Development of Delayed Fracture Prevention Technology for High-Strength Steel Sheet Parts

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KEY WORDS: materials, high-strength steel sheet, shear edge, delayed fracture, residual stress, edge compression(D3)

This study proposes an edge compression technique to prevent delayed fracture in high-strength steel sheet parts by reducing tensile residual stress at sheared edges. As the use of high-strength steel sheets increases in automotive body structures to achieve both weight reduction and structural strength, delayed fracture originating from sheared edges has become a critical issue.

Delayed fracture in high-strength steels occurs when material strength, diffusible hydrogen content, and tensile residual stress reach critical conditions. Among these factors, tensile residual stress generated during shearing is particularly important, as cracks often initiate at the shear edge. Therefore, reducing residual stress at sheared edges is essential to improve resistance to delayed fracture.

In this study, a post-shearing edge compression process was introduced to apply controlled plastic deformation to the shear edge. The effectiveness of this method was evaluated using finite element analysis (FEA) and experiments. Numerical simulations were conducted using a two-step model consisting of a shearing process followed by an edge compression process (Fig. 1). A 1470 MPa-grade martensitic steel sheet with a thickness of 1.8 mm was analyzed using a two-dimensional axisymmetric model. The results showed that high tensile residual stress was generated near the sheared edge after shearing, whereas edge compression significantly reduced the tensile residual stress. (Fig. 2) Furthermore, increasing the compression amount enhanced stress reduction.

Experimental investigations were carried out using both straight-sheared and pierced specimens made from the same high-strength steel. Edge compression was applied under various load conditions, and the compression amount was measured using laser microscopy. Residual stress at the sheared edges was evaluated by X-ray diffraction. The results demonstrated that residual stress was reduced for both straight and pierced edges, and that stress reduction was confirmed for compression amounts of up to at least 20%, regardless of the edge geometry(Fig.3).

For pierced specimens, the effect of punch center offset during edge compression was also examined. Even when the compression area was offset by up to 0.75 mm from the hole center, residual stress reduction comparable to that of the non-offset condition was observed at all measured positions. This indicates that the proposed technique is robust against reasonable processing deviations.

To evaluate delayed fracture resistance, hydrochloric acid immersion tests were performed. As-sheared specimens exhibited multiple cracks at the shear edges, whereas no cracks were observed in compressed specimens. These results clearly demonstrate that reducing tensile residual stress through edge compression improves resistance to delayed fracture.

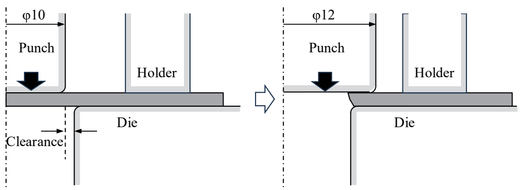

Fig. 1 FEM analysis model simulating shearing and compressing

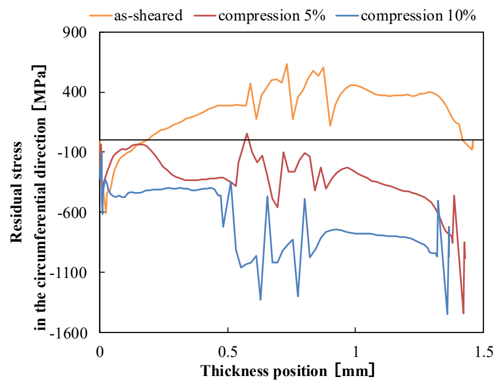

Fig. 2 Rsidual Stress after piercing edge compression in numerical analysis

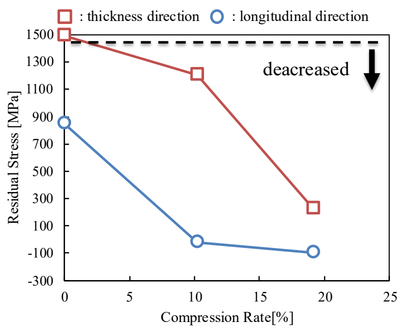

Fig. 3 Rsidual Stress after shearing edge compression (straight-sheared specimen)