Effect of Plastic Strain and Ductile Damage on Elastic Modulus of Multiphase Steel and its Impact on Springback Prediction

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Abstract. The static elastic modulus of cold formable steels has been reported to depend on the amount of plastic pre-strain. Systematic studies on a variety of different cold formable sheet steels for automotive application revealed that pre-straining will significantly reduce the elastic constants, whereas heat treatments (180°C, 20 min) will result in an almost full recovery of the elastic constants. The decrease of Elastic Modulus with increasing plastic strain has therefore been attributed to the increased density of lattice defects that decrease the material´s Elastic Modulus. In addition, it is also altered by the accumulation of ductile damage. The suggested contribution therefore addresses the challenge to evaluate the springback behaviour of multiphase steel with consideration of pre-strain and damage-induced reduction of Elastic Modulus. The method of investigation is based on a combined experimental and numerical approach. It initially relies on an experimental quantification of pre-strain induced decrease of the static Elastic Modulus of two different multiphase steels for automotive application (dualphase steel and complex phase steel). These experimental findings will be considered in numerical simulations of bending experiments according to VDA standard. The bending angles will be sufficient to trigger ductile damage initiation and accumulation, so that both pre-strain and ductile damage effects on elastic properties will have to be considered during springback evaluation. The simulations are performed with a macroscopic ductile damage mechanics model that depends on pressure and Lode angle. It applies different criteria for damage initiation and ductile fracture and considers damage-induced softening. The model relies on damage indicators to take non-proportional strain paths into account; and it is enriched with a plastic-strain-dependent formulation of the elastic constants. Finally, experimental validation will reveal whether the effect of plastic strain and ductile damage has to be considered to predict the springback behaviour of cold formable sheet steels for automotive application.