ALLEGRO

High-performance components made of aluminium alloys through resource-optimized process technologies

Editor	Timon Suckow M. Sc.
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Abstract

The core objective of Allegro was to create a technology base for new efficient processes of integrated shaping and heat treatment of the high strength AA7075 aluminum alloy. The technology development meant to be accelerated and transferred into the application by a synergistic combination of the relevant technology building blocks (forming, tribology, joining, coating, material characterization, component properties and service life). At PtU, a roll forming process was investigated using temperature-supported process routes. The temperature support favors the formability of the high-strength aluminum alloy AA7075.

Project description

Current research in production technology focuses on the increase of resource-efficiency and follow the approach of a fundamental sustainability of products and processes. Resource-efficiency refers to the entire lifecycle of the product, including the use of energy and other resources up to the point of reintroduction into the material cycle. In the area of aluminum forming, there is a great improvement potential to achieve higher resource efficiency. In the electric mobility sector in particular, sustainable lightweight construction is required, as there are limited energy storage capacities. Cost-effective mass production, which is made possible by the roll forming manufacturing process (project A1), is one way to achieve this goal.
In addition to PtU, the Institute of Materials Science and the Fraunhofer Institute for Structural Durability and System Reliability in Darmstadt were involved in the overall ALLEGRO project, furthermore two institutes of the University of Kassel. These include the Institute of Materials Science / Metallic Materials and the Institute of Cutting and Joining Manufacturing Processes.

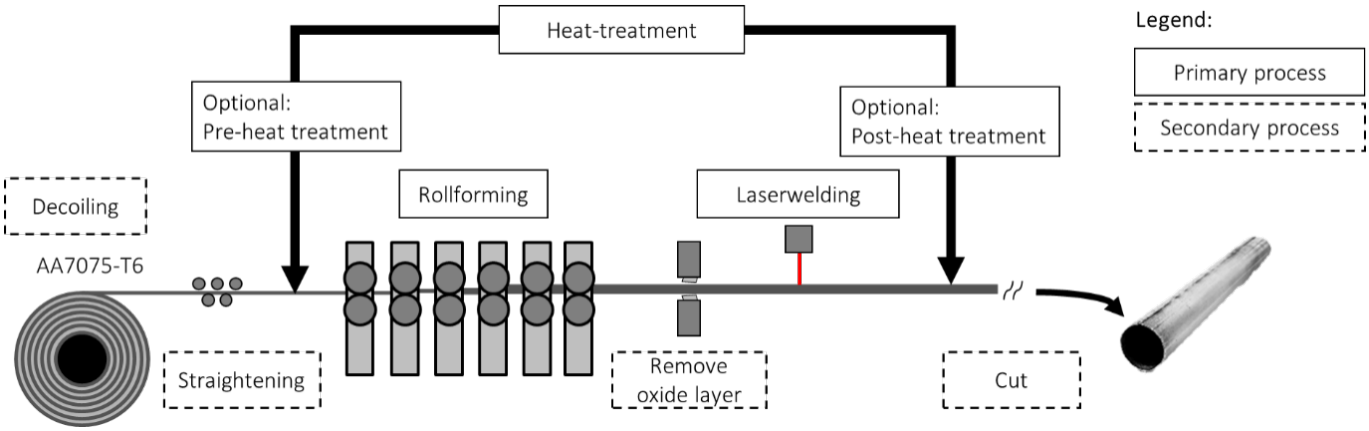
Additionally, a number of SME joint projects were technically integrated into the Allegro project at PtU.

- RAmP – Tool-integrated local blank heating
- Multi-hot – Multi-stage (hot-)forming of high-strength aluminium alloys
- Tribo-AL-Hot – Investigation of friction and wear in temperature-supported aluminium sheet metal forming

The objectives of the SME joint projects were the implementation and testing of the technological advances made in Allegro in an industry-related environment and the development of new product groups with a significant increase in the complexity of the components. The partners for process implementation and method planning were Werner Schmid GmbH (multi-stage deep drawing) and Hörmann Automotive Gustavsburg GmbH (deep drawing with local heating). Filzek TRIBOtech GmbH as an expert in tribological issues completed the co-operating partners list. In addition to the SME joint projects, the focus of the investigations at the PtU was on roll forming (project A1) and press hardening (project A2) of high-strength aluminium profiles.

Results

Within project A1, a process chain for the production of a tube made of the high-strength aluminium alloy AA7075 was developed and experimentally realised (Figure 1). The process development includes the design of the roll forming process, the welding process and the process-integrated heat treatment. To achieve optimum component properties, a holistic view of the process chain was followed. The challenge in the production of the tube is the low deformation capacity and the poor weldability of the high-strength aluminium alloy AA7075. A resource-optimised design of the process chain does not include energy-intensive heat treatment (e.g. soft annealing or solution annealing). Due to the incremental character of roll forming, high-strength materials can be formed. The challenge in roll forming a high-strength aluminium tube is the high springback during the forming process. This can lead to difficulties during welding due to high elastic recovery forces of the tube and thus to high residual stresses.
A lower springback can be achieved by temperature-supported process routes. Within the project, forming in the W-temper and in the soft-annealed O-state was therefore investigated in addition to cold forming in the T6 state. Temperature-supported forming combines the advantages of cold forming and hot forming with regard to simple process control and design as well as the increased formability of the material.

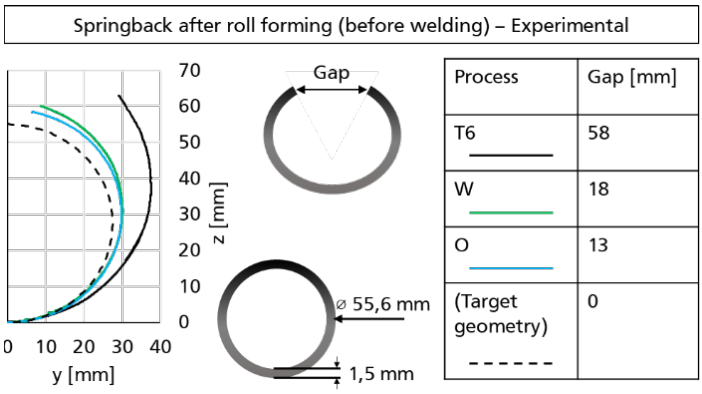


[1] Process chain for the production of a high strength AA7075 aluminum tube

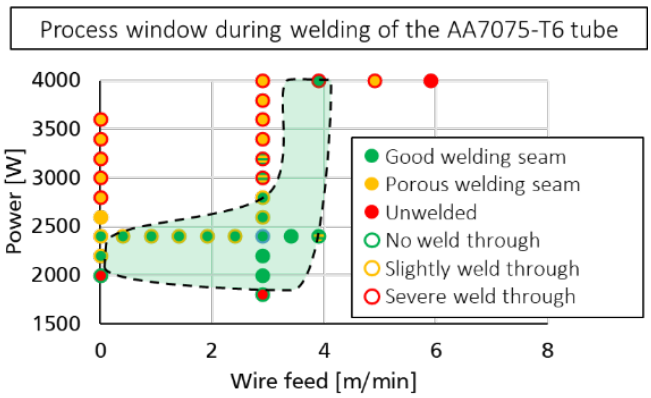
The advantage of the W-Temper heat treatment is the integration of the solution annealing and quenching into the process chain. Before roll forming, the material is heated inline to the solution annealing temperature of T = 460 °C - 480 °C by induction heating and then quenched. The resulting W-temper condition leads to a temporary improvement in the forming capacity and thus also an extension of the process limits, even though forming is performed in the cold state. This process route can also be used to produce profiles with small bending radii (e.g. U or hat profiles). In the process route with soft-annealed material (O-state), the material is soft-annealed in a defined cycle for 10 hours at temperatures of 410 °C - 230 °C before forming. The heat treatment is carried out separately from roll forming. Within this process route, energy-intensive post-heat treatment is necessary after roll forming to restore the T6 state. Figure 2a shows the springback of the tube after roll forming and before welding. Within the welding tests it was shown that the tubes can be welded after T6 forming. Figure 2b shows the process window (laser power / wire feed). An AA7075 TiC-nanoparticle-enhanced wire was used as filler metal. When using the filler material, the process window increases significantly. Likewise, the reduced springback after roll forming leads to lower requirements for the welding process. Especially the clamping situation of the pipe during and after the welding process is improved.

Within the project it was shown that a process chain for the production of a high-strength tube made of the aluminium alloy AA7075 is possible in different process routes. Below is a summary of the most important findings obtained in the project:

- Roll forming of a high strength tube is possible even in the high strength T6 condition.
- The reduced springback in the temperature-supported process routes enables the simple implementation of the welding process with conventional tube welding rolls.
- Various heat treatments within the process chain can be used to adjust the properties of the final components. This applies in particular to the mechanical properties and corrosion resistance.
- The choice of parameters (temperature, holding times, heating rates and quenching rates) within the heat treatments also has a significant influence on the properties of the final components.
- For this reason, accurate temperature control during the heat treatments is of great importance. Deviations from the target temperatures, e.g. during solution annealing, lead to a significant reduction of the strength in the final component.
- Post-heat treatment leads to an improvement in weld strength of up to 50 %.



[2] a) Springback after roll forming – Comparison of the process routes.



b) Process window during welding of the tube with and without filler wire (AA7075-TiC)

Project related publications (01/2023)

Groche, Peter; Günzel, Janosch; Suckow, Timon (2018):
Blechkomponenten aus hochfestem Aluminium – Möglichkeiten und Potenzial der Inline-Wärmebehandlung von EN AW-7075 beim Walzprofilieren.
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Cooling rate as a process parameter in advanced roll forming to tailor microstructure, mechanical and corrosion properties of EN AW 7075 tubes.
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