ARCHIVES OF CIVIL AND MECHANICAL ENGINEERING 13 (2013) 1–6

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Original Research Article

Improvement of ductility for Twin Roll Cast and rolled AZ31 strips by use of Taguchi method

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ARTICLE INFO

Article history:
Received 15 August 2012
Accepted 24 September 2012
Available online 28 September 2012

Keywords:
Taguchi methods
Experimental design
Magnesium alloy
Rolling

ABSTRACT

Magnesium alloys have great potential in the area of lightweight production especially in the automotive industry due to their favorable combination of mechanical properties and low density. The effects of various rolling parameters on ductility were investigated using the Taguchi method. The optimum combination of process parameters has been found through analysis of main effects of ductility and signal-to-noise ratio, and the significant parameter were identified depending on analysis of variance. The results demonstrate that reduction is the most important factor for improving the ductility of the final strips, followed by rolling temperature and rolling speed. The optimal levels for the controllable factors were rolling temperature of 375 °C, rolling speed of 175 m/min and reduction of 70% for higher ductility.

1. Introduction

Magnesium alloy sheets have potential applications in the automobile and aircraft industry owing to the low density and excellent specific strength [1,2,11]. To be used as structural components, magnesium alloys should exhibit sufficient ductility, to prevent failure under shear or tensile loads [4]. Rolling temperature, speed and reduction have the most significant effect on the properties during strip rolling. The interrelationships between these parameters are complex, and analysis of this process, optimizing these factors, is a time and labor consuming work. Hence, the analysis using conventional experimental methods are inefficient. Therefore, Taguchi method was introduced in this work. This method provides a simple efficient and systematic approach to optimize design for performance, quality and cost [5,6].

The objectives for this work are: (1) using Taguchi method to determine the most important parameters for ductility, and (2) to determine the optimum parameter combination leading to the maximum ductility.

2. Experimental details

2.1. Taguchi method

Taguchi method is a powerful tool for the design of a high-quality system. This method considers three steps: system design, parameter design, and tolerance design.

In system design, the engineer uses scientific and engineering principles to determine the fundamental configuration. In the parameter design step, the specific values for system

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1644-9665/$ - see front matter © 2012 Politechnika Wrocławska. Published by Elsevier Urban & Partner Sp. z o.o. All rights reserved.
http://dx.doi.org/10.1016/j.acme.2012.09.001

parameters are determined. Tolerance design determines the best tolerances for the parameters. Taguchi uses signal–noise (S/N) ratio as the quality characteristic of choice. The highest ductility is required for the present study, thus "higher is better" has been depended on to find the optimum rolling parameters which result in the best ductility. The signal–noise [S/N] ratio is calculated from the following equation [8–10]:

$$\frac{S}{N} = -10\log\left(\frac{1}{N}\sum_{i=1}^{n}\frac{1}{y_i^2}\right) \quad (1)$$

where S/N is the signal–noise ratio; n is the number of observations; and y_i is the observed data. The y_i represents the ductility which will be repeated three times in each experiment. In addition to the S/N ratio, a statistical analysis of variance (ANOVA) is employed to indicate the impact of process parameters on surface roughness. In this way, the optimal levels of process parameters can be estimated.

2.2. *Experimental conditions*

The feedstock was produced in cooperation with the MgF Magnesium Flachprodukte GmbH in Freiberg. The average chemical composition of the TRC AZ31 material is shown in Table 1.

The strip rolling experiments were carried out on the quarto-reversing mill of the Institute of Metal Forming, TU Bergakademie Freiberg. Before rolling, the twin roll cast strips were homogenized above 400 °C. After the heat treatment the coils were rolled from 5 to 5.5 mm to final thickness 1.5–2.5 mm. The process route is shown in Figs. 1 and 2 (see also [1–4,11,12].

The rolling conditions of final strip rolling were: rolling temperature 350, 375 or 400 °C, rolling speed 125, 150 or 175 m/min and reduction 50, 60 or 70% (see Table 2).

The technical data of the twin roll caster and the quarto reversing mill in Freiberg are shown in Table 3. The tensile

Table 1 – Average chemical composition of the investigated twin roll cast AZ31 strips (Mass %).

Al	Zn	Mn	Zr	Cu	Si	Fe	Ni	Ca	Sn	Be	Pb	Mg
2.59	0.671	0.32	<0.001	<0.001	0.02	0.002	<0.001	<0.001	<0.005	0.001	<0.005	96.39

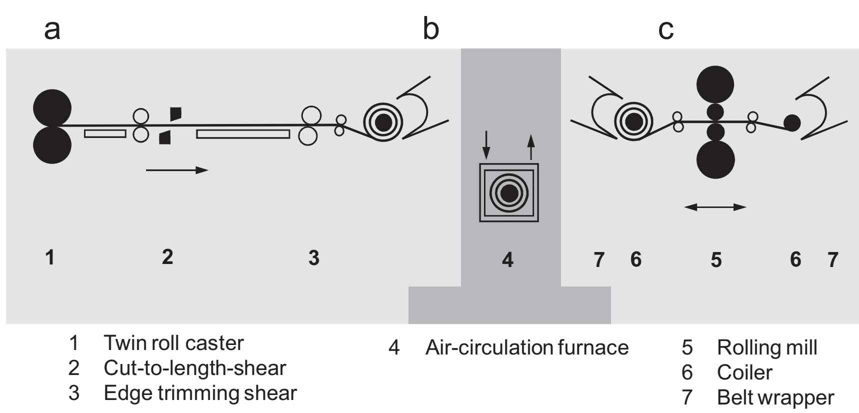

Fig. 1 – Facility concept. (a) twin roll casting, (b) heat treatment and (c) strip rolling.

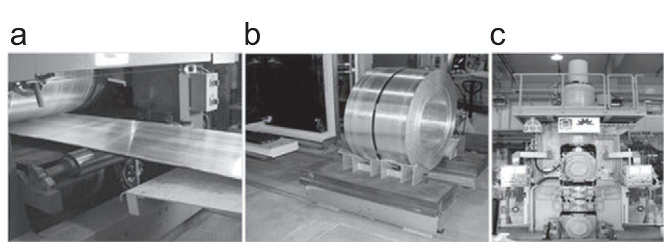

Fig. 2 – Pictures of the facility. (a) Twin Roll Casting, (b) Air-circulation furnace and c) Quarto reversing mill.

Table 2 – Rolling conditions and their levels.

Symbol	Cutting conditions	Unit	Level 1	Level 2	Level 3
A	Rolling temperature	°C	350	375	400
B	Rolling speed	m/min	125	150	175
C	Reduction	%	50	60	70