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Abstract of doctorate thesis

Title: Mechanical and Microstructural Aspects of Plastic Deformation of Metallic Materials in the KOBO Extrusion Process

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Abstract: This dissertation presents the results of research on shaping the microstructure and properties of 5083 and AlSi11 aluminium alloys by the KOBO extrusion process. The investigated materials differed in their chemical composition, initial microstructure and susceptibility to plastic deformation. The 5083 alloy is intended for plastic working, whereas the cast AlSi11 alloy exhibits limited deformability under conventional forming conditions due to the presence of a brittle silicon eutectic.

The main objective of the study was to determine the influence of the die oscillation frequency and extrusion ratio on the course of the KOBO process, as well as on the microstructure, mechanical properties, microhardness and surface quality of the obtained rods. The extrusion process was performed at room temperature using billets with a diameter of 60 mm. Die oscillation frequencies of 3, 5 and 7 Hz and extrusion ratios of $\lambda = 36$, $\lambda = 60$and $\lambda = 100$were applied. The die oscillation angle was ±8°, while the punch displacement rate was 0.1 mm/s.

The experimental programme included recording the maximum extrusion force, tensile testing, microhardness measurements, surface roughness measurements and microstructural observations of longitudinal and transverse sections of the extruded rods. The microstructure was examined using light microscopy and scanning electron microscopy. The evaluation of the morphology and distribution of individual microstructural constituents was supplemented by energy-dispersive X-ray spectroscopy.

The results demonstrated that the KOBO process enables effective plastic forming of both investigated aluminium alloys. A particularly important result was the successful production of continuous rods from the cast AlSi11 alloy, confirming the applicability of the KOBO method to materials with limited susceptibility to plastic working. The die oscillation frequency and extrusion ratio were found to affect the maximum extrusion force. For the AlSi11 alloy extruded at $\lambda = 100$, increasing the oscillation frequency from 3 to 7 Hz reduced the maximum extrusion force from 2067 to 1471 kN. An increase in the extrusion ratio also contributed to a reduction in the extrusion force, although the extent of this effect depended on the alloy type.

The KOBO process resulted in a significant modification of the microstructure of both investigated materials. In the AlSi11 alloy, fragmentation of the silicon eutectic constituents, changes in their morphology and a more uniform distribution within the aluminium matrix were observed. In the 5083 alloy, the process resulted primarily in the fragmentation and redistribution of secondary-phase particles and a reduction in microstructural heterogeneity. Increasing the extrusion ratio generally promoted a more uniform distribution of the microstructural constituents.

The process parameters also affected the mechanical properties, microhardness distribution and surface quality of the rods. Serrations associated with the Portevin–Le Chatelier effect were observed on the tensile curves of the 5083 alloy. Increasing the extrusion ratio generally reduced the surface roughness of the products. The microhardness measurements did not reveal substantial variations that would indicate significant material heterogeneity.

The obtained results confirmed that an appropriate selection of the KOBO process parameters enables controlled modification of the extrusion conditions, microstructure and properties of aluminium alloys. It was also demonstrated that the extent and character of these changes depend on the die oscillation frequency, extrusion ratio, alloy type and initial microstructure of the processed material.