Distortion Analysis for Stamping an Automotive Part with Advanced High Strength Steel Sheet

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Abstract

Due to the requirement of environmental protection as well as the pressure of increasing the fuel efficiency, lightweight vehicles become the aiming target for every major car manufacturer. Although the use of lightweight metals such as aluminum alloy and magnesium alloy can achieve the purpose of weight reduction, the material cost seriously affects the market competition accordingly. Therefore, in order to achieve the target of lightweight, advanced high strength steel (AHSS) has been widely adopted by the automotive industry to produce car body structural parts. However, because of the increased strength of steel, the formability of advanced high strength steel is much inferior to that of traditional low strength steels. In addition to the fracture defect, the occurrence of springback, side-wall curl and distortion makes it more difficult to be coped with in the stamping of advanced high strength steels. Therefore, the die design concept for stamping low strength steel sheets is no longer applicable to advanced high strength steel sheets. Among these forming problems, distortion plays a critical role in influencing the overall size variation of parts, resulting in the difficulty in welding and assembly process of the automobile parts. In order to cope with this dilemma, the finite element analysis is employed to help the tooling design so as to reduce the springback in the stamping of advanced high strength steel sheets. As for the study of springback predicted by the finite element simulations for stamping advanced high strength steel sheets, the efforts have been endeavoured on the topics such as mesh size, number of integration points, punch velocity, and mass scaling which could be found in published literatures. However, these efforts still could not make the springback prediction meet the production requirements for stamping advanced high strength steel sheets. Thus, the researchers turn to focus the efforts on material models, such as hardening rules and yield criteria. In the aspect of hardening rules, considering the Bauschinger effect of material seems to be more close to the material properties exhibited in the advanced high strength steel sheets. While the biaxial stretching tests could generate more deformation data required for the yield criteria and justify the validity of yield criterion that most fit the deformation characteristic of advanced high strength steels.

Accordingly, this paper investigates the optimum material model that describes the material behavior best to improve the accuracy of the finite element simulations on the prediction of springback and distortion. The cyclic tension-compression tests were conducted to examine the Bauschinger effect of the DP590 steel sheet. The biaxial stretching tests were also performed to investigate the effectiveness of various yield criteria that best fits for the DP590 steel sheet. With the use of the optimum material models, the distortion occurred in the stamping of advanced high strength steel sheets was studied and the die design for stamping an automotive structural part, an A-pillar, which possessed a complex shape, was conducted. The formability of the A-pillar without any die addendum design was studied first to identify the potential defects that might occur in the stamping process. The fracture and wrinkle defects were then eliminated by an optimum die face design with the use of the finite element analysis. In addition, this paper also constructed the fundamental concepts on the die face design that could compensate for springback and distortion. The distortions occurred in the actual stamping of an A-pillar with DP590 steel sheet were compared to the finite element simulation results with the optimum material model adopted. The consistency between the production A-pillar part and the finite element simulation results confirms the efficiency of the die compensation design developed in this paper.

Keywords: lightweight vehicles, A-pillar, DP590 steel, stamping, springback, distortion, Bauschinger effect.