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On Cold Roll Bonding of Polymeric Films

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Abstract : Recently a new phenomenon for bonding of polymeric films in solid-state, at ambient temperatures well below the glass transition temperature of the polymer, has been reported. This is achieved by bulk plastic compression of polymeric films held in contact. Here we analyze the process of cold-rolling of polymeric films via finite element simulations and illustrate a flexible and modular experimental rolling-apparatus that can achieve bonding of polymeric films through cold-rolling. Firstly, the classical theory of rolling a rigid-plastic thin-strip is utilized to estimate various deformation fields such as strain-rates, velocities, loads etc. in rolling the polymeric films at the specified feed-rates and desired levels of thickness-reduction(s). Predicted magnitudes of slow strain-rates, particularly at ambient temperatures during rolling, and moderate levels of plastic deformation (at which Bauschinger effect can be neglected for the particular class of polymeric materials studied here), greatly simplifies the task of material modeling and allows us to deploy a computationally efficient, yet accurate, finite deformation rate-independent elastic-plastic material behavior model (with inclusion of isotropic-hardening) for analyzing the rolling of these polymeric films. The interfacial behavior between the roller and polymer surfaces is modeled using Coulombic friction; consistent with the rate-independent behavior. The finite deformation elastic-plastic material behavior based on (i) the additive decomposition of stretching tensor (D = De + Dp, i.e. a hypoelastic formulation) with incrementally objective time integration and, (ii) multiplicative decomposition of deformation gradient (F = FeFp) into elastic and plastic parts, are programmed and carried out for cold-rolling within ABAQUS Explicit. Predictions from both the formulations, i.e., hypoelastic and multiplicative decomposition, exhibit a close match. We find that no specialized hyperlastic/visco-plastic model is required to describe the behavior of the blend of polymeric films, under the conditions described here, thereby speeding up the computation process .

Keywords : Polymer Plasticity, Bonding, Deformation Induced Mobility, Rolling
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