

## INCREMENTAL SHEET FORMING PARAMETERS AND TOOLS

Pablo Josué da Silva<sup>1, a</sup>

Leonardo Moreira Leódido<sup>2, b</sup>

<sup>1</sup> School of Mechanical Engineering -Universidade de Brasília – UnB.Campus Universitário Darcy Ribeiro – Asa Norte – Brasília - DF CEP 70910-900 Brazil

<sup>2</sup> Instituto Federal Brasília IFB – Campus Taguatinga  
 QNM 40 AE 01 – Taguatinga – DF – CEP 72.146-000 – Brasil

<sup>a</sup>pablo.silva@ifb.edu.br, <sup>b</sup>leonardo.leodido@ifb.edu.br

Alberto José Alvares

School of Mechanical Engineering -Universidade de Brasília – UnB.Campus Universitário Darcy Ribeiro – Asa Norte – Brasília - DF CEP 70910-900 Brazil  
 alvares@alvarestech.com

**Abstract.** *The incremental sheet forming allows the production in high quality of extremely complex pieces of steel, aluminum, titanium and many other materials, in order to reduce time and costs production and cost of tooling used in low production. Working with tools of various diameters and a suitable machine programming is possible to produce complex parts of small lots in few hours, which in conventional sheet forming process would take days. This paper aims to introduce process parameters and analyze results from practice tests and computational analysis by changing the rotation, advancement in XY and Z advancement, tooling options, fixture plate and forming tool for producing pieces of varying size and complexity in the shortest time and at highest quality possible. Thus, presents the incremental sheet forming as an alternative for rapid prototyping, as well as its devices and tools.*

**Keywords:** *Incremental sheet forming, rapid prototyping and parameters*

### 1. INTRODUCTION (TIMES NEW ROMAN, BOLD, SIZE 10)

Reducing the time and cost of manufacture with increased quality production are the main targets of product manufacture. Accordingly, new manufacturing techniques and processes have been developed, notably among them the incremental sheet forming.

The Incremental Sheet Forming (ISF) is usually applied in two situations: in the manufacture of prototype, for analyses of functionality and design for a new product, and the manufacturing custom, personalized or small scale.

In the process of ISF a tool of simple geometry performs the conformation of a metal plate via successive deformations applied locally using a CNC - Computerized Numerical Control (Shim and Park, 2004). In this process, the printing is done through a tool tip ball that moves through a path programmed by a software CAM (Computer Assisted Manufacturing) and executed by a CNC machining center or CNC milling machine.

To perform the printing, the sheet to be formed must be centered and fixed by screws in one gland plate with its central section leaked. The sheet forming can be made in various ways, considering the configurations adopted for the amount of support points or tools used. Besides the simple sheet forming point, using a tool that performs movements of translation and rotation, there is a double point sheet forming, that uses a simple geometric shape and a stationary tool positioned under the plate. There are processes which make use of die positive or negative, also positioned under the sheet which will form the final product, as shown in Fig. 1 (Bambach et al.).

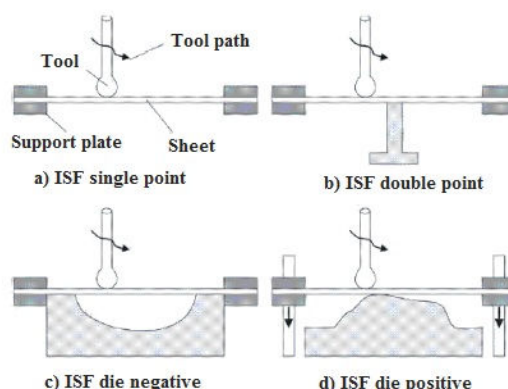


Figure 1. Different configurations ISF.

Attanasio et al. (2006) observed that the ISF may cost in the order of 5 to 10% of the total cost in conventional sheet forming. The cost composition allows define the minimum and maximum quantity to be manufactured with economically feasible.

The ISF presents as main advantages: low cost preparation machine, the use of common three-axis CNC machinery and great flexibility, as new products are obtained by changing only its CAD model, thereby enabling the production of small batches (Micari et al., 2007).

The process usually has plate to be formed into a rectangular shape (independent of the shape final format), with thickness varying between 0,7 and 1,5 mm, depending on the type of material and its mechanical characteristics. This plate is attached to a mobile device, sliding parallel to the Z axis of a CNC system (Russain et al., 2007). Fasteners prevent the plate from moving while printing is taking place, thus allowing plastic deformation of the plate occurs. This plastic deformation is generated by a rotating tool attached to the spindle of a CNC device, which starts the sliding process of ISF on the surface of the plate by means of vertical increments negative, carrying out the forming. This process is called "single point", this point being determined by the rotary tool conformation (Hirt et al., 2005). In this kind, the tool base disposed at the bottom embossing assembly is eliminated and only the tool attached to the spindle comes in contact with the plate. As the process uses a simple tool, the higher cost of this process is to manufacture the fixation device.

Presented the basic operation of ISF becomes evident the ease of application and market interest in introducing it as a process that can be used as rapid prototyping for sheet metal.

For this reason, it becomes necessary to improve the devices and tools used in ISF, as well as setting parameters of materials and processing, since there is little information available in the literature related.

This paper aims to introduce process parameters and analyze results from practice tests and computational analysis by changing the rotation, advancement in XY and Z advancement, tooling options, fixture plate and forming tool for producing pieces of varying size and complexity in the shortest time and at highest quality possible. To this was developed in which one tooling tests were performed to analyze the process parameters and set limits to the manufacture of parts made of steel with low carbon content.

## 2. MATERIALS AND METHODS

In the initial phase of this research, were produced and used two different fixation devices (Fig. 2) to analyze the difficulties and what could change to promote the improvement of the process.

Figure 2a shows a standard device commonly used and Fig. 2b shows a device having an oxicut base whose attachment piece is performed by rivets.

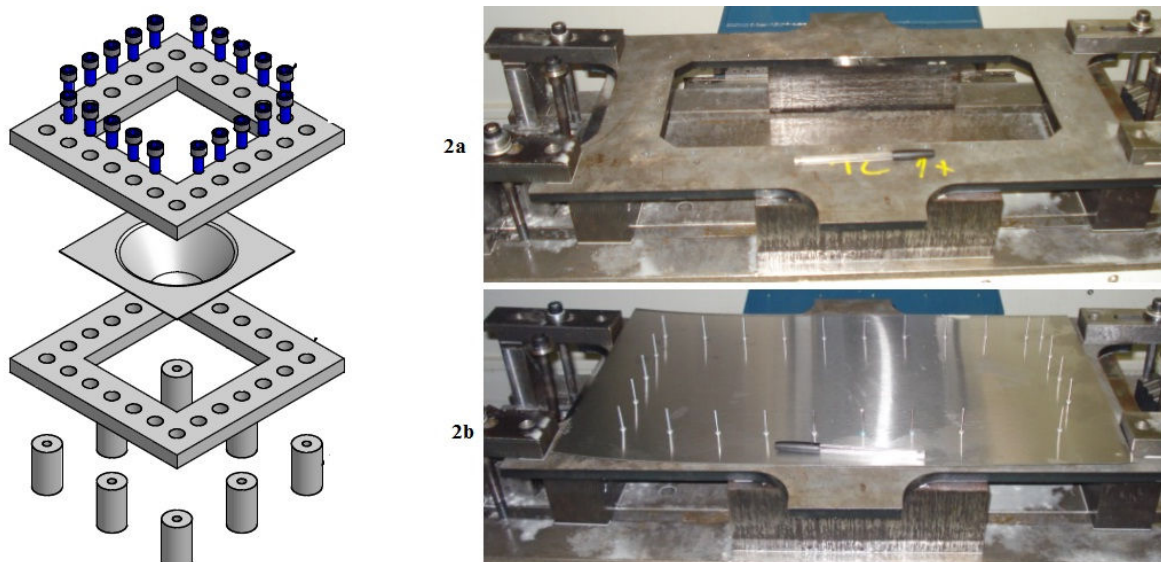


Figure 2. Different fixation devices for ISF.

The two devices in Fig. 2 were used for the manufacture of parts by means of ISF. By studying the two devices noted that it is possible to develop a third one, enabling reduction of process time and cost of the ISF.

This new device has a size adjustable executed by slots "T" profile and the fixing plate to be formed will be done by clamps.

Taking into account the high set-up time, the setting will feature quick release clamps. This way, you can reduce the time by half, as to steady the sheet will not be necessary to use allen key. The entire assembly work is manual and the

clamping force is defined by the type of clip to be used. The new device, as well as that shown in Fig. 3, is formed for two sheets, support sheet and clamping sheet. The clamping sheet distribute the force of the clamps equally over the whole plate being formed.

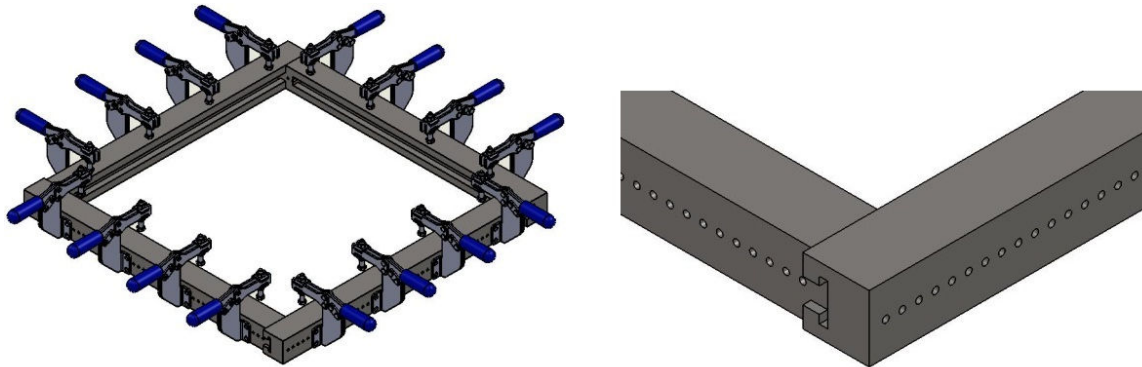


Figure 3. Fixation device with quick clamping.

In ISF process there is friction during contact between the tool and the plate to be formed. The most important point is to know how it will influence the process to define the parameters and try to control their negative effects. The control of friction is done by use of a good lubricant and an excellent surface finish of the tool and the sheet. Therefore it is necessary to polish the tool tip and plate to be formed must not contain surface imperfections, scratches or dimples. A high friction can result in the incidence of premature wear of the tool or the plate.

Getting control these parameters and if the incidence of premature wear during printing continues must be analyzed where wear occur first. If wear has occurred on the first tool is a sign that the material used for its manufacture was not the most appropriate or the heat treatment was not effective and the tool did not remain with the hardness required for the process. If wear has occurred on the first plate may be that the tool is the tip or with an irregular surface finish inadequate, or process parameters may be unsuitable as the high rotational or a very small incremental forming tool pace.

To reduce or eliminate some variables of the process was developed a tool with special features for ISF. It has two simple bearings and an axial at the top so that rotation is not specified by the programmer rather defined by the process itself.

The rotation when set by the programmer result in a constant rotation and the ISF this should not occur. The rotation must vary as the profile of the piece to be shaped, thus having a variable rotation to the process, as the tool rotates free into contact with the surface.

During the ISF process, the tool tip is much in demand, so the choice of material of manufacture thereof is an important step in research. The tool shank must be malleable to support small deformations and vibrations, while the tip has to be of material with high polishing strength, good wear resistance and dimensional stability. These are the requirements of an ideal tool for the incremental process and to don't make this process so expensive it is important that the rod is a single piece of a same material.

Analyzing the easy acquisition material on the market come to H13 steel because it's a material that meets most of the mechanical properties. Fig. 4 shows the tool with the two-piece tool in hardness desired.

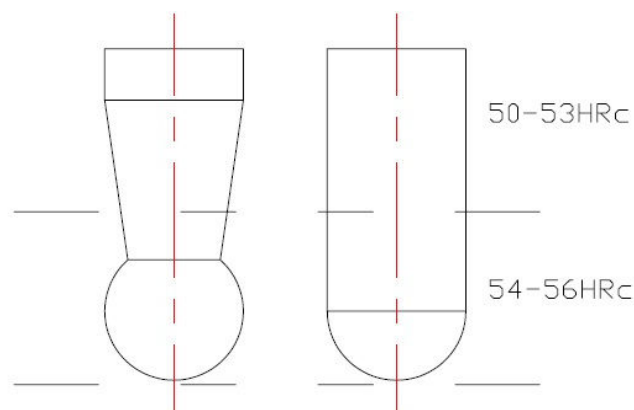


Figure 4. Drawing showing the 2D H13 hardness of the steel used in the tool. The right tool with ball nose point and left tool with semi-spherical point.

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The tool formats commonly used are the two shown in Fig. 4. The tool from the left has a very high complexity for its manufacture, this tool can only be produced by a CNC lathe, and it makes the process difficult and expensive. At the right is a tool known as Ball Nose, which is a very useful tool, because it is easier to manufacture. But the ball nose is not the most appropriate for ISF with high quality as it can let bad superficial quality, however as the objective of this process is always cost reduction, ball nose ends up being the most used tool profile.

Using tools developed, press plate and the forming tool, tests were performed to analyze the process parameters and set limits for the manufacture of steel parts with low carbon content. In practical tests was ranged up the speed on XY, the lowering speed of the tool in Z and the depth of each step, also known in the industry machining as AP.

In practical tests were used a CAD modeling of three distinct parts, one of simple geometry, Fig. 5a, one large piece of simple format Fig. 5b and other very complex geometry Fig. 5c.

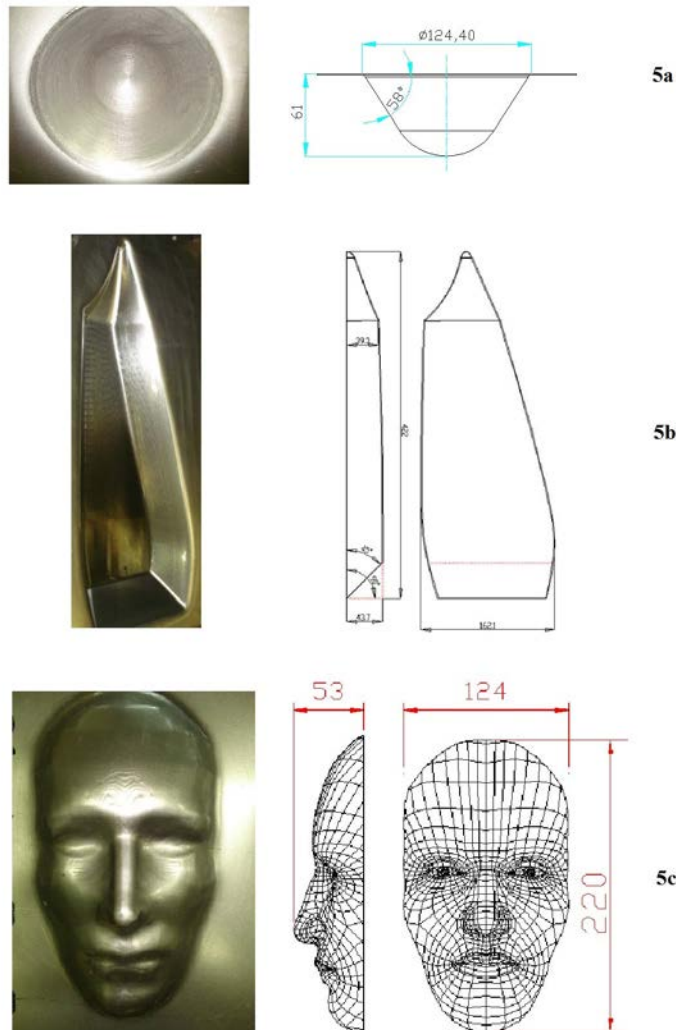


Figure 5: Produced example of the ISF in steel sheet SAE 1008 with 1mm of the thickness.

### 3. MATERIALS AND METHODS

The parameters used in the tests of ISF were modified according to the needs of production determined by the characteristics of the parts to be produced.

In the model shown in Fig. 5a, is possible to manufacture pieces using Z increment of 0.2 mm to 0.6 mm, a feedrate in XY ranging from 600mm/min to 8400mm/min and the free RPM. The spindle necessarily have to be free to rotate with the contact of the tool on the workpiece.

The definition of which parameters should be used depends on the quality of the final surface to be obtained.

All tests were performed using a helical trajectory tool, it is the trajectory smoother and that leaves less marks on the piece and also features a shorter time implementing it.

When using high advances, there is an increase in temperature by friction part by measuring the temperature of the piece subjected to a forward speed of 8400mm/mim was obtained 215 degrees Celsius.

In the manufacture of the part shown in Fig. 5b, the set up process parameters in XY advance was of 1600mm/min, Z increment of 0.2 mm, free rotation and varying the speed of descent Z from 100 mm/min to 1600 mm/min.

It was found that descent speed in Z also influences the surface finish of the material. In the analysis, the best outcome was what kept the speed of descent in Z equal to XY.

The piece of the Fig. 5b is formed by various different angles, of which the bottom part has a small inclination. This detail proved paramount importance for trajectory programming, therefore, to maintain the high quality of the bottom surface like of the side, it is necessary to reduce the increment in Z.

To produce the piece shown in Fig. 5c, of complex geometry, was used the same data piece of the Fig. 5b. However, the piece could not be formed with the same tool and the forming had to be made in two steps.

In the first step, the plate was formed with a tool diameter of 14mm, leaving the piece without forming details such as eyes, nose and mouth.

The second step was performed using a shaping tool of 10.5 mm to forming perfectly to all the details of the part, and a Z increment of 0.1 mm.

In the trajectory of the tool, was modified the helicoidal descent angle, which had an inclination of 15 degrees and this inclination was increased to reduce the effort of forming during the descent of the tool Z.

#### 4. CONCLUSIONS

The analysis of the results leads to conclusions concerning the mounting device, the tool conformation and the following process parameters: tool sheet forming rotation speed and XY advance speed.

The use of a mobile device with quick clamping make possible a significantly reduce the time and cost of the ISF. The clamps cannot be used directly in the plate to be formed, as this will not fix the plate with the force required to not occur the sliding of the workpiece. To avoid this, it is necessary to have a more uniform distribution of clamping pressure, as well as having a single sheet between the piece to be formed and clips.

As the tool, it is noted that it must be malleable to support any type of impact, and very resistant to withstand high friction and heat the sheet forming process yield. She has to rotate freely with the friction that occurs between the workpiece and the tool, and the rotation must fit the part to be formed.

In the process parameters, the high speed is not beneficial to the process. It causes a high friction between the tool and the plate, caused wear in both. This friction generates sufficient heat to degrade the lubricant and thus has a plaque marked wear which can result in microcracks in the wall part.

When the piece has multiple angles or is of high complexity, it is necessary that these difficulties are assessed and considered in scheduling the tool path, thus it will be possible programming that has a variation in the increment and the helical angle of trajectory.

Para se realizar detalhes com perfeição na peça, o incremento em Z tem que ser menor do que o aplicado no restante da peça, pois quanto menor o incremento maior é o tempo de processamento. Mas se o incremento for muito pequeno, a peça fica com marcas da trajetória da ferramenta.

To achieve perfection in detail with play, the Z increment has to be smaller than that used in the rest of the part, since the smaller the greater the increase in processing time. But if the increase is too small, the piece gets marks the path of the tool.

The ISF is capable of producing pieces of any shape and complexity, simply using the appropriate parameters.

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