Process limits improvement in sheet injection using locally heat-treated aluminium alloy

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Abstract. The present study investigates the possibility of improving the technological limits of the sheet injection process using locally heat-treated aluminium alloys to address challenges such as underfilling and material flaws. Aluminium alloys are highly valued in lightweight design due to their excellent strength-to-weight ratio, but their limited formability remains an open challenge in advanced manufacturing processes. This work focuses on the design of the laser heating to locally bring an age-hardenable aluminium alloy (AW6082) from the T6 purchasing temper to a full overaged condition to improve its formability in targeted zones. The sheets, characterized by a gradient of properties, are then subjected to injection by upsetting the side walls. The experimental work includes mechanical characterisation by means of tensile and compression tests, as well as sheet injection trials. Numerical simulations are conducted to predict and optimise the material flow during the injection process. Results demonstrate that the localised heat treatment allowed to effectively enhance the formability of aluminium alloys at room temperature, enabling the successful achievement of complex geometries with a reduced risk of defects such as material flaws. Key insights include material flow control in obtaining defect-free sheet-bulk parts. The study offers a comprehensive approach combining the local modification of the material properties with an advanced forming process, paving the way for more efficient production of lightweight and high-performance parts.

Keywords: Sheet-bulk forming; Sheet injection; Laser heat treatment; Process limits.

1 Introduction

Due to the increase in greenhouse gas emissions and the urgency to reduce its impact on climate change, saving resources has become a key priority in the 21st century [1]. This creates new challenges in the manufacturing industry due to the growing emphasis on shorter production processes and enhanced material and energy efficiency [2]. To meet these requirements, lightweight design is a promising approach in which aluminium alloys play an important role due to their excellent strength-to-weight ratio. The problem with aluminium alloys is their low formability which poses a challenge for their application in advanced manufacturing processes, especially in sheet-bulk metal forming (SBMF) where sheets are subjected to three-dimensional forming [3]. Therefore, sheets with customized mechanical properties can be a solution to overcome this limitation by improving the material formability in critical areas.

In this context, to produce such sheets, currently named Tailored Heat Treated Blanks (THTB), Laser Heat Treatment (LHT) is applied on the surface of an aluminium alloy AW6082-T6 sheet (initial thickness, 3 mm). LHT is appropriate for this purpose because the treatment can be limited to the area of forming, thus offering the potential to save process time and energy, when compared to treatment in a furnace [4].

Ultimately, the THTB will be used as a semi-finished product in a SBMF process combining bending and upsetting, to manufacture a bent part with a rib (Fig. 1).

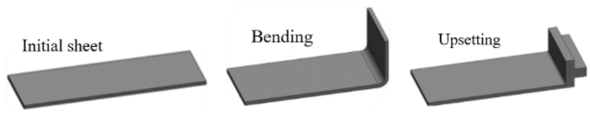

Fig. 1. Schematic representation of the process chain.

2 Experimental work

The experimental work consists of characterizing the alloy in the as-received conditions as well as after being locally altered by the local laser heating. For this purpose, several tensile and stack compression tests were performed on aluminium alloys AW6082-T6 sheets with 3 mm thickness and on the same sheets but subjected to LHT, referred to as AW6082-LHT. The geometry and operation conditions of the tensile and stack compression tests follow the ASTM E8/E8M-22 [5] and ASTM E9-19 [6] respectively (Fig. 2). In the case of the AW6082-LHT tensile specimens, the LHT covers only a specific area in the middle represented in

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orange, in contrast with the AW6082-LHT stack compression specimens, where the LHT covers its entire volume (Fig. 2). Consequently, deformation in the AW6082-LHT tensile specimens is localized in the LHT zone, leading to a lower true strain measured over the gauge length compared to the AW6082-T6 specimens.

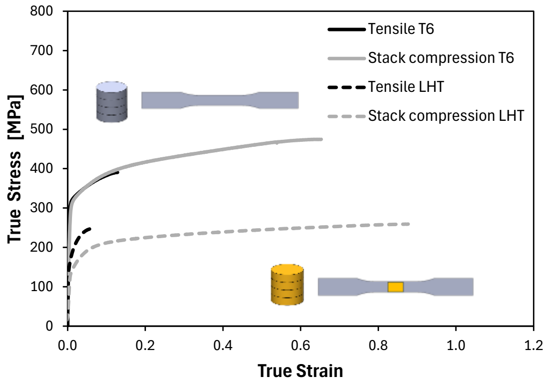


Fig. 2. Material stress-strain curves.

Furthermore, the formability limits by necking and fracture associated to crack opening by tension were determined to analyse the heat treatment effects on material formability. The material curves indicate the improvement in the formability of the material subjected to heat treatment.

3 Numerical Work

The numerical work considered the SBMF demonstrator developed in [7] and the software used was i-form 2D. The simulations were run under plane strain conditions and the initial workpiece was defined as a sheet blank with 150x3 mm.

The numerical work was performed considering a blank with layout 1, T6 condition, and using layout 2, LHT at the edge where the deformation occurs (Fig. 3).

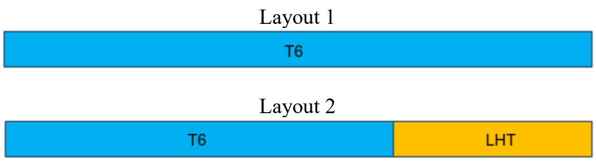
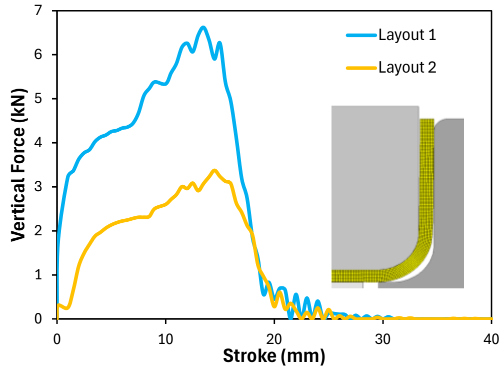


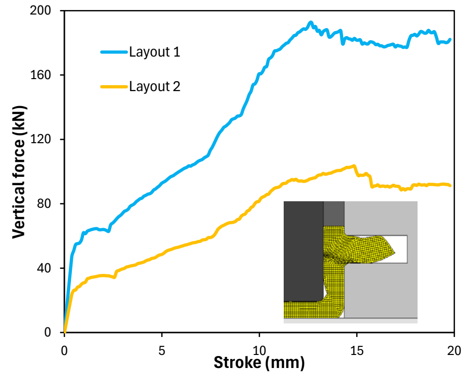
Fig. 3. Blank layouts.

4 Results

The force evolutions of the numerical models during bending and upsetting are presented in Fig. 4.



(a)



(b)

Fig. 4. Numerical force evolution: (a) bending, (b) upsetting.

During both bending and upsetting operations, the application of a THTB as a semi-finished product allowed for a reduction of approximately 50% of the process force, which is advantageous for tool life.

5 Conclusions

The material characterization served to analyse the differences in formability between the T6 and the treated material. The material curves of both materials show a clear improvement in formability induced by LHT. To enable an accurate design of the THTB, numerical simulations were performed to identify the areas of higher deformation. Furthermore, the force evolution graphic shows the benefit of using THTB as a semi-finished product, as the maximum force on both forming processes was significantly reduced.

These results open the way to the adoption of THTB to manufacture a broad range of components and reinforce its potential to extend the process limits of SBMF.

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