SUMMARY OF THE DISSERTATION

Title: The experimental and computational studies on the impact energy absorption characteristic of TRIP steel at various deformation rate

(様々な変形速度における TRIP 鋼の衝撃エネルギー吸収特性に関する実験的ならびに数値解析的研究)

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Transformation-induced plasticity (TRIP) steel is proven to have favorable mechanical properties due to strain-induced martensitic transformation (SIMT). In addition, TRIP steel might have a high energy-absorption characteristic because it could possibly consume impact energy by not only plastic deformation but also SIMT during deformation. Therefore, TRIP steel is considered to be suitable for automotive structures from the viewpoint of safety. Generally, bending deformation due to buckling is one of the major collapse modes of automotive structures. Thus, an investigation on the bending deformation behavior and energy-absorption characteristic in TRIP steel at high deformation rate is indispensable to clarify the mechanism of better performance. Some past studies have focused on the improvement of mechanical properties by means of SIMT; however, the mechanism through which the energy-absorption characteristic in steel can be improved is still unclear and has become a critical issue in the design process of vehicles. Therefore, energy-absorption characteristic of TRIP steel in bending deformation at various deformation rates is investigated in this dissertation.

Firstly, in Chapter 3, energy absorption is experimentally evaluated by quasi-static and impact three-point bending test for both smooth and pre-cracked specimens made of type-304 austenitic stainless steel, a kind of TRIP steel. Energy absorption is discussed by examination of characteristic of force-deflection curves and value of *J*-integral. The results showed a positive rate sensitivity of the external force and *J*-integral in TRIP steel. The positive rate sensitivity of *J*-integral was also confirmed by the rate-sensitivity of stretch zone width. As a result, TRIP steel might have excellent energy-absorption characteristic under impact loading deformation.

Then, the computational methodology described in detail in Chapter 2 is applied to discuss the mechanism of energy-absorption characteristic in three-point bending deformation of the smooth specimen in Chapter 4. The computational results

showed a fairly good agreement with experimental results. A positive rate-sensitivity of the energy absorption could be observed. At room temperature, the effect of SIMT could not be seen at high deformation rate because of a stability of the parent phase as well as a relatively high temperature rise near the loading point. The mechanism of higher energy absorption at higher deflection rate could be explained from the viewpoint of rate-sensitivity on strain hardening in austenite. At high deflection rate, the concentration of relatively-high temperature rise induced a localization of deformation near the loading point; however, this localization was retarded because of SIMT at low test temperature. At 80 K, the impact energy-absorption characteristic was clearly improved by an increase in the strain hardening as well as the ductility because of SIMT.

In Chapter 5, finite-element simulations are performed for the small punch test by an inclusion of isotropic damage variable and its evolution equation in the parent phase. The validity of computation was confirmed. From the obtained results, TRIP steel indicated a negative rate-sensitivity of maximum force and deflection at the maximum force. At high deflection rate, the damage occurred when deflection is lower level. The mode of failure in the specimen presented a rate-sensitivity. Although the total consumption energy was considerably higher in case of larger puncher and bigger specimen, a similar tendency of deflection at the maximum force could be obtained for different sizes of the puncher and specimen. At room temperature, fracture-mechanical characteristics at lower deflection rate were enhanced by means of SIMT. The impact fracture-mechanical characteristics were clearly improved at 80 K due to an increase in the deflection at the maximum force because of a saturated value of volume fraction of martensite. A correlation between equivalent fracture strain and fracture toughness could not be obtained based on the conventional method.

Finally, in Chapter 6, the main findings, conclusions, and the required further works are described.