INCREMENTAL SHEET FORMING OF ALUMINUM FOR COMPLEX PIECE

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Abstract. *This article aims to present a study of single point incremental sheet forming (SPIF) with heat for aluminum sheet, Alloy1050, of 1 millimeter (mm) thickness, which proposes to evaluate the contribution of adding heat to the process by halogen lamps during the production of complex pieces. The heat SPIF allows obtaining parts with geometric details at angles close to 90 degrees at a low cost by the halogen lamps heating device; moreover, the maximum temperature of this process is achieved by the union of two heating processes: halogen lamps and high speed tool rotation (6,000 RPM). The insertion of temperature into the process plus rotation, results in the conformation of a human face in rich detail. In addition, this work has the objective of presenting process parameters for a complex aluminum surface, in which a comparative study is carried out between the stamping with or* without heat by heating device.

Keywords: *SPIF, Alloy, high speed*

1. INTRODUCTION

The industry and the academic community have shown an augmented interest towards the process of Incremental Sheet Forming (ISF) in recent years, and furthermore, its application to thermal plastics such as PVC (Silva and Alvares, 2015). The ISF produces pieces which are similar to the conventional sheet forming process, however, tools or dies for different shapes are not required by the ISF, and that results in lower costs for small batch production. It is a flexible procedure and most of the researches use lightweight materials (Silva et al, 2013). The ISF is applied in forming a plate by using a simple tool with ball tipped staff and a fastening device with two hollow plates. In the forming process, the tool follows a path created by a CAD/CAM and is performed by a CNC machine (Xu et al, 2014). This process aims to produce prototype pieces, rapid prototyping and small batch production. Many authors point out the low accuracy as a major obstacle for the process to become commercially feasible, and they are tempting to improve the accuracy by heating the plate through a laser beam (Silva et al, 2013 and 2015).

The SPIF process has some limitations, including the long processing time, low geometric accuracy and the rough surface finish. Several papers and researches have been studying a way to minimize these problems and make the process more competitive (Wang et all, 2016).

One of the great problems of incremental stamping is the difficulty of obtaining complex surfaces with good surface and dimensional quality. In order to solve this problem, the heating in the forming process was introduced with additional heat to the sheet to be formed, which makes it more adaptable.

For the improvement of the stamping process, several authors carry out different types of searches such as: hot laser forming (Hino et all, 2014), electric current (Xu et all, 2014) halogen lamps or using high rotations to perform heating (Hussain et all, 2009), forming multiple passes, optimizing a toolpath for forming, working with a negative matrix, working with two support points. However, these modifications in the process increase the cost or the time of conformation.

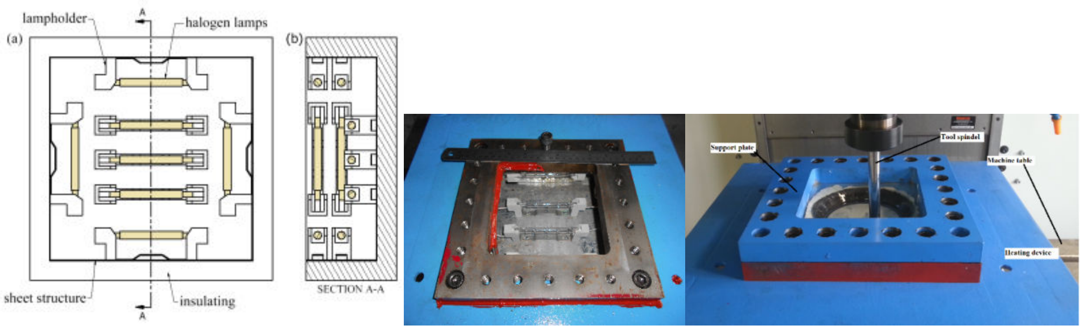
One of the main limitations of the SIPIF process is the wall angle. Aiming at the production of complex geometries with angles close to 90 degrees at a reduced cost, a conformation study was carried out with halogen lamps and high rotation. In this study the two processes were combined in order to achieve a conformation of a complex geometry in low time and high quality by the conformation process of the SPIF method, since this method is the one with the lowest manufacturing costs.

The present experiment intends to increase the conformation capacity of the incremental single-point stamping process for the conformation of a complex geometry with the insertion of heat, which increases the flexibility of the sheet to be formed and, on the other hand, makes difficult the dimensional control of the process, due to the consequent expansion of the materials involved - tool and sheet.

2. EXPERIMETAL SETUP

The heating, during the SPIF, aims to increase the ductility of the material, and also makes the deformation process easier and even faster. At an elevated temperature, the materials strength is reduced by strain hardening. As the conformed plate is made from aluminum (Alcoa 1050), the experiments are scheduled to obtain the highest temperature possible during processing. Therefore, the heat also provides a reduction in strain hardening of the workpiece during the SPIF process.

The dimensions of the heating device were defined in accordance with de external dimensions of the piece to be conformed; i.e. width, length and depth of 150x150x80mm respectively. It has a square base, 11 halogen lamps of 100W and length of 117.6mm, which were installed by 2 on each side and 3 on the bottom, as shown in Figure 1.



(a) (b) (c)

Figure 1. The figure (a) shows the device design; (b) shows the real device and (c) device overview

To start with the initial warming, the forming process was performed with a pre-heating of 30 minutes. During this preheating time, measurements were carried out by checking the temperature which was performed with two different equipments: a thermal FLIR camera brand I40 (-20 to 350 ° C) with an accuracy of ± 2 ° and an infrared thermometer brand model FU 900 EN 00 with a temperature range of -50 to 900 degrees Celsius, including an accuracy of ± 1.5 degrees, from which the acquired data is presented in the heating profile, as shown in Figure 2.

The temperature was increased until the heating had been stabilized and the temperature had stopped rising. This heating process occurred in 45 min, whereby the temperature reached 192 degrees Celsius and remained unchanged for 50 min until the measurements had been interrupted and the conformation tests could be started.

It is known that at a rotation of 6000 RPM a temperature above 100 °C can be achieved.

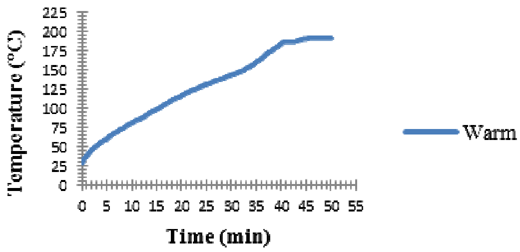


Figure 2. Heating profile

2.1. Experiment planning

The conformation strategy is to use the process heating combined with high tool rotation, which gives the process, in addition to the general heating, a point heating projected on the plate for conformation of the human face geometry at scale, Figure 3.

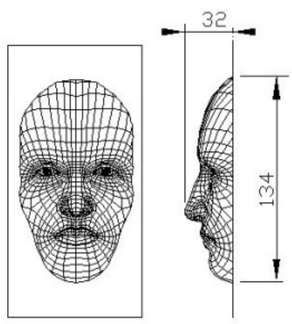


Figure 3. Face design

Three tests with different conformation parameters were performed for better analysis of the process. The conformation parameters kept the Ap (vertical pitch in Z) unchanged at 0.2mm and the tool speed at 6000 RPM, and varied the conformation and heating strategy to analyze the ability of the process to be able to conform complex geometry pieces with Or without the aid of heating, Table 1.

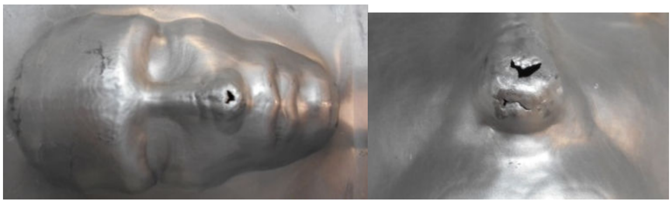
TABLE I – Parameters of Process

Test number	Parameters of Process			
	Ap	*S(RPM)*	*Strategy*	*Heating Device*
01	0,2 mm	6000	Total forming	No
02	0,2 mm	6000	Forming initiated by the details	No
03	0,2 mm	6000	Total forming	Yes

Test 1 presents a strategy of total sheet forming that is done from the outside to the inside (finishing strategy) and without heat. Test 2 is performed without heat by the device and the conformation is initiated by the details conforming initially by the nose and a part of the forehead, to avoid more thinning of the sheet at the time of deeper conformation. Test 3 is performed under full forming strategy (finishing strategy) and heat device by halogen lamps, as well as high speed

2.2. Execution of the test

In the execution of test 1, the conformation was completed, but the nose tip ruptured the plate in the deepest part. The material at the point where the rupture occurred was remarkably fused and subsequently reshaped by the tool tip, see Figure 4.

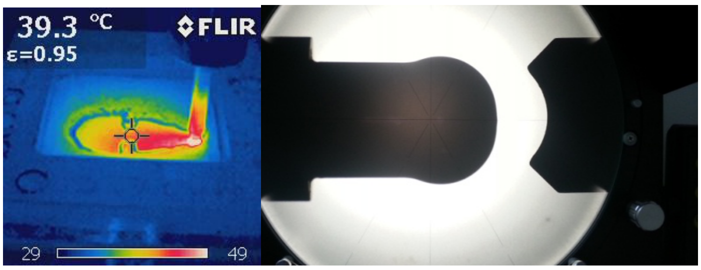


(a) (b)

Figure 4.Test 1 (a) final piece (b) break detail

In order to reduce the errors of the forming process, the tool was checked after each test to see if there were no wear, as the use of high rotation generates high friction that can cause premature wear of the tool.

The tool check was performed on a profile projector with the aid of a template produced specifically for this purpose, as shown in Figure 5.

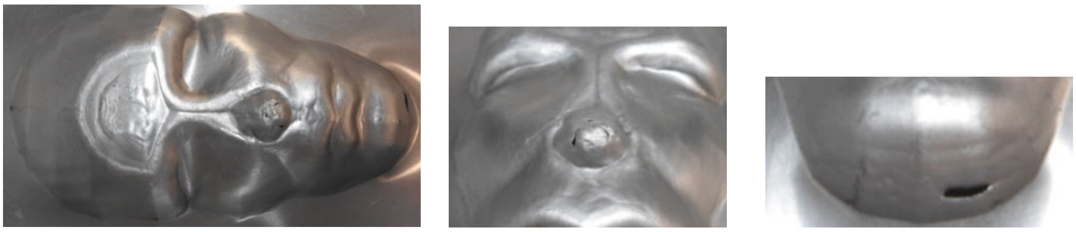


(a) (b)

Figure 5. Thermal vision camera (a) and (b) profile projector image da ponta da ferramenta de conformação

Figure 5 (a) was generated by the thermal camera where the path that the tool traverses generating heat is visualized as the back of the tool or the path that the tool recently passed becomes warmer, thus reducing the hardening of the material that is generated by the plastic deformation of the process. As the piece is being formed, the plate heats punctually. Keeping the forming tool unchanged, the impact of this point heating can be minimized by increasing the sheet to be formed, since the point heating will remain the same and the piece itself will get larger.

The execution of test 2 proceeded without warm and with the conformation initiated by the deeper parts of the specimen, such as: the forehead, nose and mouth. This test was done in an attempt to avoid the thinning of the plate in these more demanding points, however, it also showed ruptures as seen in the first-piece test. As presented in Figure 6, the rupture which occurred in the nose was smaller than by the conformation parameters of test 1. This piece was the one that owned the most errors, because the conformation left marks in the piece in two parts, resulting in an irregular conformation and also in the rupture of the same two points in the nose and the chin.



(a) (b) (c)

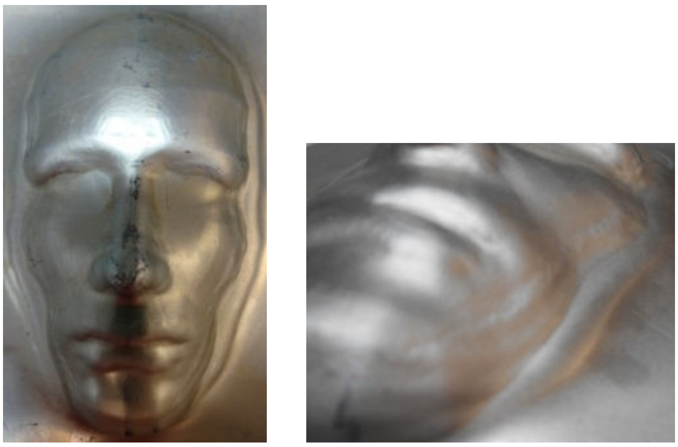
Figure 6. Test 2 (a) final piece (b) detail of nose break (c) detail of chin break

The sheet ruptures occurred at the two most crucial points where the part geometry approaches an angle of 80°. The rupture of the chin, due to the thinning of the material together with the later forces of conformation, caused the rupture that appeared after the conformation of this point.

Test 3 combines the two forms of heating, high rotation and heating by halogen lamps. The sheet forming was carried out in a direct manner, allowing the heating matrix to reach the stability temperature in 50min, after which the total conformation strategy was performed, from the outer part of the piece to the inner part, see Figure 7.

Figure 7. Sequence of the process

The part resulting from the execution of test 3 did not present any cracks and it was able to obtain all the details of the CAD model, see Figure 8. It is worth noting that prior to forming, the forming plate swelled, creating an upward protrusion, caused by the heat of the device. Due to this heat the Aluminum plate suffered expansion and with it attached to the four sides, this ended up causing an undesired deformation of the whole plate. This deformation generated a mark on the part, thus creating an unwanted conformation in the final piece.



(a) (b)

Figure 8. Final peace of test 3

The undesired deformation caused by heat device is shown in figure 9, which shows the plate before and after heating.

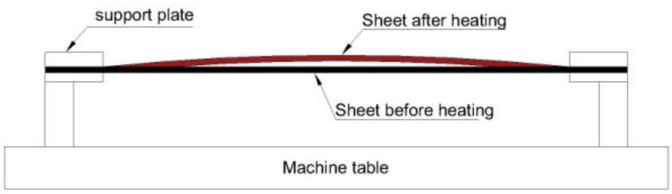


Figure 9. Undesired deformation (z-flexion) in the sheet caused by heat device

3. CONCLUSION

The single point incremental sheet forming has limitations when it comes to forming angles. These limits can be minimized or even eliminated when we insert new factors to the process, as done in the present research with the insertion of heat.

The heating insulation in the process can enable the conformation of a piece of complex geometry and with well-inclined wall angles, close to 90 degrees, but can also bring inconveniences to the process such as the expansion of the sheet to be formed.

The Z-flexion, which occurs in the part shown in Figure 9, can be compensated in the forming strategy in the CAD / CAM process, must be enough to measure the z-flexion and informing to the Software that the initial sheet format is no more than Z = 0, eliminating largely the error of the final part.

To conclude, we can affirm that the insertion of heat and high rotation in the process in SPIF can generally give good results while conforming geometries of high complexity, thus reducing the process limitation and creating a heating device that can be easily applied in industry and academia.

4. REFERENCES

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