Influence of aluminum alloy sheet on the Formability in Single Point Incremental Forming Process

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Abstract

Incremental forming process is one of the most promising newer techniques in metal forming process. Formability of analysis has to be carried out in order to obtain successful forming process. This research study investigated the influence of various types of aluminum alloy sheet that affect strain behavior by single point forming process. Investigate the aluminum AA1100, AA3003 and AA5052, forming a conical piece, inclined angle 20 degrees, speed 50 mm / rev, tool rotation speed 1500 rpm, ball forming tools, radius 8 mm. step depth 0.5 mm at room temperature. A computer controlled numerical machine was used for forming. FLD and thickness distribution has been predicted and compared for all three the material. The forming limit diagram received through incremental forming very much varies from conventional forming limit diagram. Comparison of FLD and thickness distribution shows that AA1100 has higher forming limit than AA3003 and AA5052 the thickness after forming is better in AA1100 than in AA3003 and AA5052.

Keywords: *Aluminum alloy sheet, Strain behavior, Single Point Incremental Forming Process*

1. Introduction

Incremental sheet forming (ISF) is one of the newer forming technologies where complicated external shapes can be formed without using punches and dies. Often used for the prototype and small batch production. A hemispherical tool is pressed over the sheet metal to form the desired shape. The tool path is controlled by a Computer numerical control : CNC machine. It is based on the methodology of producing the designed shaped by progressive movement of the hemispherical tool. Since localized deformation is developed during forming, more stretching occurs than in conventional forming. This process is mostly applied due to more flexibility and less tooling cost. Due to slow forming process, this can be limited only to small batch production systems. This process is capable of forming sheet metal which is used in automotive, biomedical and aerospace industries [1]. To improve the formability of sheet metal, many researchers have studied the process mechanics [1-2]. Deformation in single point incremental forming (SPIF), is due to combined shear and stretching [3]. in few cases, bending of sheet metal also involved in addition to shear and stretching. The stretching and shearing of sheet metal induces wall thinning in parts, which can be predicted by Sine’s law [4]. The wall thickness mainly depends on the forming wall angle that the sheet metal can withstand without fracture. The formability of the sheet metal can be predicted by forming limit diagram (FLD) which separates the forming region and failure region. It is represented in terms of major strain and minor strain under plane stress condition [5-7]. FLD is controlled by the sheet thickness, forming speed, tool diameter, material and step depth [8-10]. Tool path influences the formability and surface finish of sheet metal. SPIF has high forming limits in comparison to conventional stamping process [11-12]. This study aims to compare the FLD obtained by forming a material type between aluminum AA1100, AA3003 and AA5052. An investigation the cone geometry in aluminums alloy sheet.

2. Material and experimental procedure

2.1 Materials

The base materials used in this work are three aluminium alloys currently used in the industry : AA1100, AA3003 and AA5052. The nominal chemical composition and mechanical properties of these alloys is shown in **Table 1**. Which the aluminum alloys, AA1100 series alloys Commonly in chemical and food processing industries for the corrosion resistance qualities. Also, parts have difficult bends or need excellent electrical conductivity. Likewise, AA3003 material widely used general-purpose alloy for moderate-strength applications that require good workability. Heat exchangers, cooking utensils. And AA3003 material very wide range of uses because of great qualities-constructions, storage tanks and pressure vessels, electronics and beverage cans.

Table 1 Mechanical properties and chemical composition of the AA1015, AA3003 and AA5052 aluminium alloy.

Material	Element									Mechanical Properties		
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al	F_u (MPa)	% *El*	*HB*
AA1100	0.18	0.26	0.05	0.04	0.05	-	0.03	0.02	Bal.	89	17	23
AA3003	0.54	0.62	0.17	132	-	-	0.04	-	Bal.	110	40	28
AA5052	0.25	0.40	0.10	0.08	2.41	0.23	0.06	-	Bal.	193	30	47

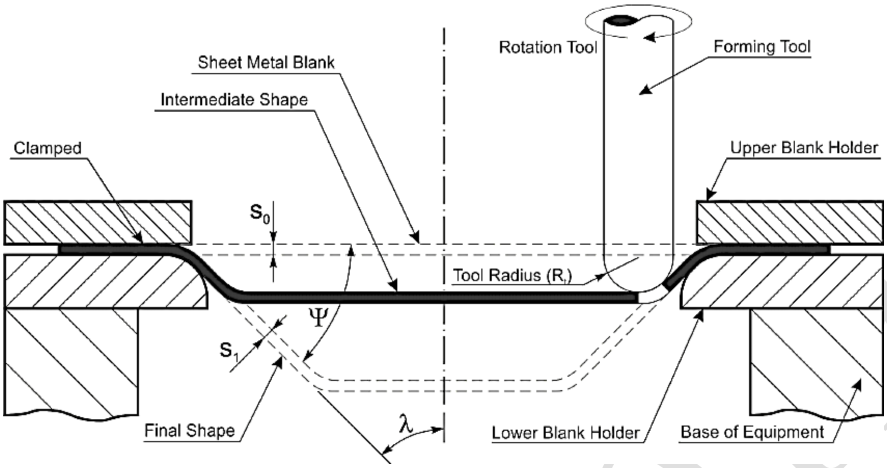

Figure 1 Single Point Incremental Sheet Metal Forming Process [12]

2.2 Experimental procedure

Single point incremental sheet metal forming process as shown in **Figure 1**. Characterize of workpiece in ISF are a truncated cone with wall angle 20°, with outer diameter of 100 mm and inner diameter of 50 mm as shown in **Figure 2 (a)**, workpiece is to generate the grid pattern on the blank sheet metal. Initially the power source is attached to the electrode and the sheet blank. Desired pattern stencils then carefully placed on the surface of the sheet which in our case was around grid pattern of circle 2.5 mm. for deformation measurement as shown in **Figure 2 (b)**. Formed from a square sheet blank (250 x 250 mm) by ISF. The plate was sliced by using Hydraulic Cutting Machine. Aluminium sheet blank with 1 mm thickness obtained in cold rolled condition was held into a specially designed fixture as shown in **Figure 2 (c)**. The formed by CNC 3 axis ,the ISF parameters consist of a rotational speed of 500 rpm/min at the feed 100 mm/min. and the 0.5 depth of cut.

2.3 Forming limit diagram (FLD)

FLD is a tool used to determine the formability of the material. FLD is constructed using minor strain as abscissa and major strain as ordinate. FLD can be calculated by measuring the deformed circular grids obtained after forming. Researchers started the first research on this field using circular grids which deformed into elliptical after forming. They obtained the right side of the FLD known as tension/tension side ($\varepsilon_{minor} > 0$, $\varepsilon_{major} > 0$). Later research continued on FLD gave the left hand side called tension/compression side ($\varepsilon_{minor} < 0$, $\varepsilon_{major} > 0$). They all three experiments used hemispherical punch test to obtain the FLD. The comparison FLD for conventional and incremental forming has been given in figure 3. In this test, incremental forming procedure is used to compare the FLD for the AA1015, AA3003 and AA5052 aluminium alloy.

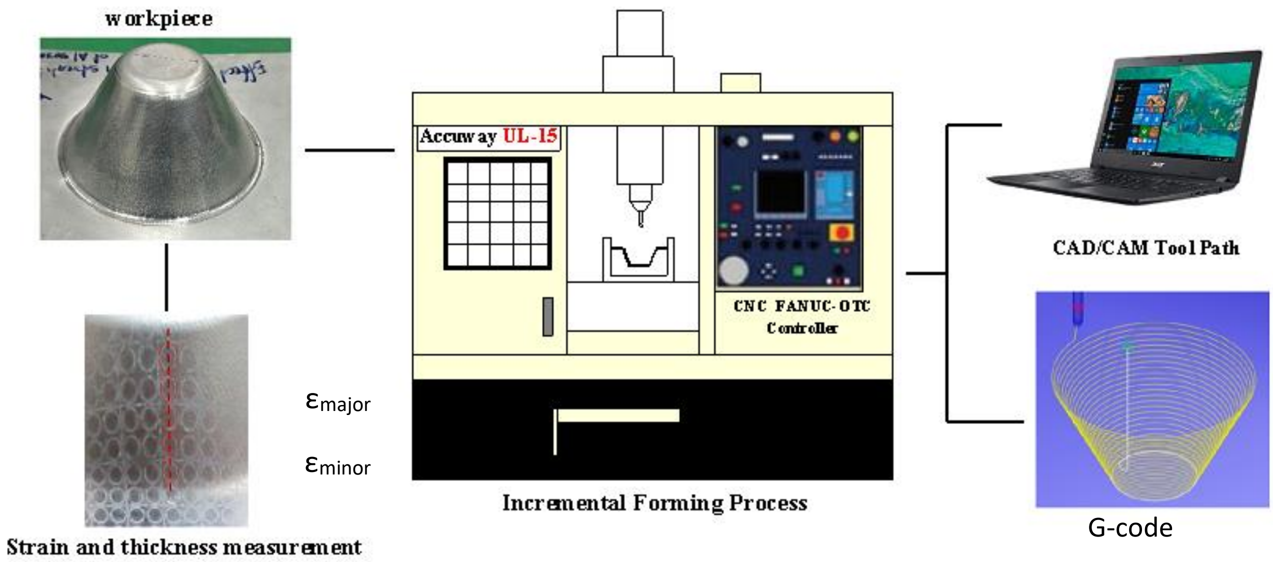

Figure 2 The experimental process for Single point incremental sheet metal forming

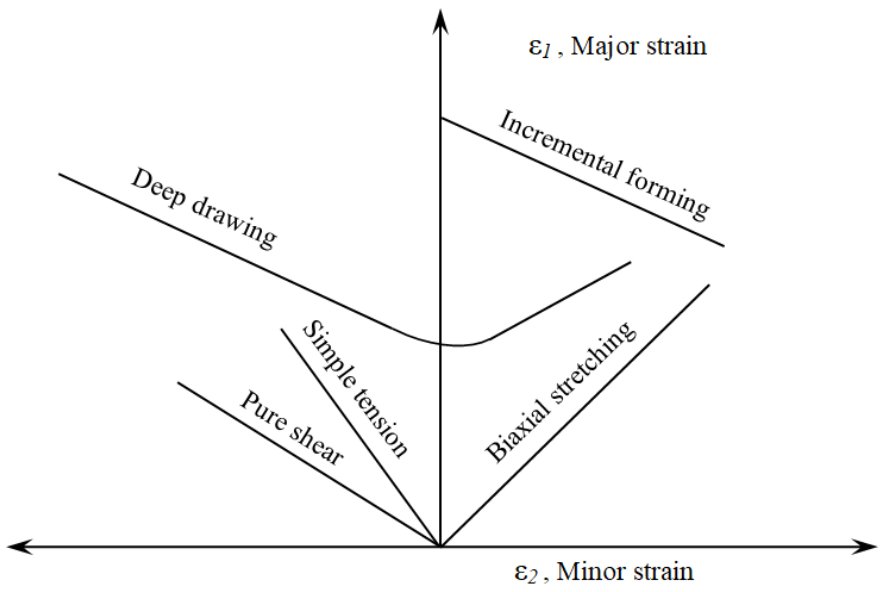

Figure 3 Comparison of conventional and incremental FLD [13]

3. Results and Discussion

3.1 Strain Measurement

The formed parts are formability analysis, circle grid measurement is done. This method provides the basis to predict the failure in sheet metal forming. The developed strain can be measured by comparing the circle before and after forming. During forming, the circle grids are converted into ellipse, and the major and minor strains can be calculated by measuring the lengths of the major and minor axes, d_1 and d_2 [19]. The principal strains are calculated by

$$\varepsilon_1 = \ln(d_1 / d_2) \text{ and } \varepsilon_2 = \ln(d_2 / d_0) \tag{1}$$

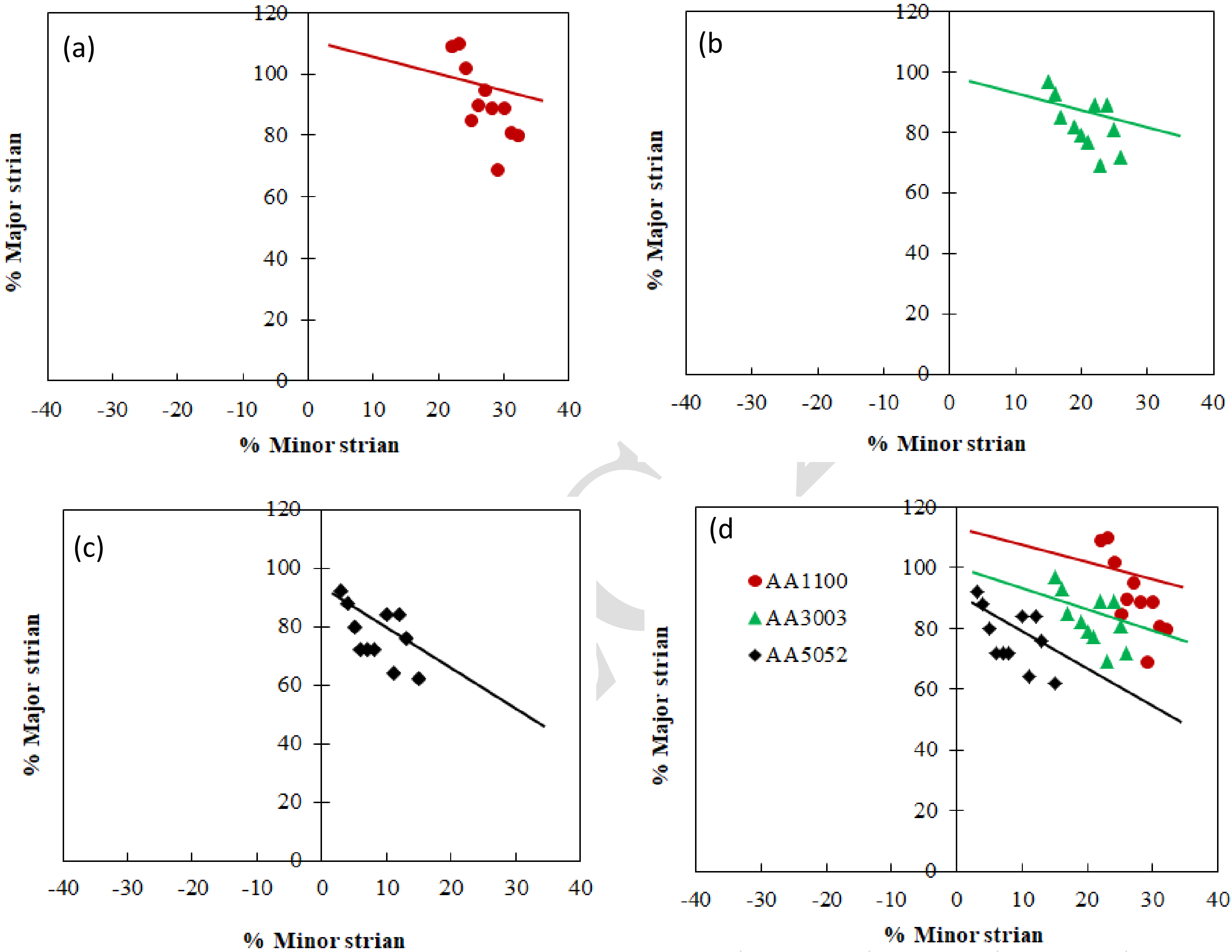

Figure 4 FLD for (a) AA1100 (b) AA3003 (c) AA5052 and (d) Combined FLD for AA1100 , AA3003 and AA5052

A Mylar tape is used to measure the strains in the major and minor axis and is tabulated. FLD graph is plotted against minor and minor axes for the for AA1100 , AA3003 and AA5052 separately as shown in **Figure 4(a-c).** A combined FLD for the parts are shown in **Figure 4(d)**. AA1100 has higher major and minor strain than AA3003 and AA5052. Combinations of FLD for third the parts shown that AA1100 parts have higher formability than AA3003 and AA5052 parts. This is mainly due to mechanical properties of materials.

3.2 Thickness measurement

The material thickness used in this analysis is 1 mm. Thickness before and after forming is measured using dial gauge. The values are taken from various regions for analysis. A comparison graph between the thickness measurement from AA1100 , AA3003 and AA5052 is drawn. The variation in thickness along with forming depth is shown in **Figure 5.** Thinning in AA1100 is lesser in AA3003 and AA5052. This is due to mechanical properties of AA1100 lower than AA3003 and AA5052. resulting flow of AA1100 was increase more than AA3003 and AA5052 during incremental forming.

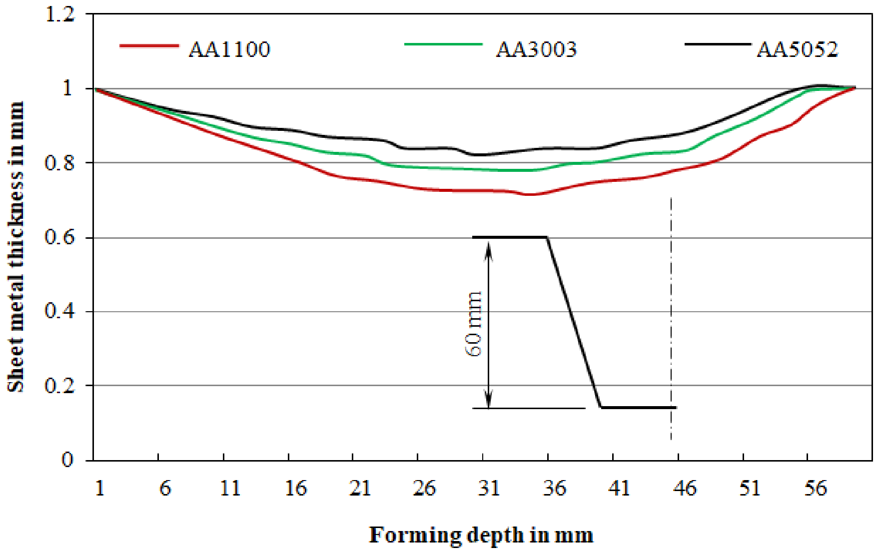

Figure 5 Comparison of formed thickness

4. Conclusion

In this paper, formability type of aluminum alloy sheet metal with 1 mm thickness at room temperature was investigated through formation of AA1100 , AA3003 and AA5052 by single point incremental forming processes. Formability analysis and thickness distribution study was carried out over the sheet metal. The conclusions are:-

- Comparison of FLD shows that the difference of material has on the effect formability with ISF process

- The experimental comparison of materials type, it is found that AA1100 has higher formability than AA3003 and AA5052 by ISF process.

- The experimental results is found that mechanical properties effect on the flow of material. Namely, a high strength material is more withstand to material flow than a low strength material.

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