Friction Modelling In Connection With Cold Forming Processes

This thesis describes theoretical as well as experimental studies of friction in cold forming processes. In cold forming, a main obstacle impeding accurate prediction in numerical modelling is the lack of knowledge with regard to the friction conditions at the tool/workpiece interface. Friction has a vital influence on metal flow, form filling, strain distribution and total load as well as local tool stresses. The commonly applied Coulomb's friction model and the constant friction model are not sufficient. Although the general friction model developed by Wanheim and Bay is usually accepted as a better solution, it is still not satisfactory. Because of the complex nature of the interrelations between a great variety of parameters involved, the subject of friction modelling in cold forming remains nascent and as yet difficult to address. The literature review presented here covers: friction models applied; previous friction testing; key parameters affecting friction and facilities available at the Technical University of Denmark (DTU). The project tasks are outlined with relation to the observations of the review. The FEM codes DEFORM™ and SORPAS® are used in numerical simulations. Friction models are developed and implemented in FEM simulation for analysis of the plastic friction test and forming processes. Experimental investigations include the following workpiece materials: aluminium alloy AA 6082; low carbon steel W.No.1.0303 and stainless steel W.No.1.4301. Aluminium alloy is first coated with aluminate conversion coatings and then lubricated by alkaline soap, molybdenum disulphide (MoS₂), alkaline soap followed by molykote grease paste, or kerosene respectively. Steel and stainless steel are first coated with zinc phosphate coatings and then lubricated by either alkaline soap or molybdenum disulphide. As processes testing friction sensitive flow, the ring-compression tests and the double cup extrusion tests are carried out. An absolute constant friction model has been proposed to separate the influence of strain hardening from friction. This model has been applied in the FEM analyses of the process tests. In the simulative testing, the compression-twist tests in open die and closed die are carried out to measure friction stress directly at varying normal pressure, surface expansion, sliding length and tool temperature etc. It is found that normal pressure and lubrication significantly influence friction stress. Although other parameters, like surface expansion, also affect friction, their influence is less significant. Comparison of theoretical and experimental analysis of the tests with friction sensitive flow and the three friction models, show appreciable differences in the results. New empirical friction models have therefore been developed, based on the results of the simulative tests. Applying these models in the FEM simulations shows that they are acceptable for direct applications. In direct process testing, the forward rod extrusion test is investigated for different reductions. Comparison of the results with the empirical friction models obtained by simulative testing shows good agreement. A new process test has been developed for the upsetting test, applying a new friction sensitive parameter, i.e. the relative shrinking ratio of the original end face. The parameter is very sensitive to friction, which has been verified by experimental studies and FEM analysis. In the new test, five different friction models have been implemented in FEM analysis of metal flow and normal pressure, showing no significant difference and resulting in the same shape of calibration curves as experimentally observed.

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