IMPACT SIMULATION OF AUTO-BODY STRUCTURES WITH AN ELASTO-PLASTIC EXPLICIT FINITE ELEMENT METHOD

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ABSTRACT- Simulation of auto body structures has been carried out by an elasto-plastic explicit finite element method with shell elements and the plastic-predictor elastic-corrector (PPEC) scheme in stress integration. A dynamic constitutive model of sheet metal is constructed with the tension split Hopkinson bar experiment and used in simulation. Simulation results demonstrate remarkable difference in deformed shapes and the impact energy absorption between the static model and the dynamic model.

INTRODUCTION: The automotive industry has made an effort to develop light-weight auto-body structures for the purpose of fuel efficiency and satisfying emission gas regulation of vehicles. Since the weight reduction of an auto-body should not sacrifice the safety, the crash analysis has to be accurately conducted for efficient reduction of the auto-body weight. As the dynamic behavior of a material is different from the static one, an adequate dynamic model has to be developed to obtain the dynamic response for the corresponding level of strain rate. The constitutive relation of sheet metals is determined by a tension Split Hopkinson bar apparatus and interpolated with a modified J-C model. In this paper, crash analysis is carried out by an elasto-plastic finite element method with explicit time integration. A shell element formulation by Belytschko et al. [1994] has been used for simulation of thin-walled structures. In order to keep track of the stress-strain relation for a rate-dependent model accurately, the plastic-predictor elastic-corrector (PPEC) scheme proposed by Nemat-Nasser et al. [1992] is adopted.

CRASH ANALYSIS OF AUTO-BODY STRUCTURES: The crash analysis of an s-rail and a hood of an automobile is performed for the dynamic and static constitutive relations. The steel sheets used in crash analysis are SPCEN and 60TRIP. 60TRIP is one of the high strength steels made from the transformation-induced-plasticity process for the purpose of weight reduction while SPCEN is one of the sheet steels that has been commonly used in auto body structures. The conventional Johnson-Cook and modified Johnson-Cook model of the sheet metals (Johnson et al. [1983]; Kang et al. [1999]) are written in Eqn. (1) and (2) respectively:

$$\bar{\sigma} = (A + B\bar{\varepsilon}^{n})(1 + C\ln\dot{\bar{\varepsilon}})(1 - T^{*m}) \tag{1}$$

$$\bar{\sigma} = (A + B\bar{\varepsilon}^{n})[1 + C_1 \ln \dot{\bar{\varepsilon}} + C_2 (\ln \dot{\bar{\varepsilon}})^2](1 - T^{*m}) \tag{2}$$

where T^* is the homologous temperature represented by Eq. (3).

$$T^* = \frac{T - T_{room}}{T_{melt} - T_{room}} \tag{3}$$

The crash analysis of an s-rail and a hood in Taurus model is carried out. The impact loading is applied to the one end of the s-rail and the hood. The impact velocity of a rigid wall is 48km/h and the mass of the wall is 200kg.

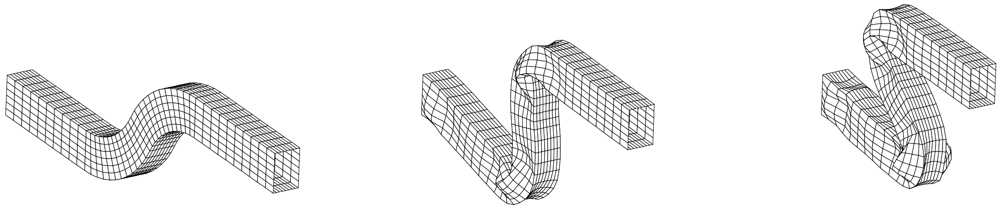

(a) (b) (c)

Fig. 1 The initial and deformed shapes of an s-rail: (a) initial shape; (b) displacement of 200mm; (c) displacement of 480mm.

The initial and deformed shapes of an s-rail are shown in Fig. 1. The deformation is localized at the curved part of the s-rail. The hood of an automobile is composed of inner and outer panels, which contact each other as deformation progresses. The initial and deformed shapes of the hood are shown in Fig. 2. In order to effectively absorb the impact energy, structural weak parts are formed in the inner panel. It leads to the localized deformation as shown in Fig. 2. Deformed shapes become quite different depending on the material model as shown in Fig. 3 (a). The displacement of the front end of the hood is shown in Fig. 3 (b). When the strain rate hardening effect is considered with the dynamic constitutive relation, the final displacement becomes relatively small compared to the one with a quasi-static model.

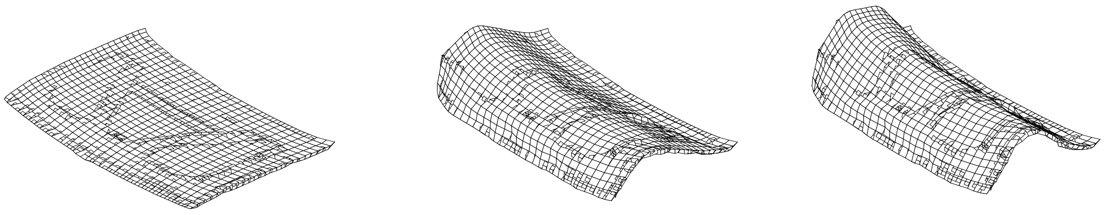
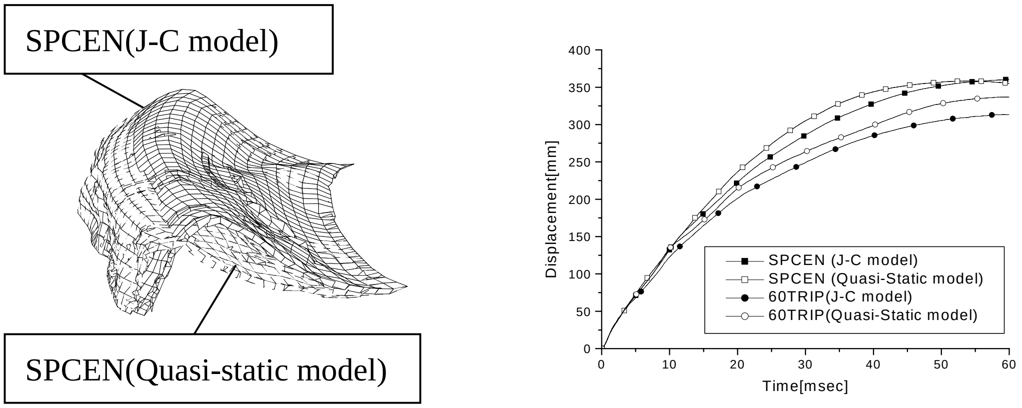

(a) (b) (c)

Fig. 2 The initial and deformed shapes of the hood: (a) initial shape; (b) 120mm deform; (c) 350mm deform.



(a) (b)

Fig. 3. Deformed shapes and displacement–time curves for constitutive models: (a) deformed shapes; (b) displacement–time curves.

The simulation results also show that 60TRIP is more effective in crash-worthiness than SPCEN. It is noted from the result that the rate-dependent crash analysis must be carried out with its proper material properties for successful light-weight design of an auto-body with the high strength steel.

CONCLUSION: Simulation results demonstrate the remarkable difference in the deformed shapes and final displacement between the static model and the dynamic one. It is noted that the dynamic analysis shows 60TRIP is more effective in the crash-worthiness than SPCEN.

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