FEM Simulation of Strain Gradients Induced in Metal Sheets by Special Rolling Techniques

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Abstract. Creating of gradient structures with the grain size changing from microns to nano-scale through the thickness of processed metallic materials represents a new advanced strategy for producing a superior combination of high strength and good ductility. Predetermined strain gradient can be considered as a mechanism of creating of gradient structures. Strain gradient through sheet thickness can be achieved by special rolling techniques. Searching the process parameters, which provide predetermined strain gradient, is very important. This paper presents the distributions of the plastic strain through sheet thickness of low-, medium- and high- strength aluminum alloys processed by different rolling techniques: skin pass rolling with high contact friction and high-ratio differential speed rolling (HRDSR). Effects of sheet thickness, contact friction, thickness reduction per pass, rolls speed ratio, back and front tensions were investigated by the rigid-plastic finite-element analysis. The results of the numerical simulation have demonstrated that plastic strain is more severe in the material surface, where the circumferential speed of the work roll is lower. In all cases, strain is continuously and unidirectionally increased from the minimum value on the contact with faster roll to the maximum value on the contact with slower roll during HRDSR. The non-linear effect of the influence of the rolls speed ratio on strain difference was found. The extremum of the strain difference through the sheet thickness exists. Extremely high strain difference through sheet thickness was found during a single-pass HRDSR. The extremum can be reached, when rolls speed ratio is optimal. Finite element analysis of strain gradients can be used for development of the special rolling techniques for fabrication of metal sheets with gradient structures and improved properties.