ABSTRACT

Sheet metal forming has been a major means in production of automotive parts. In general, tearing and wrinkling are the primary design concerns while springback is the secondary design concern. This paper primarily focuses on tearing and wrinkling that are defined on forming limit diagram (FLD). A nonlinear finite element analysis has been applied to simulate the forming process of the engine cross member. The material used in this study is JSC440W with the initial thickness of 1 mm. The main design parameters in this study are binder forces and drawbeads to control metal flow behaviors during the forming process. It is found that a proper drawbead configuration can reduce tearing and wrinkling problems in forming of the engine cross member.

KEY WORDS

Sheet metal forming; Engine cross member; Tearing; Wrinkling
The stamping process of an engine cross member shown in Fig. 1 in this study has been constrained on most tooling configurations. Therefore, the process control parameters in this study are only the binder force and the drawbead configuration.

2. Tooling and Materials

The stamping process of the engine cross member mainly consists of a punch, a binder, a die and a blank sheet as shown in Fig. 2. The die is fixed throughout the process. First, the binder moves down to hold the blank with the die. Then, the punch moves down to form the part.

The blank sheet in this study is JSC440W steel with the initial thickness of 1 mm. The material property is anisotropic. The relationship between the effective true stress and effective true strain is assumed to follow the power law ($\sigma = K\varepsilon^n$). The material properties are as follows: Young’s modulus ($E$) of 207 GPa, yield stress ($Y$) of 312.6 MPa, Poisson’s ratio ($\nu$) of 0.28, strength coefficient ($K$) of 745 MPa, hardening exponent ($n$) of 0.181, and anisotropy coefficients ($R_{00}$, $R_{45}$, $R_{90}$) of 1.16, 0.746 and 1.37, respectively.

3. Finite Element Models and Forming Conditions

The CAD model of tooling and blank in Fig. 2 can be discretized into small elements. The blank is modeled by using 3D shell elements in [2]. The tooling is modeled as rigid body while the blank is modeled as deformable body. The punch stroke is set as 101.134 mm. The punch speed is set as 20,000 mm/s. If a drawbead line is used, the line drawbead model with the full lock force and depth is set as 534 N/mm and 1 mm, respectively. An explicit nonlinear FEM is used [3]. This information will be used in every case.

To design the stamping process, the binder force ($BF$) and drawbead location are explored and analyzed the formability of the process via the same FLD [4]. Five cases are analyzed as follows

1. Apply $BF$ at 20 kN with no drawbead
2. Apply $BF$ at 50 kN with no drawbead
3. Apply $BF$ at 50 kN with 2 drawbead lines
4. Apply $BF$ at 50 kN with 8 drawbead lines
5. Apply $BF$ at 50 kN with 6 drawbead lines

4. Discussions and Conclusions

It is found that the Case 1 results a lot of wrinkles. Case 2 results fewer wrinkles than Case 1. Case 3 results fewer wrinkles but cracks are detected. Case 4 results fewer wrinkles and no crack. Case 5 results even fewer wrinkles but the risk of cracks is detected.

It can be concluded that there is a need to find a compromise between crack and wrinkle corrections. It can be seen that a wrinkle correction may increase the risk of cracks. Similarly, a crack correction may increase the risk of wrinkles. It is noted that the design in this work did not take the drawbead configuration into account. The drawbead configuration besides the location would also help the design process.

5. Acknowledgements

The authors would like to express their gratitude to Engineering Technology Associates Inc. (ETA) from USA for providing the commercial software package and to KMUTT’s research funding for providing the partial financial support.

6. References