

Development of Guidelines for the Groove Rolling of Magnesium Alloys Which Contain Calcium

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Abstract

The topic of climate protection and, for example, the resulting need for a reduction in the use of fossil fuels, is a major focus of research. Particular interest is taken in the substitution of traditional metals such as steel with lightweight materials like aluminium and magnesium alloys in the automotive and generally in the transportation sector. [1] Due to the hexagonal crystal structure of magnesium, the processing of its alloys contains some almost unique challenges. By alloying calcium, for example in ZAX-alloys – containing zinc, aluminium and calcium – the formability at room temperature is improved through a less pronounced texture with a basal pole split. [2] To join the replaced components in the cars, welding can be used. This process profits from procedure where base and weld material are of similar compositions. For welding, and for wire-based additive manufacturing too, wires with a diameter of approximately 1 – 1.6 mm are required, which can only be produced through drawing. The production for the preliminary products can be achieved through either extrusion or groove rolling. For the latter there is a lack of fundamental empirical experience and research results that are required for a successful application and implementation in the industry. The extrusion process is more established but groove rolling has the potential to produce larger quantities in the same time and has the added advantage of a greater grain refinement. In order to ensure the economic use of magnesium alloys, the challenges of production, mainly the tendency to crack, have to be understood and subsequently prevented. To improve the design of groove rolling mills for magnesium alloys, the material parameters required for a simulation were determined.

The parameters c_p , a and λ of the materials AZ80 and ZAX210 were determined through laser-flash-analyses and with a high-temperature calorimeter and an Archimedes-scale. Those values are important for the design of the rolling process to improve the control of the temperature in the process in order to avoid the melting of grain boundaries and a reduction of the formability due to low temperatures. Additionally, rolling trials were carried out to determine the spreading coefficients according to Wusatowski for the alloy ZAX210. The temperature and the material coefficient were calculated from the results. For the groove rolling of AZ80 both preliminary and validation trials were carried out. Different initial diameters were used in the preliminary trials, concluding in the choosing of an initial diameter of 15 mm, because a crack free bar could be produced in the first oval groove. In addition, the bar did not twist in second groove. In the validation trials on the other hand, cracks occurred at the edges of the oval of the several bars in the first roll pass, presumably due to a different starting texture of the material. The groove rolling trials to determine the spreading coefficients according to the Freiberg spreading model for ZAX210 were carried out according to

the parameters, including the heat treatment, of Dressler [3], who produced crack-free wires on the same three-high rolling mill. However, the current trials were not successful presumably because the average grain size of the starting material of Dressler was 213 μm compared to the current trials with 608 μm . Additionally, the present material showed increased precipitations at the grain boundaries after the heat treatment, which were identified by EDX as aluminium and calcium-rich phases. This indicates Al_2Ca and complex ternary precipitates. Due to their location at and along the grain boundaries, they are possible crack initiation points, but not through grain boundary melting, but exclusively through a weakening of the bond between the grains. This can be compensated for in subsequent research, for example through a smaller grain size. A process improvement, especially concerning the heat treatment, is needed here. Parameters for the Freiberg flow curve model for ZAX210 were determined through cylinder compression tests. The groove rolling simulation was carried out for AZ80 using two analytical calculation programmes, which are being developed at the Institut of Metal Forming in Freiberg. Due to the empirical nature of the model, if the fill level is far below the usable width, meaning a filling ratio of less than 0.88, the results of the Freiberg spreading model are getting less accurate. This challenge was met in the first roll pass. Therefore, values from another project were used, which made it possible to meet the minimum requirement of the filling ratio of the first groove by replacing an almost perfectly filled square groove with a square with an equal cross-section area. The tendency of the calculated fill values corresponds to those of the real values, but the filling levels for the square-oval groove sequence are constantly below the real results. It is therefore possible that the parameters for this groove sequence, and possibly other sequences which were not tested in this work, must be adapted to the anisotropy of the magnesium. But this hypothesis must be validated by further investigations.

In summary, many material parameters for a complete, simulative representation of the groove rolling process for the magnesium alloys AZ80 and ZAX210 were determined. However, further investigations and a greater focus must be on the fracture deformation as a function of the stress-strain state in different points of the groove and the correction of the spreading models, which has to be adapted to this material in connection with the groove sequence. This approach is now being pursued further in the CLEAN-Mag project.

Keywords *Groove Rolling, Magnesium Alloys, ZAX210, AZ80*

Literatur

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