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Transverse Bending Characteristics in U-channel Forming of Tailor Rolled Blank

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Abstract: Research on the formability of tailor rolled blank (TRB) is of good practical significance and application value because of the enormous potential of TRB in the aspect of automobile lightweight. However, the forming of TRB is problematic because of the varying properties; especially, springback is a main challenge. The transverse bending (bending axis is perpendicular to the rolling direction) of TRB U-channel was studied through simulation and experiment. The forming characteristics of TRB U-channel during transverse bending were analyzed. The mechanisms of forming defects, including bending springback and thickness transition zone (TTZ) movement, were revealed. On this basis, effects of blank geometric parameters on springback and TTZ movement were discussed. The results indicate that springback and TTZ movement happen during transverse bending of TRB U-channel. Nonuniform stress distribution is the most fundamental reason for the occurrence of springback of TRB during transverse bending. Annealing can eliminate nonuniform stress distribution, and thus diminish springback of TRB, especially springback on the thinner side. Therefore, springback of the whole TRB becomes more uniform. However, annealing can increase the TTZ movement. Blank thickness and TTZ position are the main factors affecting the formability of TRB U-channel during transverse bending.

Key words: tailor rolled blank; transverse bending; springback; U-channel; annealing; thickness transition zone

Tailor rolled blank (TRB) was developed by Institute of Metal Forming (IBF) at Aachen University in Germany in the 1990s[1]. Auto panels made of TRB, which have advantages of better rigidity and strength, can enhance the load-carrying capacity, improve the dent resistance, strengthen the energy absorption capacity, and significantly lighten the mass of autobody, compared with auto panels made of sheet metal with uniform thickness[2,3]. Moreover, TRB is also much better than tailor welded blank (TWB) in terms of mechanical properties, mass-saving effect, surface quality, and production cost[4]. The emergence of TRB makes the prospect of automotive lightweight brighter, and TRB can play a great role in the automobile field by substituting TWB with the same material, the same width and different thicknesses[5].

Stamping process is one of the most important ways to manufacture auto panels. After forming, sheet metal tends to return to the initial shape and inverse elastic deformation happens, which is called springback[6]. Springback is a common phenomenon, especially during bending and drawing[7]. Because of variable thickness in the rolling direction, properties of TRB are not even, and thus springback of TRB is also nonuniform[8]. The thinner side and the thicker side interact, which makes springback of TRB more complicated[9]. Moreover, because of the property difference between the thinner side and the thicker side, not only springback, but also thickness transition zone (TTZ) movement happen in U-channel forming of TRB[10,11].

At present, scholars have made some researches into the formability of TRB[12-16], but study on bending springback is rare. Weinrich et al. [17] presented an innovative process of incremental stress su-

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perposition during air bending to reduce springback of TRB. Jiang et al. [18] carried out numerical simulation on the resiliencies of the continuous variable cross-sectioned beam, and the block blank holder technologies were employed to achieve a descent of the entire amount of springback. However, existing studies on bending springback mainly focus on the longitudinal bending (bending axis is parallel to the rolling direction), and there is few study on the transverse bending (bending axis is perpendicular to the rolling direction) of TRB.

In this paper, the transverse bending characteristics of TRB U-channel were studied through simulation and experiment. The stress distribution of TRB during transverse bending was obtained. The mechanisms of forming defects, including bending springback and TTZ movement, were discussed. On this basis, effects of blank thickness, TTZ length and TTZ position on springback and TTZ movement of TRB U-channel were analyzed.

1 Simulation Setup and Experimental Conditions

1.1 Simulation setup

The model of TRB U-channel during transverse bending is shown in Fig. 1. TRB property parameters were obtained from stress-strain field[19], as demonstrated in Fig. 2. The blank width was much larger than the thickness, and thus the blank was presumed under the plane strain condition. The material model followed the hardening exponent method and the Barlat yield criterion. Belytschko-Tsay shell elements and full-integrated elements were adopted for the forming simulation and the springback simulation, respectively. An explicit finite element code was used to model the forming stage, and an implicit code was applied to simulate springback after forming. Detailed simulation parameters are listed in Table 1.

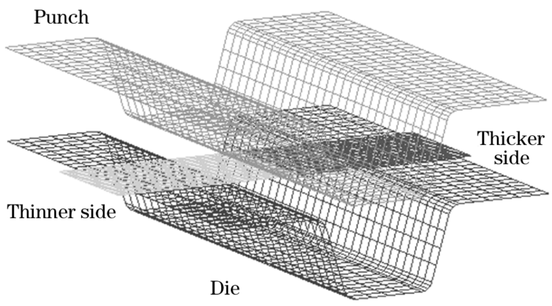
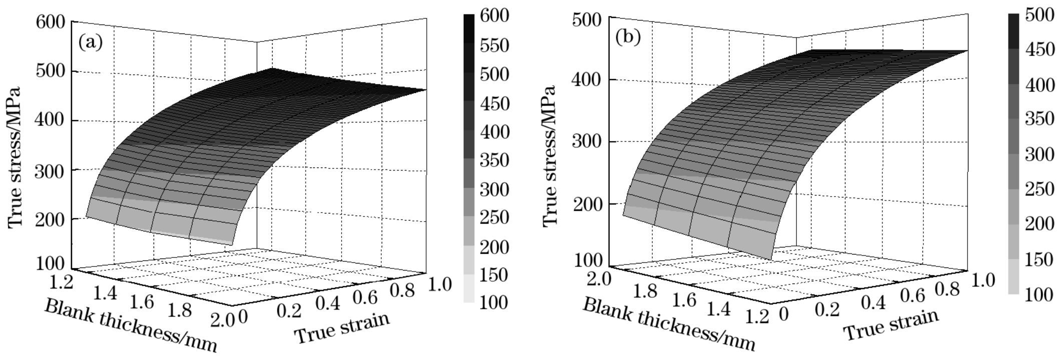


Fig. 1 Stamping model of TRB U-channel



(a) Unannealed TRB; (b) Annealed TRB.

Fig. 2 True stress-strain fields of TRB

Table 1 Simulation parameters

Punch stroke/mm	50
Punch velocity/(mm · s^{-1})	5 000
Number of integration points through thickness	9
Mesh size/(mm × mm)	2 × 2

1.2 Experimental conditions

Trademark of TRB is SPHC, and some of TRBs are annealed. Experiments were carried out by hydraulic press. Specific experimental conditions are presented in Table 2. TRB U-channels obtained during experiment are shown in Fig. 3. Fig. 4 shows the springback sketch map of U-channel. The flange end was selected as the measurement position. Springback was measured by ΔL which synthetically considers vertical and horizontal springbacks.

2 Results and Discussion

2.1 Transverse bending characteristics of TRB U-channel

According to Fig. 3, for unannealed TRB U-channel, springback on the thinner side is much larger than that on the thicker side. For annealed TRB, springback on the thinner side is slightly larger than that on the thicker side. The reason is that annealing