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Twin-Roll-Casting Technology for the Magnesium Strip Production at the Institute of Metal Forming: State of the Art

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Abstract

Magnesium alloys are still the focus of current research. Special importance is attached to the economic production of semi-finished magnesium products, for example flat products. In the past 20 years, twin-roll-casting of magnesium alloy strips has been intensively investigated at the Institute of Metal Forming and successfully applied to various alloy compositions (from AZ31 to ZAX210 and WE43). The TRC technology enables the production of strips providing a wide range of strengths and ductility depending on the alloy composition and further processing.

Keywords: Twin-roll-casting; Magnesium alloys

Introduction

In 2001 research into twin-roll-casting (TRC) at the Institute of Metal Forming began with the built-up of a pilot plant for the production of magnesium strip [1]. At the beginning, the focus was mainly on the magnesium alloy AZ31 [2]. It was shown that TRC with subsequent strip rolling is an energy-efficient and economical alternative to conventional thin strip production of magnesium alloys. The twin-roll-cast strips with initial thicknesses between 7 mm and 5 mm can be hot rolled to final thicknesses between 3 mm and 0.8 mm after an adapted heat treatment. The thinner the strips, the better the mechanical property profile and the lower the anisotropy of the AZ31 strips [3-6]. This can be attributed to the applied deformation and the recrystallisation processes that take place. For this alloy, numerous studies are available on the initial TRC state, the influence of heat treatments, the recrystallisation behavior during hot deformation, as well as on texture and microstructure development. The microstructure of the twin-roll-cast AZ31 alloy shows the typical herringbone-like solidification structure and can be divided into three zones: the rapidly solidified edge zone, the crystal zone with columnar grains and the mid-thickness, which is often characterized by the occurrence of center segregation [7,8].

In the meanwhile, other magnesium alloys have also been processed using the twin-roll-casting technology. For example, when using rare earth alloys, the TRC process enables the production of sheets with high strengths. Important alloys in this regard are WE43 [9] and, most recently, WZ73 [10,11]. In addition, investigations were carried out with the calcium-containing alloys MX21 and ZAX210 [12-14]. In contrast to AZ31, these alloys do not show a preferential orientation (basal texture) during subsequent forming. It is therefore possible to produce sheets that have a weakened texture and thus improved formability. As a result of the wide range of alloys, a large property profile can be provided, and thus various fields of application can be served.

Discussion

At the Institute of Metal Forming, a wide range of magnesium alloys were processed in the twin-roll-casting process, which provide a wide range of mechanical properties (Figure 1). The magnesium alloy WE43 offers an ultimate tensile strength above 400 MPa. For the other alloys investigated so far, ultimate tensile strengths between 200 MPa and 300 MPa are predominantly achieved. Elongation at fracture in the twin- roll-cast state is generally very low with values between 2 % and 4 %. However, adjustments to the casting system, in particular the geometry and the material of the casting nozzle (steel-ceramic hybrid nozzle), allow a significant increase in the elongation values of up to 8 %. This can be attributed to the solidification influenced by this. As a result, fewer large columnar grains are formed and the overall structure becomes finer and more homogeneous.

An improvement in elongation can also be achieved by a heat treatment adapted to the alloy composition. Responsible processes for increasing elongation are the transformation of the dendritic structure into a grain structure, dissolving brittle intermetallic phases and generally homogenizing the microstructure. For the high strength alloy WE43 elongation at fracture after a heat treatment at 500 °C and 1 h is 15 %. Standard magnesium alloy AZ31 offers an elongation at fracture of about 25 % (430 °C, 8 h). Highest values are provided by ZE10 (430 °C, 6 h) with 28 % and by ZAX210 (420 °C, 2 h) with 30 %. It should be noted that increasing elongation induced by heat treatment is accompanied by decreasing strength values. However, further processing by hot rolling leads to an excellent combination of strength and ductility as can be seen from Figure 1. WE43 offers after hot rolling a balanced combination of the mechanical properties, while the Ca-containing alloys (ZAX210 and MX20) as well as AZ31 or ZE10 provide rather average strength characteristics at very high elongation.

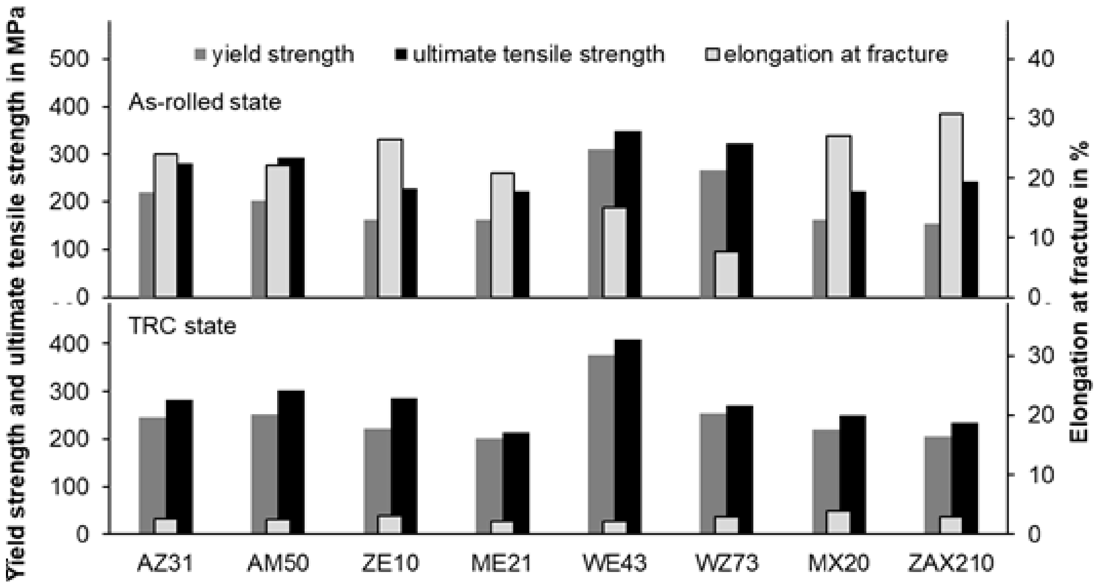

Figure 1: Mechanical properties (0°, room temperature) of several magnesium alloys after TRC and after subsequent hot rolling (as-rolled state).

Research in the field of twin-roll-casting at the Institute of Metal Forming is still focused on the enhancement of process conditions and optimization of the casting system to improve the flow behavior of the melt. The aim is to produce a low-segregation strip with a homogeneous structure that only requires a short heat treatment before further processing. Furthermore, an improved formability leads to a reduction of processing steps, for example when higher strains are applied. Optimization and adaptation are carried with regard to the alloy composition, while considering the main influencing factors solidification interval and the precipitation behavior of intermetallic phases.

Conclusion

The twin-roll-casting process enables the production of thin magnesium strips. Several magnesium alloys have been twin-roll-cast providing a broad field of strength and ductility properties. Further research on optimization of the process parameters and the casting system is aimed on the production of a suitable initial condition (TRC strip) for further processing by hot rolling. The purpose is to obtain high strains in fewer rolling passes and to reduce the necessity for heat treatment steps.

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Conflict of Interest

The authors declare no conflict of interest.

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