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Twin Roll Casting and Rolling of New Mg-Wrought Alloys for Body Protective Safety Equipment

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Extended Abstract

Currently magnesium alloys are used for different applications in the transportation industry where cast magnesium alloys dominate the market. Although cast alloys predominate over wrought products such as extrusions, forgings, sheet and plate, the latter are also being used in a variety of different applications. Recently, a growing interest in the automotive industry in looking at potential applications for magnesium turned back towards wrought alloys. Typically, applications of magnesium sheets are sought in automotive or aeronautics industry. However, the spectrum of potential applications can be significantly expanded. For example, body protection systems for civil services like police, custom officers and prison personnel currently include anatomically shaped aluminium alloy sheets. Replacement of aluminium alloys by magnesium to result in substantial weight savings up to 30%.

Unfortunately, commercial magnesium alloys don't provide the required protection level due to limitations like e.g., high reactivity, insufficient corrosion resistance, and low tensile strength. In addition, poor low temperature formability and cost issues are also known as significant limitations.

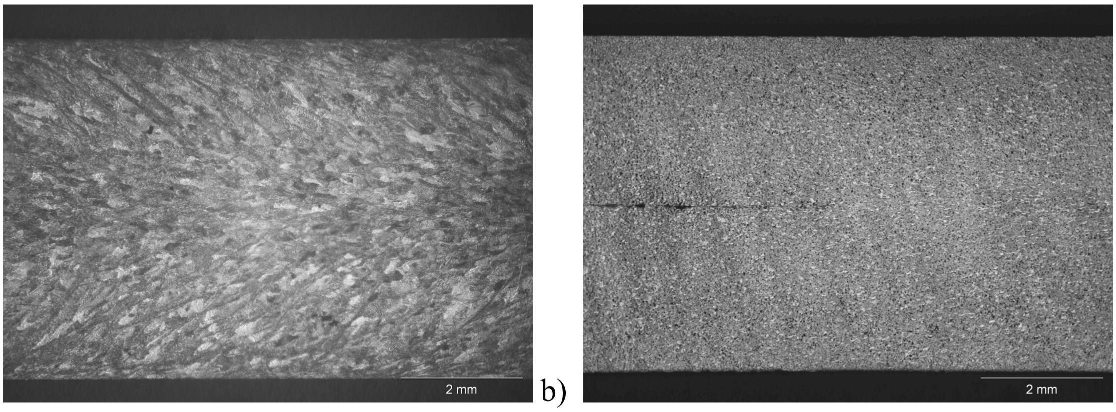
The presented paper describes a new approach allowing to tackle the above drawbacks by applying the twin roll casting (TRC) [1] with subsequent rolling of sheets to newly developed wrought magnesium alloys.

In a first step protectors were produced from twin roll cast AZ31 sheets, which serve as reference material for the further developments. However, new aluminium-free Mg-alloys containing rare-earth elements (RE) are in the focus of this research. The simultaneous development of new wrought alloys and of the magnesium twin roll casting process enables the production of high strength magnesium sheet with good formability at moderate temperatures. The sheets produced of a new alloy were formed to body protectors. Both sheets and protectors were tested for different mechanical properties and compared to those of AZ31 sheets and AZ31 protectors.

On the first step, a new Mg-Zn–RE alloy designated as DSM-1, was developed and tested. Whereas Zn was used to confer improved strength properties, the RE-element additions enable the development of a weak non-basal texture of the rolled sheets, which is favourable for good formability [2]. By means of the TRC-process this alloy was cast into strips of 5.6 mm thickness and 300 mm width. Prior to rolling the strips were homogenised for 16 hours at 400°C. The rolling

procedure was carried out at a sheet temperature of 400°C and initially included four passes with a degree of deformation φ of 0.1 each. On the second stage, three additional passes with φ = 0.2 were applied resulting in a final gauge of 2 mm. Between each two passes the sheets were intermediately annealed at the rolling temperature for 20 minutes to maintain the rolling temperature at the same level. For further processing the sheets were heat treated for one hour at 400°C and then formed into the final shape by a deep drawing procedure.

The twin roll cast strip shows a homogeneous microstructure with slightly squeezed equiaxed grains. An average grain size of 20 µm was determined by means of the line intersection method. Clear centreline segregation was revealed as well as numerous precipitates especially located at grain boundaries. Figure 1 compares the microstructures of AZ31 and DSM-1 alloys. AZ31 strip exhibits coarse and partially columnar microstructure. Contrary to this, the fine grained microstructure of the DSM strip is favourable for good rollability. The homogenisation treatment did not affect the grain sizes but allows resolving the precipitates at the grain boundaries. After subsequent rolling, the DSM sheets exhibit a typical deformed microstructure with squeezed grains, twins and intermetallic phases that mostly consist of small particles aligned with the rolling direction. Homogenisation heat treatment for 30 minutes at 400°C leads to a recrystallized microstructure with an average grain size of approximately 10 µm.



a) b)

Figure 1. a) Coarse microstructure of the twin roll cast AZ31 strip with columnar structures near the surfaces and the equiaxed area in the centre of the strip. b) Fine grained microstructure of the twin roll cast DSM strip with local centreline segregation. Both strips are shown in the as cast condition.

Throughout the process the texture of the strips and sheets develops from a broad and weak texture with components in transverse direction (TD) of the strips (maximum intensity of (002) pole figure of 2.8 m.r.d.) to a typical RE-texture of similar intensity. The basal pole figure exhibits two poles towards TD and a pronounced TD-component.

The comparative mechanical properties of AZ31B and DSM-1 sheets are listed in Table 1. First of all it should be noted that the new alloy exhibits both in RD and TD significantly higher elongations compared to those of AZ31B alloy. Furthermore, it is also noteworthy that the yield stress of the DSM-1 sheets is higher in RD than in TD, which can be attributed to the typical RE-texture with the spread of the basal poles towards TD [3].

Erichsen tests performed with these sheets gave an Erichsen index of IE = 6.6, which clearly excels the value of 1.7 measured with AZ31 sheets.

The good formability of this material was confirmed when forming the protector parts, where several shapes could be formed even at room temperature. After forming the protectors were subjected to standardised tests examining their potential for hit and stab protection. These tests gave results comparable to those achieved with AZ31 sheets.

Table 1. Mechanical properties of twin roll cast AZ31 and DSM-1 sheet.

Alloy	**AZ31**		**DSM-1**	
Direction	**RD**	**TD**	**RD**	**TD**
TYS [MPa]	130	176	174	122
UTS [MPa]	276	266	238	221
Elongation [%]	12	11	26	33
IE	1.7		6.6	

Finally, it should be noted that the present paper addresses just intermediate results of a project that aims at establishing the twin roll casting technology for producing high strength magnesium sheets and a parallel development of wrought magnesium alloys that are especially designed for this process. Up to now a new aluminium-free alloy was developed that is appropriate for the TRC process and exhibits excellent formability while the achieved strength properties are similar to those of commercial AZ31 sheets. In the further project steps fine-tuning of alloy composition will be carried out in order to increase strength properties whilst maintaining the good formability.

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