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A Perspective: Towards improvement of the formability of magnesium alloys

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Abstract

It is the lowest density of any structural metals that makes magnesium and its alloys to be very attractive materials for a wide range of structural applications, especially where weight saving is of paramount significance, such as in automotive or aerospace industries. Despite the attractiveness as a lightweight structural metal, the use of traditional Mg alloys is limited mainly due to its poor formability, corrosion resistance, and a limited strength capacity at elevated temperatures. The forming of magnesium alloys is still difficult, and its plastic deformation mechanisms are not yet clarified. Alternative slip systems, other than basal slip, have to be activated during the deformation process of Mg-alloys to extend its utility. Therefore, twinning, as another deformation mechanism, can play an important role in coordinating the plastic deformation. Experimental investigations have revealed that texture plays a significant role in improving or impairing the ductility of Mg-alloys. The activated deformation modes highly depend on the orientations of the grains, in such way depend on the texture, the deformation path and the mechanical process. The combined effect of grain boundary strengthening, second phase strengthening and activation of non-basal slip mechanisms may lead the way to better Mg-alloys, which will have both decent ductility and impressive strength.

The application of magnesium alloys requires reliable simulation tools for predicting the forming capabilities, the structural response to mechanical loads and the lifetime of the component. The respective constitutive models have to take into account the peculiarities of the mechanical behaviour assuming yielding under multi-axial stress states. A reliable numerical model of strain hardening, which is going to be developed in the project, will give an explanation and a prediction of both stress-strain curves and texture evolution. Recently developed method combining accumulative angular drawing (AAD) with wire drawing is used as a testing method to effectively induce severe plastic deformation (SPD) effects into the drawn metallic material. The influence of the combined effects, such as area reduction, bending, shearing and burnishing, on the accumulated deformation energy and microstructural inhomogeneity in the h.c.p. wires is discussed with respect to possibilities of formation of ultrafine-grained and multi-layered structures in subsequently drawn wires. The basic idea of AAD process is deformation of the metallic material tomuch higherplastic strains compared to the conventional wire drawinginducingvery high grain refinement allowing for achievement ofsignificantly higher tensile strength and ductility. It can be especially beneficial for Mg alloys.

The dynamic material modelling (DMM) approach is presented and demonstrated as a useful tool to predict workability of Mg alloys. The approach is based upon the fundamental principles of the continuum mechanics of large plastic flow, the physical system modelling and irreversible thermodynamics. In DMM approach, an efficiency of power dissipation between heat and microstructural changes is assumed to bea measure of workability of metals.

Based on the above assumption, the processing maps (P-maps) are constructed as an explicit representation of the material response in terms of the microstructural mechanisms and the applied process parameters. P-mapsare prepared by means of the combination of the power dissipation map, illustrated by isoclines, with the instability map, plotted in the frame of the temperature and the strain rate at a constant strain. The variations of the instability parameter, as a function of the strain rate and the temperature,allow for plottingthe instability maps. The regions on the map, where the instability parameter is lower than zero, correspond to the microstructural instabilities in the material. This parameter is considered to be an important warning sign for designing aneffective metal forming operation for a specific material.

High-temperature rheological research is modern research, allowing for obtaining the key information on the influence of forces and the time of their impact on a specific material. Such information is essential for designing of the forming processes in semi-solid states. A comprehensive and accurate description of the rheological behaviour seems to be a key factor for development and optimisation ofsemi-solid forming of Mg alloys. Rheological testing of Mg alloys is challenging due to the high reactivity of the materials.The results of the recent rheological testing of AZ91, WE43B and E21 Mg alloyswith different chemical compositions are discussed. The findings are presented in the form of flow curves. The preliminary results indicated that the highest shear stresses,around of 50Pa, were obtained for AZ91 alloy, while only the stresses within the range of 10 – 20Pa have been registered for E21 and WE43B alloys. Both E21 and WE43B alloys contain rare earth elements, such as yttrium, neodymium, gadolinium, which may influence the changes in the shear stress. Further rheological testing of the materials with various contents of the rare earth metals are planned to verify the above mentioned statement.In addition, a tendency towards non-linear growth of the shear stress with the growth of the strain rate is noticed that may indicate decline in the dynamic viscosity coefficient, as a result of the applied load.

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