | 9-10.5 | 0.8 | 0.25 | ≤0.2 | 1-2 | 0.2 | ≤0.1 | 0.0003 | ≤0.1  | Balanced |

3. Results and discussion
The brazing has evolved significantly, the introduction of flame, in-oven or vacuum brazing has expanded the brazing applications to different material systems such as aluminium, stainless steel, superalloys, titanium and ceramic materials. Recent discoveries in aluminium brazing in the industry include the application of non-corrosive fluxes in conjunction with a dry nitrogen atmosphere in a
toothed belt furnace. Apart from these conditions, only the small amount of flow is necessary for the protection of the joint so that no flow is required after brazing [11,12].

If we analyse the volume element is passed of the blank-holder edge we notice that it is subjected in addition to bending deformation and with as the volume element is into blank-holder axis the main application is axial stretching. If is considered a polar reference system the tensions \( \sigma_1 \) and \( \sigma_2 \) will be the main normal stresses.

Displacement of volume element meaning drawing applications it’s due to the total blood drawing action [3]:

\[
\sigma_t = \left[ (\sigma_2 + \sigma_f) e^{\mu \alpha} + \sigma_r \right] \sin \alpha
\]  

(1)

where \( \sigma_f \) is radial tension is derived from the sheet friction with blank-holder and \( \sigma_r \) is radial tension is derived from material bending on the connection to the drawing plate.

It’s envisaged that the clearance of drawing active elements is greater than the thickness \( g \), aspect to be taken into account by angle \( \alpha \), for simplicity it will be considered and therefore \( j \approx g \) and \( \alpha = \pi/2 \).

To determine the radial pressure \( \sigma_3 \), considering the plane stress state, the equilibrium equation is:

\[
r \frac{d \sigma_3}{dr} + \sigma_2 - \sigma_1 = 0
\]  

(2)

The plasticity condition is [3]:

\[
\sigma_2 - \sigma_1 = \beta R_{def}
\]  

(3)

where \( R_{def} \) is deformability resistance and \( \beta \) is deformability coefficient is 1.1 in general.

From the equation (2) and (3) are obtained:

\[
r \frac{d \sigma_3}{dr} + \beta R_{def} = 0
\]  

(4)

After integration:

\[
\sigma_2 = R_{def} \ln \frac{r}{r}
\]  

(5)

The use of different phases in the gap can cause chemical resistance and high breaking point. Currently, processes such as sintering at the intersections, splashing and sintering of layers and chemical vapor deposition of thin layers (brazing) are applied when joining different types of materials, figure 5.

![Figure 5. Brazed joint.](image_url)
specific processing conditions, as well as the effect of the joint processes on the state of joint stresses, during manufacture [10].

In the experiments, determination by differential thermal analysis points solidus and liquidus was conducted for the filler material, type 4043, in the conduct of the three samples so, they were compared with the second filler type 4104 of which were also performed three analyses, figure 6. Following the analyses carried out, the following solidus and liquid temperatures were determined. This distribution below highlights the solid and liquid temperatures for the aluminium alloys discussed. A much more detailed presentation was made in the three graphs of differential thermal analysis of the solid and liquid points of the studied materials.

This determination was performed only two types of fillers which we considered as representative and have performed best in tests. The figure 7 a show what a typical brazing sheet of small thickness looks like after brazing. The aluminium alloy microstructure is shown after recrystallization and solidification. Another characteristic feature is the presence of dendritic cells surrounded by eutectic network.

If analyse graph of differential thermal analysis and the micrograph of the brazed area with additive material, liquidus and solidus temperature they have a smooth distribution, and the micrograph of the brazed area shows that the additive material is correctly chosen.

Once the brazing of the two pieces of sheet is done, they must behave during the stamping as a single piece. Thus, correlated drawing forces should be used so that there are no cracks that may occur during deformation in this process.

It all depends on how the materials were chosen for the brazing and how this combination was made, if all these conditions are respected and the brazing has proceeded in good conditions, then the brazed aluminium sheets will be able to be formed without problems.

What is also noteworthy is that the filler metal formed a metallurgical bond between collector body of radiator parts. The machine building and electronic component manufacturing industry requires material joints that offer high properties and if different materials are brazed. An example is the combination of ceramic materials with metals that have different melting points and expansion coefficients.

4. Conclusions

These small thickness brazed plates with dimensions shown in this work are very well behaved in brazing process, as can be seen from the graph effect of brazing time on shear strength of joint and thickness and increased age hardening response for brazing alloys.

By making correct joints, the brazing temperature and brazing time have a good influence to the way in which base materials are diffused with filler material, result a good homogeneity, composition and microstructure.
Different industrial processes have been developed to combine materials with different properties. The choice of the joining technique will depend on the correct use of the materials and on the optimization of the properties of the joint. In fact, in order to obtain high mechanical strength, or good resistance to temperature, the reaction in the thin layer must have a high melting temperature of the components. For good dielectric properties, the reaction in the layer must contain oxidizing compounds.

The production of aluminum parts has shown that we must pay particular attention to particularities of the brazed aluminum plate by drawing in manufacturing the auto components. Manufacturing process of the carcasses made out of sheet metal is a mixture of drawing and forming by stretching.

5. References

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