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SPIF of Brass Alloys: Preliminary Studies

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Abstract. This article discusses the preliminary studies of the Single Point Incremental Forming (SPIF) process applied brass alloy Cu-35Zn, with different sheet thicknesses and formed geometries. Despite being a material widely used in industry, with excellent cold formability, there is still no relevant research on this material concerning SPIF. As a result of these preliminary studies, the necessary forces (*F*) during the process, the true strain (ε_1, ε_2) and maximum wall angle (ψ) supported by materials are presented and discussed.

INTRODUTION

The incremental dieless forming process was described and patented by Lezak in 1967 [1], time that CNC technology was still elementary. Because of this, only in the 90s, with the technological evolution of CNC equipment, especially thanks to advances in electronic field, the research on ISF returned, being widely researched and developed since then [2]. As from few resources (backing plate, punch and a CNC machine), it is possible to form a series of products with different formats, allowing such design flexibility and manufacturing of parts, becoming a competitive alternative to economically and efficiently produce small batches of stamped products in sheet metal [3].

In the Single Point Incremental Forming (SPIF) process, the sheet to be formed (blank) is clamped in a fixed support (backing plate), usually next to a CNC machine. Coupled to the spindle, a simple tool (cylindrical shank with the spherical/hemispherical cutting edge) produces a small deformation on the sheet. Accordingly, the tool moves over the sheet, with gradual negative vertical increments (Δ_Z), it will deforming the new contact regions. Generally the product to be manufactured and the tool deformation path, are generated from the CAD / CAM software [4].

The particular deformations mechanisms during the forming operation contribute to a higher flexibility by increasing the formability of the sheets [3], making it a very interesting process, especially for industries that require prototyping sheet metal, as the automotive and aerospace industries. The vast majority of research has been carried out on steel, aluminum, titanium and magnesium alloy sheets, [5], [6], [7], [8], [9], [10], with few approaches in other materials.

Aiming to expand the range of materials employable within this process, this paper aims to introduce the brass alloy in the SPIF research, analyzing the influence of thickness sheet and vertical increment in the brass alloy formability. As having an excellent cold workability and a good hot formality, the brass alloys are applied in the manufacture of various products, such as core automotive radiators, heat exchangers, locks, ammunition cartridges, medical and surgical devices, wind musical instruments, ornaments, among others.

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MATERIAL AND METHODS

For this research the brass alloy Cu – 35Zn (SAE J463) was used. Its excellent cold formality, good corrosion resistance and its golden aspect, provide easy manufacture of various products, such as core automotive radiators, heat exchangers, wind musical instruments and decorative parts. Its chemical composition is shown in Table 1 and their mechanical properties in Table 2.

Tests consisted in incrementally forming conical and pyramidal frustums, in blanks of 150 mm x 150 mm, of 5 mm thicknesses (t_0), with radial profile wall (50mm radius), diameter 100mm and square 100mm, respectively (Fig. 1). The tool was also heat treated, resulting in an increased hardness to 58HRc. Its geometry consists on a spherical tip with a 15 mm diameter. The trajectory performed by the tool consists in the 3-axis contour tool path, with a vertical increment (Δ_Z) of 0.1 and 1.0 mm. The tool has passive rotation, as described in [3] and average travel velocity of 3000mm/min.

TABLE 1. Chemical composition of brass alloy Cu – 35Zn

Cu	Pb	Fe	Zn
64,00 – 68,50%	Máx. 0,15%	Máx. 0,05%	31,50 – 36,00%

TABLE 2. Mechanical properties of brass alloy Cu – 35Zn

Properties	Value
Density	8,47 g/cm³
Young Modulus	105 GPa
Tensile Yield Stress	97 to 427 MPa
Hardness	132 HV

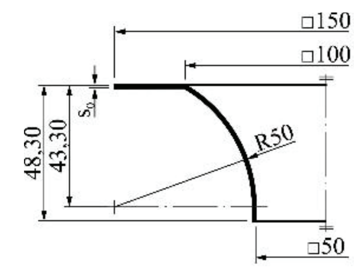
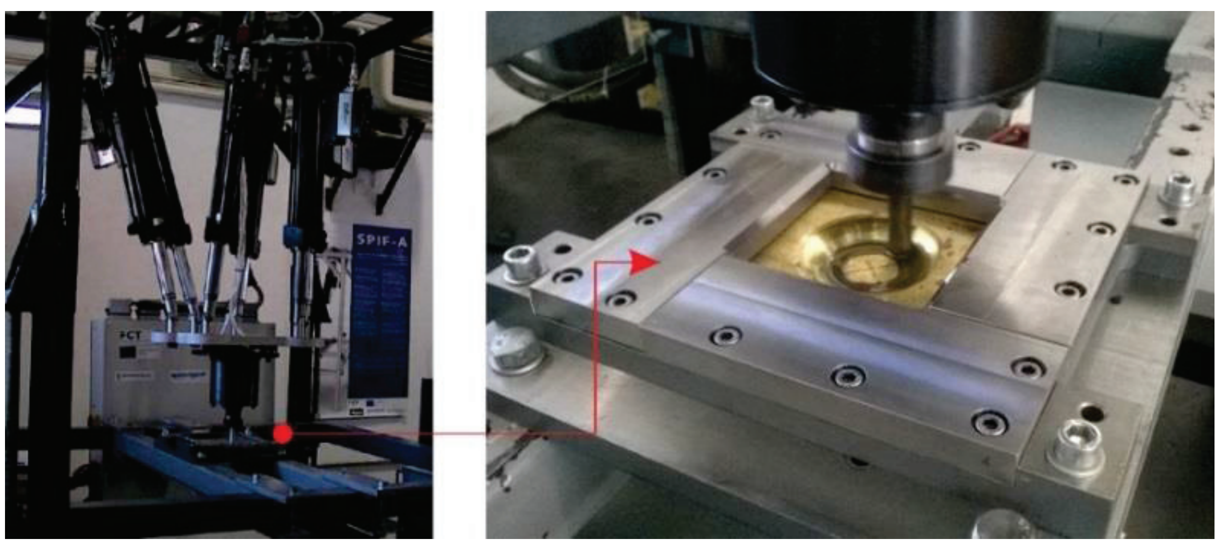


FIGURE 1. Pyramidal frustum geometry

The experiments were performed in the SPIF-A machine [11], developed specifically for incremental sheet forming (Fig. 2).



(a) (b)

FIGURE 2. (a) SPIFA machine; (b) Forming conical frustum brass alloy Cu – 35Zn.

To analyze the true strains (ε_1, ε_2), electrochemical recording was made using a grid of circles (Ø2,75mm) on the surface of each sheet. The measurements were performed with a Digital Microscope. The determination of the maximum wall angle (ψ) was carried out according to the maximum depth reached. The machine control system continuously measures forces resorting to a system of 3 load cells [11].

RESULTS

Figure 3 presents values for forming forces along the tool axis (compressive) direction, according to the vertical increment (Δ_Z). Also, for vertical increment (Δ_Z) of 0.1 mm, the initial slope of the force curve is lower than for vertical increment of 1.0 mm, showing out a greater force required at the beginning of SPIF process. Furthermore, with a vertical pitch of 0.1, it was possible to reach a greater depth in the experiment. The maximum wall angles (ψ) were found 66.90° and 63.30° for vertical increment (Δ_Z) of 0.1 and 1.0 mm, respectively.

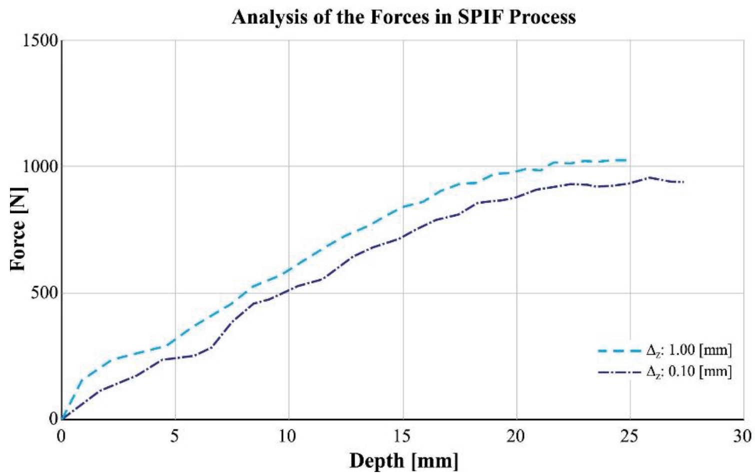


FIGURE 3. Evolution of the forces during the SPIF process with different thicknesses and vertical increment.

The ellipses next to fractures were measured and plotted on the graph of true strain (ε_1 x ε_2), thus building Fracture Forming Line – FFL, of each vertical increment (Δ_Z), together with Forming Limit Curve – FLC of material. In figure 4 it can be seen how much the SPIF process deforms more than conventional forming processes, also reported by Jeswiet [3]. Also realizes the increased formability (strains) by reducing the vertical increment (Δ_Z).

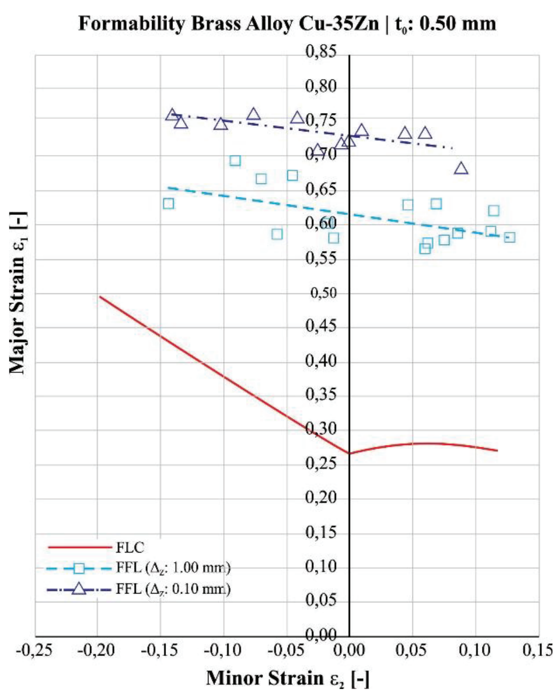


FIGURE 4. Experimental FLC and FFL with two differents vertical increment (Δ_Z).

CONCLUSIONS

The results herein presented give a preliminary insight into the mechanical resistance of a brass alloy under incremental forming processing. Further studies will include thickness profile, geometry accuracy and different tool diameters. From the small set of analysed results, the material presents the typical trends regarding the rise of forming forces with increasing vertical increment (Δ_Z), and the rise strains with decreasing of vertical increment (Δ_Z). Further studies are being carried out at the moment.

ACKNOWLEDGMENTS

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