Experimental Cases in Aluminium Foils by Dieless Process and His Comparison with Others Conventional Sheet Metal Forming Process

Gabriel J. Paramo and Adrian J. Benitez

***Abstract*—Incremental sheet forming by the method of single point incremental forming Dieless, is a widely studied process, experimented and developed in countries with high manufacturing technologies, with friendly costs when the productive configuration in a productivity system is based in small production batches. Previously mentioned, this work pretends to develop experimental cases in aluminum foils with 1 mm- thickness, and some specific process parameters, the analysis of forming limit curve (FLC), with the objective to emphasizes in this innovative method based in CAD-CAM technologies, compare with other analogous process of deformation sheet metal like embossing, deep drawing, stamping, spinning, superforming, take correct decisions about the viability and applicability of this process (Dieless) in a particular industrial piece, which responses to the necessities of productive configurations mentioned and be highly taken like a manufacturing alternative to the others conventional process of forming sheet metal , for systems with slow batches production.**

***Index Terms*—CAD-CAM, dieless, forming limit diagram curves (FLD), toolpath.**

I. Introduction

The incremental forming process by the method of supporting a single point Dieless (SPIF), involves the transformation of a metal sheet by a mechanical stress which produces a progressive deformation in the sheet. The process is done in several stages: it starts with a CAD (Computer aided design) modeling which represents the experimental geometry in three dimensions of the particular piece, the second stage is fed by the CAD file, assigning parameters such as the advance, RPM (Rev/Min), diameter tool, step depth, to a CAM (Computer aided manufacturing) system, you get a programming tool path, expressed in machine code known as G code[1]. This code is entered into a machine with CNC technology which reproduces the toolpath on the surface and deforms the end of the geometry piece, which is the final stage. Fig. 1, illustrates a representative form of this process.

The incremental deformation process without matrix (Dieless), is a recent process (its inception refer to 1994) [1]-[3] with respect to other techniques of conventional foil strain such as embossing, stamping, superforming and hydroforming, which are costly and involve working tooling and high volume production runs for its construction and operation.

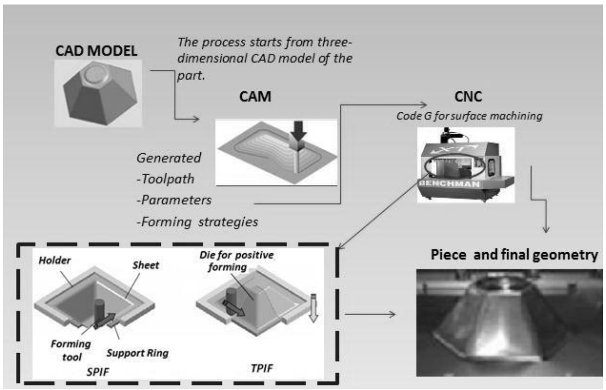

Fig. 1. Dieless representative illustration.

The purpose of this paper is to study experimental cases associated with a particular one, which is due to a conical geometry, to analyze the deformation of the same building through the forming limit curve diagram (FLD). The formability of a sheet or foil, such as its ability to be deformed by forming a specific process from its original form to the final piece flat, without the occurrence of failure in the material, either broken or necking, the ease of a material to plastic deformation without defects [4]-[6].

The above is intended to orient the investigation to work with geometries that approximate and apply to a principle or Industrial application case, making decisions on the viability argued acceptable or not the process and have a specific comparison with the filling process. With the ultimate goal of making a functional prototype tested mechanical and dynamic evaluations of this process, to ensure the functionality and usability of a product manufactured under this innovative manufacturing process such as Dieless.

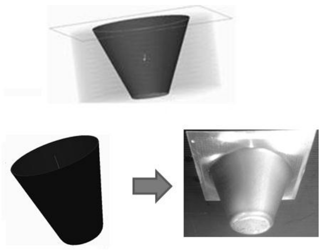

Fig. 2. Geometry associated an experimental case.

II. Methodology

For the experimental procedure followed the next

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[1] G-Code: The G code is a language trough which people can tell computer-controlled machine tools do and how. These "what" and "how" are defined mostly by instructions on where to move, how fast moving and toolpath or follow. Typical machines are controlled is code are milling machines, cutting machines, lathes and 3d printers.

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methodology:

As a starting point, we determine the geometry of the part: settled for the experimental case geometry conical differential characteristic angle formability, as shown in Fig. 2.

The blank plates or training are square sheets of 100 mm 1100 aluminum side and 1 mm thick.

For construction of diagrams-forming limit curves, it was necessary to perform the marking of the pieces, which consists of a grid of continuous circles of 5 mm diameter. In Fig. 3, this system can be observed on the piece of lined, which was made into a laser marking machine.

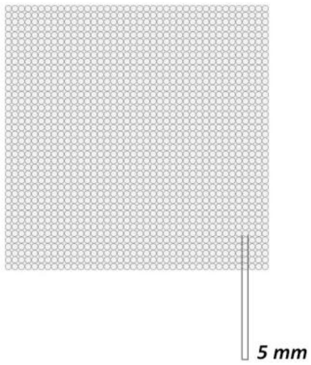

Fig. 3. Marking system plates under laser technology

Once the marking of parts is carried generation strategy and toolpath: The helical toolpath responds to a helical scan is made along the inner surface of the sheet deformed, it was necessary to work with CAM software.

Was subsequently carried determining process parameters Dieless. Both for design (CAD) of the experimental geometry, generating cutting strategies CAM, and assigning values to parameters involved in the process, it has high engineering software.

Machine Preparation and installation: Dieless device, Fig. 4 shows the assembly of the part Dieless device.

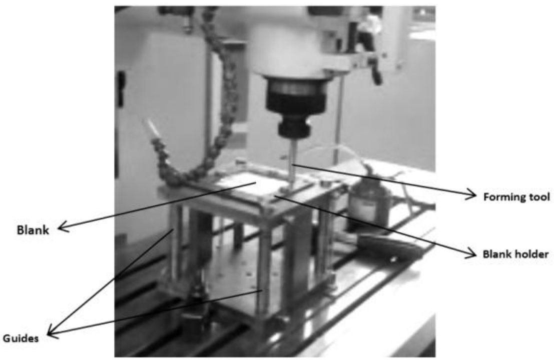

Fig. 4. Assembly of a piece in Dieless device with CNC machine-laboratories EAFIT University.

III. Results and Discussion

The testing and subsequently different experimental cases which are detailed below.

The formation and fracture criterion answers the formability evaluation part as mechanical forming; Fig. 5 shows the visual appearance of a formed part and a fractured part formation.

From a distance of 15 mm depth (Approx.), for different cases and different proofs, measured from the surface of the workpiece, such crack had fracture in the same place. As a hypothesis sheet thinning located at this point, which together with the formability angle are two extreme conditions which result in the presentation physically cracks and long shapes as shown in Fig. 6, which is then analyzed.

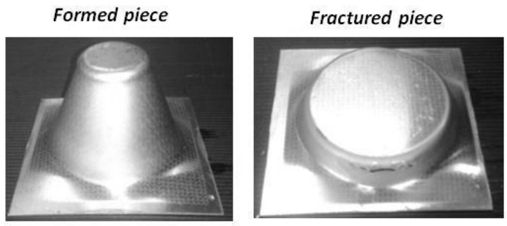

Fig. 5. Visual aspect for a formed and fractured piece from different experimental cases.

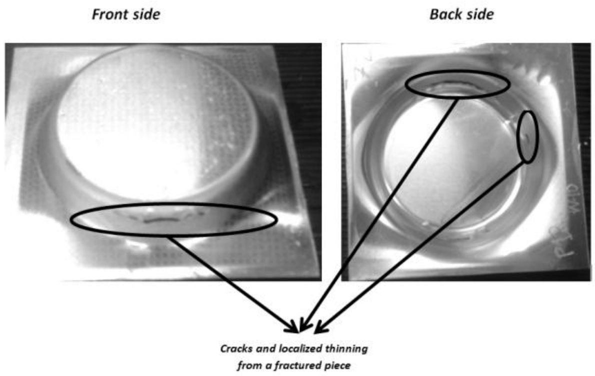

Fig. 6. Cracks and localized thinning from fracture piece in aluminum foils.

The cracks occur as a result of residual stresses produced in the work piece. These residual stresses are a major feature in the sheet forming operations and are commonly caused by non-uniform deformation during forming, causing a partial distortion when cut, and producing said cracking [5].

The parameters presented in Table I, are best suited and recommended for this geometry work, several authors in their research and procedures used tool diameters between 8 and 12 mm, high RPM and feed rates relative to the depth of cut [7] - [13], has been shown that the lower step, the surface quality and formability of the material are much better, considering cutting times are greater.

TABLE I: Nominal Values –Parameters for Experimental Cases SPIF Process

FORMING PARAMETERS PROCESS	
Tool diameter (mm)	10
RPM	3500
Cutting feed (mm/min)	5000
Step depth (mm)	1

Observing the process parameters shown in Table I, it is important to note that the progress, which has a value of 3500 mm/min, corresponds to approximately 50% of the maximum speed of the CNC machining center used (maximum advance machining center used 7200 mm / min). The strategy or tool path tool path was helical steps and 1 mm depth.

FLD Curve Construction

The diagram limit shaped for a sheet, is a graphical representation of the boundaries of main strains, where it may arise failure in plastic deformation during the forming process. From the above definition, we can identify areas along the deformed surface of the test piece, and account for the formability of the material.

For construction of the limit curves forming or diagrams FLD is necessary to calculate the result of the conventional deformation suffered by the piece, which is the relationship between the change in length of a specimen in the direction that applies strength and the original length of the sample considered [6]. In Equation (1) shows how to calculate it:

$$\%\text{Stretching} = \frac{Lf - Lo}{Lo} \times 100 \tag{1}$$

From the equation above, it is important to take data in different areas of the deformed part, before and after the process in order to obtain readings of initial lengths Lo, and final lengths of the same Lf.

Data for Construction of Curves FLD

Table II shows the data measured once deformed the workpiece, with the aid of the grid circles, ellipses now to determine the major and minor deformities in different areas of the piece, to analyze the formability of it.

TABLE II: DATUM FOR FLD CONSTRUCTION CURVE

Datum for FLD construction curve (Plate thickness 1mm)				
Datum	Major Length (mm)	Minor Length (mm)	% Major strain	% Minor strain
0	3	2,5	20%	0%
1	2,9	2,45	16%	-2%
2	5	2,2	100%	-12%
3	8	2,6	220%	4%
4	6,8	2,25	172%	-10%
5	6,5	2,3	160%	-8%
6	7	2,5	180%	0%
7	7	2,35	180%	-6%
8	6,8	2,65	172%	6%
9	7,2	2,8	188%	12%
10	4,5	2	80%	-20%

The above data obtained were plotted on the graph of FLD curve for the product obtained as show in the next figure:

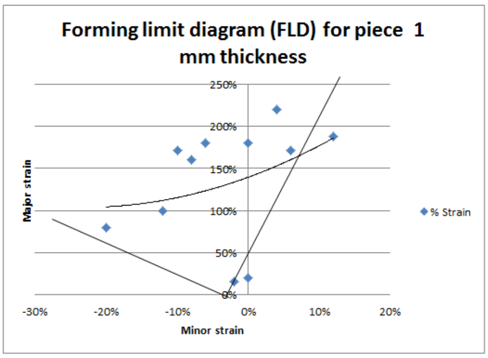

Fig. 7. Forming limit diagram for piece with 1 mm thickness.

As seen in Fig. 7, shown at the top right, a circular geometrical figure, shaded continuous contour which represents the circle inscribed in the aluminum foil before being deformed, and dashed ellipse in which due to the two-dimensional geometry of the elongated circle (ellipse) once the piece has been deformed. The dimensions of the coordinates shown with the letter b, the lengths are larger and smaller, respectively, which are the final readings (*Lf*) to determine the percent elongation and major and minor strains required for the construction of the curve obtained FLC above.

Greater deformation has been shown in axis Y, always positive due to stretching occurs and less deformation can be negative or positive, as can occur when stretched narrowing (Poisson effect) the initial specimen. It can be stated that under bounded or curved line are safe values and above the fault. For the particular case, there is an extreme value for which the strain is 80% higher and lower distortion is -20%, suffered in aluminum alloy 1100, which represents a good plastic deformation of the material obtained by through this process. The formability of a particular material will be better when the FLD curve is higher [6].

Comparing analogous to the process of drawing, on what is commonly used in the manufacture of hollow pieces such as this geometry experienced in this work and responds to the fundamental principle of sheet metal processing, are shown in Table III, a general comparative Dieless process [14]-[21] and stamping-drawing, for performing the piece addressed in this paper.

TABLE III: PROCESS COMPARATIVE - CONVENTIONAL SHEET METAL FORMING PROCESS AND DIELESS

	DEEP DRAWING	SUPERFORMING	STAMPING	SPINNING	DIELESS FORMING
COSTS	High tooling costs	Low tooling costs	High tooling costs	Low tooling costs	Low value on tooling
QUALITY	Good surface quality.	Good surface quality.	High surfaces quality	High surfaces quality	Moderate surface quality
PRODUCTION	High production batch	Medium production batches.	High production batch	High volume production scale	Low volume or production
SPEED	High process cycles	Moderate-cycles	Fast processing cycles	Fast processing cycles	Fast processing cycles
APLICATIONS	Food and beverage packaging. Furniture and lighting.	Aerospace. Furniture. Rail and automotive transportation.	Transport and Iron / Furniture/ Consumer products/ Maritime industry	Rail transportation Automotive/ Furniture /Jewelry	Rail transportation / Automotive

With the overview of processes of forming two sheet metal details the analogy to perform the experimental part, for which respective comparisons are described based on the observations in Table IV which shows a comparison of the performance part case study worked through the other processes in question, according to the calculations made for the part geometry and particular design parameters for the filling process [10]-[25], and any of the parameter values specified for Dieless.

TABLE IV: COMPARATIVE TO OBTAIN GEOMETRIC PART BY DIELESS AND STAMPING-DRAWING PROCESS

COMPARATIVE TO OBTAIN THE SAME GEOMETRIC PART					
	DIELESS	DEEP DRAWING	SUPERFORMING	STAMPING	SPINNING
Die for forming part	No	Yes	No	Yes	Yes
Blank holder for forming part	No	Yes	No	Yes	-
Speed (mm/min)	4000	30000	-	-	3000-7000
Steps Number	1	3	1	-	2 to 4
Process press (Kg/cm^2)	Low (Max. 4)	High(10)	High (8)	High (8)	Medium (5)
Tooling Costs	Low	High	Low	High	Low

According to the above Tables III and IV, that for high-speed production cycles or production rate for the manufacture of the part studied in this work, the deep-drawing and spinning process would be the most convenient alternative, but requires investment in tooling and tooling to ensure the formability of the sheet, such as matrix, blank holders to ensure the strength and pressure of the process described above. Dieless-SPIF process, contrary to what stated above, does not require blank holders, receivers and since the force and pressure in the process are relatively low

[10]-[25], only one pass is required to obtain the shaping of the work piece but the speed is much lower compared to the stamping –drawing process.

IV. Conclusions

As a conclusive principle and fundamental objective of this work was obtained aluminum sheets 1100, a conical piece with an angle of formability obedient taper experimental geometry. With the above provides a starting point and also an important step in finding a near future implementation of the process and a piece of industrial applicability.

Dieless-Spif process is a relatively new process compared with the deep drawing/superforming/stamping/spinning pieces, allows greater flexibility in the design of various surfaces, even complex, requires high labor costs in tooling and dies. Parts formability is acceptable, as demonstrated in the results of this work.

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