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RECENT PROGRESS IN INVERSE FORM FINDING FOR METAL FORMING APPLICATIONS

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Abstract. Inverse form finding determines the optimal material configuration (i.e. the un-deformed work-piece geometry) for a desired spatial configuration (i.e. the deformed work-piece geometry) for the case of prescribed boundary conditions. Previous approaches are either only available for two-dimensional problems, computationally expensive, not applicable for path dependency or suffer from a cumbersome derivation. Hence, there is an urgent need for efficient and flexible approaches applicable to elasto-plastic materials and specially to forming processes. Here, we propose two different strategies to approach these difficulties. On the one hand, we focus on an algorithm based on an inverse mechanical formulation. It determines the sought material configuration e.g. for orthotropic elasto-plasticity at large deformations. Here we invoke a material modelling approach based on logarithmic strains for our investigations due to its modular formulation. Then the algorithmic procedure starts at the given spatial target configuration. We compute the sought material configuration by a parametrization of the deformation map in terms of spatial coordinates and a formulation based on inverse kinematics. We by-pass path dependency by alternating between a solution based on a direct and an inverse boundary value problem and mapping the computed plastic variables to the target configuration. For selected benchmark problems, this approach turns out to be more stable and efficient than traditional shape optimization methods. On the other hand, we present a novel, node-based and non-invasive optimization algorithm. Its derivation relies on gradient-based optimization theory and an analysis of the deformation stage. Therefore, the algorithm avoids a cumbersome derivation as needed for the inverse mechanical formulation. Furthermore, the advocated optimization approach is entirely independent from the constitutive modelling and straightforwardly applicable to frictional contact problems. We couple our algorithm non-invasively to arbitrary (also commercial) simulation environments. By applying a line-search strategy, testing the mesh quality and controlling inner nodal positions through an additional fictitious elastic problem, we enhance the stability of the algorithm. A convergence analysis of benchmark problems shows excellent results. Comparing both strategies indicates that the non-invasive optimization approach is better suited for an application to forming processes. In order to demonstrate its practicability, we apply the method to improve the results of sheet and sheet-bulk metal forming processes (cup deep drawing, local bulk-forming operations with stamping of a sheet by tooth geometries, a combined process of drawing and upsetting). Furthermore, we verify the numerical results through forming experiments.