MODELING EFFECTS ON STRAIN AND STRAIN RATE HISTORIES IN AUTOMOTIVE IMPACT

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Until recently, characteristic size of the finite elements in large finite element modeling (FEM) crashworthiness simulations was dictated by the available computational resources. As a consequence, the finite elements were too large to comply to the deformation features of the progressive crush of vehicle components, and the material strain rate dependency was just one of the effects that was obfuscated by the heuristic modeling rules shown to yield a good correlation with experiments. With advances in computer hardware and software, it became possible to use finite element sizes that can conform to the actual physical deformation. In such models and for strain rate sensitive materials, modeling of strain rate sensitivity plays a significant role. Without strain rate sensitivity phenomena, finely discretized FEM models tend to soften as the finite element density increases. Accounting for strain rate sensitivity counters this softening trend and, moreover, models the physics of progressive crushing more accurately. This paper compares the effects of various FEM modeling approaches on the plastic strain and strain rate histories for mild and high strength steels (HSS) in impact simulations. The scope of the study encompasses the strain rate dependent piecewise linear plasticity material model, finite element formulations, time integration, and their relative effects on the structural response. The paper reports on the ranges of strains and strain rates that are calculated in typical FEM models for tube crush and their dependence on the material and finite element modeling approaches employed. This information also provides guidelines for the extent of experimental program required for characterization of strain rate effect in steels. For the axi-symmetric tube crush, models were compared to the experimental results available in literature. For the non-symmetric tube crushing, drop tower experiments were conducted for circular tubes made of High Strength Low Alloy steel and Dual Phase steels and used for comparison with the models. The histories of plastic strain rates as calculated at the computational increment time level considerably differ from average strain rates that are usually post-calculated based on deformation histories. The results show a close relation between the strain rate history, finite element type and FEM mesh discretization. For typical automotive progressive crushing conditions, plastic strain rate magnitudes of the order of 10^{+3} /s provide a reasonable upper limit for the model and are important mostly during the initial impact. For subsequent crushing, plastic strain rate magnitudes of the order of 10^{+2} /s are prevalent for shell finite elements with characteristic sizes that are of the order of 1-2 tube shell thicknesses. The material models based on plastic strain rate result in more realistically feasible strain rate histories.

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