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Effect of a local laser heat treatment on the formability of multi-layered 6000 series aluminum alloys

Marion Merklein[a], Jürgen Herrmann[a,]*

[a]*Institute of Manufacturing Technology, Friedrich-Alexander-Universität Erlangen-Nürnberg, Egerlandstr. 13, 91058 Erlangen, Germany*

Abstract

The production of multi-layered aluminum alloys using the Accumulative Roll Bonding Process (ARB) is an auspicious possibility to fabricate nanostructured sheet material with enhanced mechanical properties. The increased strength qualifies these semi-finished products for lightweight applications in automotive industry. However, the ARB process also leads to a reduced ductility of the ultra-fine grained material. Furthermore, failure mechanisms like delamination can occur during forming operations. A local short term laser heat treatment according to the Tailor Heat Treated Blanks technology can be applied in order to enhance the formability and prevent failure. Multi-layered sheets of the aluminum alloy AA6014 were produced in a warm rolling process. The mechanical properties as well as the bond strength are investigated within this contribution using tensile tests and T-peel tests. The material characterization is carried out in dependency of the heat treatment temperature. Air bending tests in combination with a local laser heat treatment are used in order to investigate the formability of the multi-layered aluminum sheets.

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Keywords: Accumulative Roll Bonding; Tailor Heat Treated Blanks; 6000 series aluminum; Mechanical properties; Bending

1. Introduction

In many sectors of industry there is an ongoing trend towards lightweight construction. Amongst others, there are legal regulations like the demand for a reduction of CO_2 emissions in the automotive industry, as described by KPMG (2010), which foster the use of lightweight materials. Regarding aluminum alloys there is a development towards high strength materials with a maintainable level of ductility (VDI 2015). The Accumulative Roll Bonding

* Corresponding author. Tel.: +49-9131-85-20774 ; fax: +49-9131-85-27141 .
E-mail address: juergen.herrmann@fau.de

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(ARB) process according to Saito et al. (1998) is an auspicious possibility to produce ultra-fine grained (UFG) sheet material with outstanding mechanical properties. However, regarding aluminum alloys of the 6000 series a significant increase in strength is accompanied by a decrease in formability. In this context the Tailor Heat Treated Blanks (THTB) technology according to Vollertsen and Lange (1998) is a good possibility to improve the forming behavior of the roll bonded sheet material. The multi-layered sheet material is produced in a warm rolling process using the aluminum alloy AA6014. Afterwards a comprehensive material characterization is carried out regarding the mechanical properties as well as the bond strength in dependeny of the heat treatment temperature. The results of the material characterization are set in context with the forming operation of an air bending test. The bending edge is locally heat treated using a Nd:YAG laser.

2. State of the art

Accumulative Roll Bonding (ARB) belongs to the so-called Severe Plastic Deformation (SPD) processes. SPD techniques are metal forming processes where a high strain is imposed on a bulk or sheet metal without a significant change of the overall dimensions (Sabirov et al. 2013). A significant grain refinement is achieved by the high strains in order to develop an UFG microstructure. The ARB process, which was developed by Saito et al. (1998), consists of three main process steps as it is presented in Figure 1. First there is a surface treatment of the sheet material using a wire brush in order to decrease the thickness of the oxide layer and to increase the surface roughness. Afterwards two sheets are stacked on top of each other while the pretreated surfaces are combined. The final step is represented by the rolling process at a typical thickness reduction of 50 % which causes bonding of the sheets. This process sequence can be repeated several times in order to increase the strain which is induced into the material. Topic et al. (2008) investigated the effect of different ARB cycles on the mechanical properties of an aluminum alloy of the 6000 series. A significant increase in the strength of the material could be achieved after 2, 4, 6 and 8 rolling cycles. However, a major decrease of the elongation to failure indicates a poor forming behavior of the ultra-fine grained sheets. For the applicability of ARB processed sheet material in forming operations an improvement of the formability is necessary.

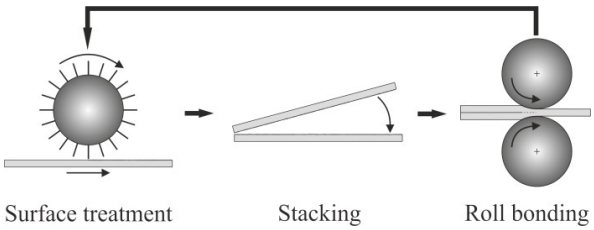

Fig. 1. Schematic representation of the Accumulative Roll Bonding (ARB) process according to Saito et al. (1998).

The effect that the strength of aluminum alloys of the 6000 series can be reduced with the help of a short term heat treatment was first discovered by Haase and Wurst (1941). Subsequently this finding was used by Vollertsen and Lange (1998) in order to improve the formability of precipitation hardenable aluminum alloys. The short term heat treatment causes a dissolution of the strengthening MgSi-clusters. This enables a local adaptation of the material properties according to the Tailor Heat Treated Blanks Technology (THTB). Geiger et al. (2009) investigated the effect of a short term heat treatment on an ultra-fine grained aluminum alloy AA6016. Besides the well-known dissolution of the MgSi-clusters a recrystallization of the nanocrystalline grain structure was discovered. Consequently, the application of the THTB technology is also suitable in order to enhance the formability of ARB processed precipitation hardenable aluminum alloys. The effect of a local heat treatment on the forming behavior of multi-layered sheet material is presented by Maier et al. (2012). Bending experiments of 4-layered, 16-layered as well as 256-layered sheets of the aluminum alloy AA6016 were carried out. An enhancement of the bendability due to a local heat treatment of the bending edge was investigated. However, an influence of