

INFLUENCE OF SHORT-TERM HEAT TREATMENT ON THE MECHANICAL PROPERTIES OF AL-MG-SI PROFILES

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Aluminium profiles, for instance made of precipitation hardenable alloys, are increasingly used for decorating details in the automotive industry. Typically, after hot extrusion and at least two to three days natural aging (NA), the aluminium profiles are artificially aged. A commercial EN AW-6060 alloy of high purity was used for this investigation. This article is focused on the effect of a short-term heat treatment on the moment, where a significant increase of R_m during NA can be measured. Short-term heat treatment is shown to delay this moment by almost four days, however, the variation of R_m is increased. A heterogeneous temperature profile during short-term heat treatment was identified to be the reason for this result. Tensile tests were used as the main measurement method.

Finally, a strategy for minimizing variations in mechanical properties of artificially aged aluminium alloys was developed based on the experimental results of this study.

Keywords: Artificial aging, natural aging, tensile test

I. INTRODUCTION

Due to the low density aluminium alloys are often used in the automotive industry. After continuous casting and homogenization (about 550°C) the aluminium is extruded. At this point of production the aluminium profiles have a relatively low strength. Because of precipitation hardening the strength of Al-Mg-Si-alloys can be increased. After NA at room temperature aluminium profiles are heat-treated. During artificial aging (AA) the mechanical properties are changed and stabilized. That is important as, for example, roof racks have to show a high strength and a brilliant surface without any scratches. However, variations in mechanical properties impair post-processing of the final geometry.

The aim of this investigation was to evaluate the influence of several parameters like duration of NA, short-term heat treatment and AA.

The ambition of short-term heat treatment was to stabilize the microstructure prior to AA. All tests were done under laboratory conditions.

II. MATERIALS AND METHODS

The investigated alloying system is EN AW-6060. A list of all experiments is shown in Table 1. After hot extrusion and NA lasting between 4 and 8 h (22 to 24 °C) one profile geometry was subjected to short-term heat treatment. For this near-infrared emitters positioned above and below the profile were used. Throughout this study the short-term heat treatment is called NIR-treatment. Figure 1 illustrates the temperature profile of 3 tests. After NIR-treatment the profiles were naturally aged (20 to 35 °C) together with samples without NIR-treatment. Tensile tests are done at different times over NA. The samples without NIR-treatment were artificially aged at different temperatures afterwards (Tab. 1).

The AA was carried out in a circulating air oven (company: Nabertherm). The tensile tests were done with a tensile test machine (company: Zwick/Roell) at room temperature. For this, the complete profiles were used. Up to a thickness of 4 mm this experimental procedure is recommended [1].

After the heat treatment metallographic specimens were cut out of the samples. The embedded samples were polished. To characterize the metallographic constituents the samples were investigated by scanning electron microscope (SEM) (company: Tescan, type: Vega3SBH) and energy dispersive X-ray spectroscopy (EDS) (company: Bruker, type: XFlash 5030, software Quantax).

Table 1. Scope of experiments.

NIR	NA	AA
yes	up to 10 d	-
no	up to 10 d	-
no	4 – 11 d	120 – 180 °C, up to 11 h
no	4 – 11 d	200 °C, up to 9 h
no	4 – 11 d	230 °C, up to 3 h

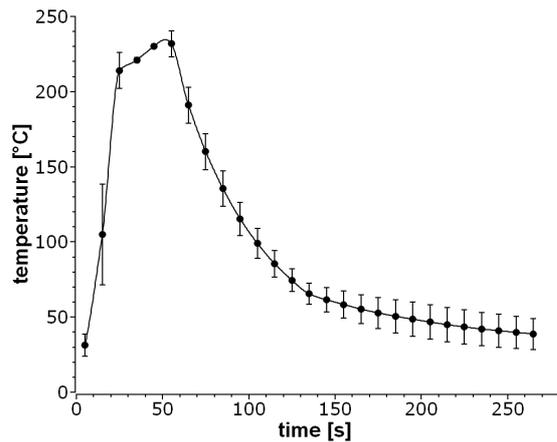


Figure 1. Temperature profile of NIR-treatment, average and standard deviation of 3 tests.

III. RESULTS AND DISCUSSION

A) Artificial aging

At different temperatures of AA (120 to 230 °C) the standard deviation of R_m does not differ significantly to each other ($\pm 0,7$ MPa) [2]. With EDS analysis the metallographic constituents were investigated. In addition to the situation after hot extrusion dispersed precipitates are present after AA. Because of the heat treatment and the chemical composition measured with EDS analysis these precipitates could be the β' -phase (Mg_9Si_5) [2]. The Fe- and Si-contents of the globular precipitates (AA at 230 °C) are closed to those of Al_8Fe_2Si or $Al_{12}Fe_3Si$.

B) Short-term heat treatment

From the beginning of the NA the tensile strength of the extruded and naturally aged samples increases. Figure 2 shows the development of R_m for these samples. Directly after hot extrusion Si-clusters (concentration of silicon atoms) are formed [3]. Vacancies are stably integrated into the Si-clusters [4]. Then Mg-clusters (concentration of magnesium atoms) are formed. Within a few days the Mg-clusters dissolve and the Si-clusters accumulate with Mg. They are called co-clusters. These co-clusters grow to coherent GP(I)-zones. They are responsible for the increasing of the strength [5].

The tensile strength of the NIR-treated samples is on a lower level than that of the other samples (Fig. 2). The reason for this could be the reduction of clusters during NIR-treatment [5]. Within the first four days after hot extrusion, the values of R_m remain almost constant. In the further course of the NA, R_m increases. Due to

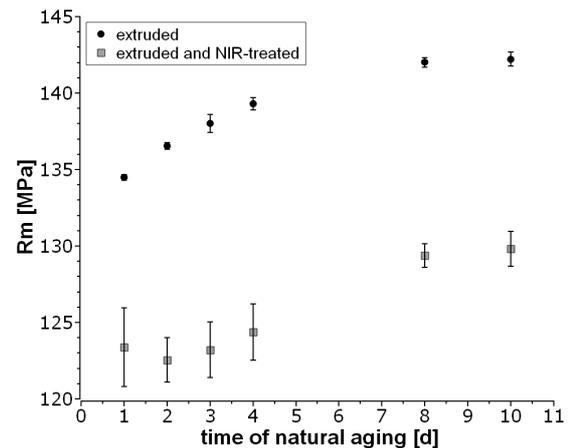


Figure 2. Tensile strength R_m depending on the time of NA after hot extrusion and after hot extrusion with short-term heat treatment subsequently [2].

the NIR-treatment, the moment at which the significant increase of R_m is detected was shifted by four days [5]. In Al-Mg-Si-alloys, vacancies are also responsible for the stability in the formation of co-clusters [3][6]. One reason for the delay of NA could be the reduction in the excess of vacancies [5].

In general, the standard deviation of the NIR-treated samples ($\pm 2,5$ MPa) is higher than that of the other samples ($\pm 0,3$ MPa). Temperature fluctuations during NIR-treatment (Fig. 1) can be responsible for this.

IV. CONCLUSION

The standard deviation of the laboratory tests for conventional production is very low. Delay of the NA by about four days by the short-term heat treatment was detected. This result can be used to shorten storage and production times. The influence of the NIR-treatment on other properties has not been investigated. In order to reduce the higher fluctuation of the mechanical properties, the consequence is the following: The duration of NA between hot extrusion and NIR-treatment should be as short as possible and constant. The temperature and the duration of the NIR-treatment should be constant.

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