Evaluation of Measurement Uncertainty for High Strain Rate Tensile Properties of Auto-body Steel Sheets

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This paper is concerned with the measurement uncertainty of the tensile properties of auto-body steel sheets at intermediate strain rates ranged from 1/sec to 100/sec. A procedure to obtain the true stress–true strain data is properly designed for the experiment and data acquisition. An analytic model is then established to evaluate the standard uncertainty of the measurand of the true stress, which is a function of the input quantities: the tensile load; the initial length, the thickness and width of a specimen; and the deformed length of a specimen. Sources of uncertainties of the input quantities are evaluated for the high speed tensile test with their associated sensitivity coefficients. Uncertainty of the stress data acquired is also considered in the procedure of a smoothing process used to remove unnecessary signals acquired from experiments. Image analysis using a high speed camera is carried out to measure deformation of the specimen during high speed tensile tests with proper uncertainty evaluation. A combined standard uncertainty is evaluated from the uncertainties of the input quantities as well as the influence factor for the true stress of auto-body steel sheets at intermediate strain rates. Some examples are presented for the standard uncertainty evaluation of auto-body steel sheets such as SPCC, DP590 and TRIP590. The results demonstrate that the standard uncertainty evaluation procedure has been successfully applied to various kinds of steel sheets.

The effect of the uncertainty on the dynamic deformation analysis is investigated using a stochastic approach which is called Monte Carlo method. The probability distribution of obtained true stress data is defined with the normal distribution function. The probability distribution function of the true stress is estimated by combining all probability distribution functions for the input quantities and influence quantities. The combination of the probability functions is shown to be properly approximated with the normal distribution function. Random samples for the true stress data is generated according to the normal distribution which is identified with measured true stress and the standard uncertainty. The generated random samples for the true stress data are applied into two numerical simulations; dynamic buckling analysis of a circular tube and crash analysis of a front side member. The effects of the uncertainty on the numerical analyses are evaluated with statistical observations of the analysis results. The results presented in the Monte Carlo simulation show smaller variance than that of material properties. Consequently, the true stress data is obtained with properly evaluated measurement uncertainty and the effects induced by variability of material properties is statistically estimated on numerical analyses for crashworthiness evaluation of auto-body parts.

Keywords: Uncertainty Evaluation, Dynamic Tensile Properties, Auto-body steel sheet, Monte Carlo Simulation