Reverse Loading Tests of Steel Tube under Biaxial Stress States

Daisaku Yanaga[†], Kouichi Kuroda[†], Satoshi Yaita[‡] and Toshihiko Kuwabara[‡]

[†]R & D Laboratories
Nippon Steel & Sumitomo Metal Corporation
1-8 Fuso-cho, Amagasaki-shi, Hyogo, 660-0891, Japan
e-mail: yanaga.2ft.daisaku@jp.nssmc.com

[‡]Division of Advanced Mechanical Systems Engineering,
Institute of Engineering, Tokyo University of Agriculture and Technology
2-24-16, Nakacho, Koganei-shi, Tokyo, 184-8588, Japan

ABSTRACT

Some kinds of steel tubes are finished by several cold working processes, such as cold drawing, cold rolling or end sizing process. The values of stress components in the axial and circumferential directions of the tube change significantly, including reverse loading, during these cold-working processes. However, there are few researches that accurately measured the deformation behavior of steel tubes subjected to nonlinear stress paths, including reverse loading, under multiaxial stress states and checked the validity of material models under multiaxial stress paths.

In this study, biaxial loading tests including reverse loading were carried out using seamless carbon steel tubes. Biaxial stress components in the axial and circumferential direction were applied to the tubular specimens using a servo-controlled multiaxial tube expansion testing machine developed by Kuwabara and Sugawara [1]. This testing apparatus is capable of applying arbitrary biaxial stress paths to the central section of the tubular specimen by controlling axial forces and an internal hydraulic pressure. The tubular specimens were loaded under linear tensile stress paths. Contours of plastic work were measured in the principal stress space, and the differential hardening (DH) behaviour was observed; the shapes of the contours of plastic work changed with an increase in plastic work. In addition, small uniaxial tensile specimens were fabricated from the mother tube wall in axial and hoop directions, and tension-compression reverse loading tests were performed to quantitatively evaluate the Bauschinger effect of the test material. Moreover, bilinear stress path experiments were performed to investigate the effect of axial prestraining on the change in the yield locus shape; compressive preloading in the axial direction (first loading) followed by the application of linear stress paths in the first quadrant of the principal stress space (second loading). The measured Bauschinger effect and the DH behaviour in the second loading were different from those measured in the liner stress path tests and the uniaxial reverse loading tests for the as-received material. Based on these experimental data, a material model that can reproduce the DH behavior for the combined loading was investigated. The material model will be utilized to improve the accuracy in the numerical analyses of the cold working processes for fabricating the steel tube.

References

[1] T. Kuwabara, F. Sugawara: International Journal of Plasticity, Vol. 45, 2013, p. 103-118, doi: 10.1016/j.ijplas.2012.12.003