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◆ 특집 ◆ 최신 정밀 설계재료 기술 II

고장력강 범퍼 빔의 롤 포밍 공정

Roll Forming Analysis for High Strength Steel Bumper Process

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Today's automotive industry is evolving toward low-emissions or zero-emissions high-efficiency vehicles. Highly efficient power sources are required, as well as high strength steels for various parts to increase safety. In this study, we investigated the roll-forming process for the development of high strength, lightweight steel bumper beams. The roll-forming process was analyzed using the software package Shape-RF in combination with a rigid-plastic finite element method model. An optimal roll-forming process based on roll-pass was obtained using finite element method simulations.

Key Words: Roll forming (롤 포밍), High strength steel (고장력강), Bumper beam (범퍼 빔), Finite Element Method (유한 요소법)

1. Introduction

Today's automotive industry is working toward the development of high efficiency, low- or zero-emission vehicles. In this study, we use lightweight materials for various parts, develop a high-efficiency power source, and use high-tensile steel to increase the safety of the vehicle.

The roll forming process is operated continuously between roll forming multi-stages while metal sheet passes sequentially. Obtaining a desired cross-sectional shape from a flat panel by progressive bending is called plastic processing. When formed at room temperature, the products have high dimensional accuracy, unlike products formed with hot extrusion or hot-rolling, and their cross-sectional shapes and surface conditions are better, as well.[1]

Because of the repeated compression and tension in the roll forming process, it is difficult to predict the shape between each pass. After multiple passes to form the final shape, residual strain remains, as well as wrinkles in the final product due to the impacts, bending or buckling. Buckling is difficult to predict exactly, because it is influenced by many factors such as, the material flow stress, material thickness, roll angle, and horizontal distance between bends.[2]

M. Kiuchi[3,4] of Tokyo University, Japan, proposed a sine functionalistic plate shape after calculating a velocity field to determine the parameters that will minimize the energy consumption using an optimization algorithm.

Farzin[5] constructed a simple model by a non-linear finite element method to analyze buckling in the roll forming process. Cheng and Rhodes[6,7] analyzed the residual stress or strain in the longitudinal direction of the boundary of a product that was produced by the roll forming process under the condition of structural buckling.

Most previous research has considered simple model geometry or symmetrical. There are many difficulties in the analysis of asymmetrical products.[8-10]

In this study, the stability of a lightweight car is increased by using high-tensile steel for the bumper beam produced by the roll forming process. Roll forming using a dedicated finite element analysis program, SHAPE-RF process by interpreting the roll forming process of design defect found during pre-production prior to and modify the design to complement material and wasted time without the roll forming process economically to develop into the roll forming process.

2. Roll forming analysis

2.1 Finite element model

In this study, the roll forming process for the production of high-tensile steel bumper beams a vehicle is analyzed. The roll forming process to produce the cross-sectional shape of the bumper beam is shown in Fig. 1. In this process, the bumper beam material is passed through rolls a total of 20 times for gradual transformation into the final cross-sectional shape to be molded.

Plastic rollers are designed on a computer to interpret the roll forming process, as shown in Fig. 2.

The characteristics of the bumper beam material used in the roll forming process are shown in Table 1. Finite element analysis was performed for the roll forming process using this material.

Shape-RF was used to interpret the roll forming process. It is an analysis tool based on the rigid plasticity model, which was developed for specialized analysis of the roll forming process.

The analysis conditions given in this program are provided in Table 2. Based on these conditions, the primary analysis was performed.

2.2 Primary analysis results

The shape of the material molded in the final roll was obtained as a result of this interpretation of the cross section, as shown in Fig. 4.

Analysis was conducted for the shape and interpretation of the results obtained from the final roll.

The shape of the product about the Y-axis is not

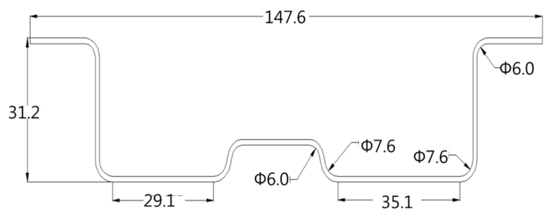

Fig. 1 Shape of cross section

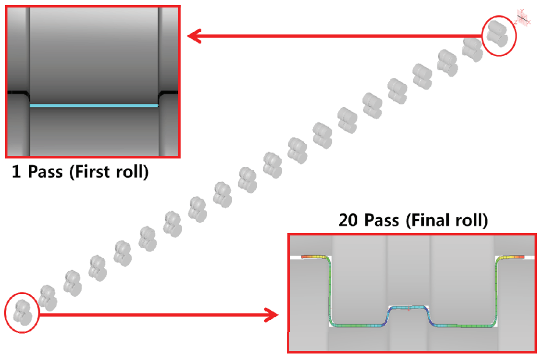

Fig. 2 Roll forming process

Table 1 Mechanical properties of materials

Young's modulus	206 GPa
Yield strength	810 MPa
Ultimate tensile strength	1237 MPa
thickness	1.2 mm

Table 2 Conditions of analysis

Number of Element in Width Direction	120
Number of Element in Width Direction	1
Number of Element in Roll Direction	20
Friction coefficient	0.1
Initial strain	0.001
Angular Velocity (rad/sec)	1
Flow stress (Mpa)	$\bar{\sigma}=1850(0.001+\bar{\varepsilon})^{0.1326}$
Horizontal distance to the previous roll stand (mm)	500

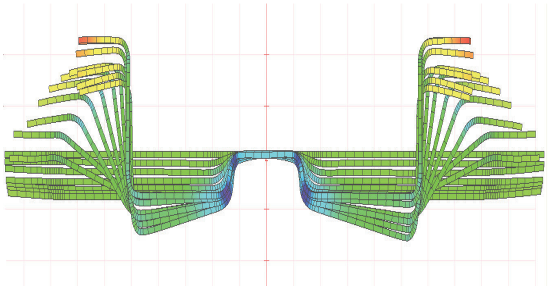

Fig. 3 Flower pattern

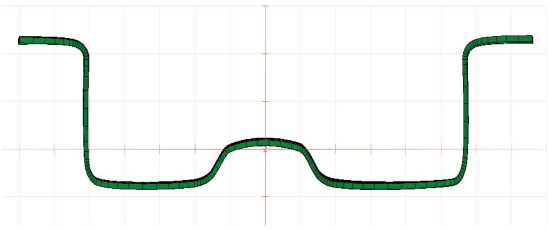

Fig. 4 Final pass shape of material

symmetrical, but the bent portions had the same radius of curvature. Therefore, any of the four points of the bends could be selected, as shown in Fig. 5(a). The roll forming process was analyzed in terms of the total effective strain and total thickness with each pass, and the trend in the variations was investigated.

Fig. 5(b) illustrates the total effective strain of the whole roll pass whole process. Fig. 5(b) indicates, Strain 3and strain 4 were higher. Repeated bending and unbending were increased. In addition, the strain remains low overall.

Fig. 5(c) presents the 4 points of the thickness at each pass. For strain 3 and strain 4, the thickness of the material in the high rate of 1.08mm decreased, but this will not be a problem.

Fig. 6 shows a comparison of the final designed cross-section and the forming section. Many errors appear at the center of the curvature part. Therefore, it is considered that this process needs to be modified.

In the distribution of strain and thickness, there is no special problem. So, the roll shape does not need to be modified, but instead, the conditions of the other molding processes should be modified, such as the distance between the rolls, the diameter of the roll, the roll rotation rate, and the molding temperature.

In the roll forming process, the larger the diameter of the roll, the slower the roll rotation speed. Higher molding temperatures give good moldability and affect other factors of formability. A secondary analysis was conducted to adjust the distance between rolls and the rotational speeds of the rolls.

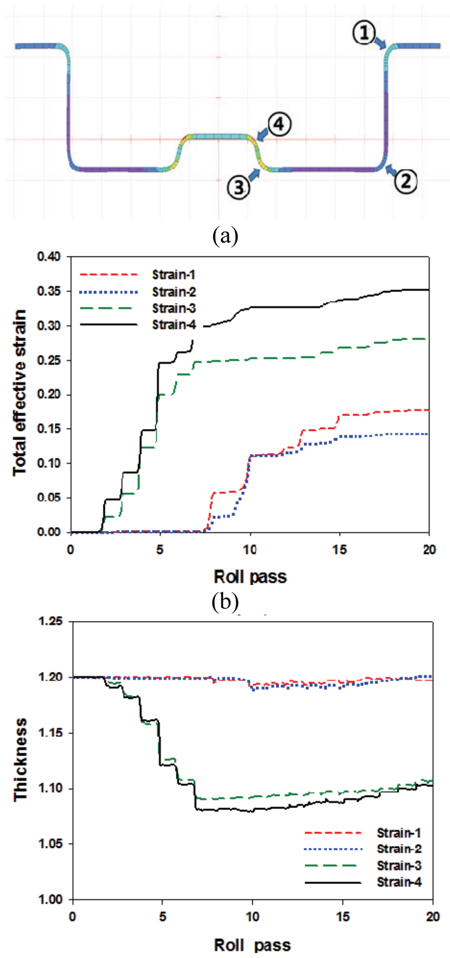

Fig. 5 Schematic diagram of measurement point (a), effect of roll passes on total effective strain (b) and thickness (c)

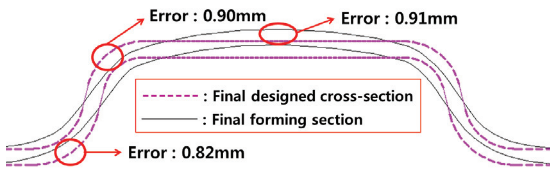

Fig. 6 Comparison of section shape

Table 3 Conditions of analysis

Number of Element in Width Direction	120
Number of Element in Width Direction	1
Number of Element in Roll Direction	20
Friction coefficient	0.1
Initial strain	0.001
Angular Velocity (rad/sec)	0.1
Flow stress (Mpa)	$\bar{\sigma}=1850(0.001+\bar{\varepsilon})^{0.1326}$
Horizontal distance to the previous roll stand (mm)	450

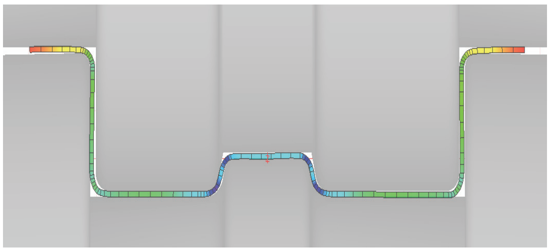

Fig. 7 Final pass shape of material

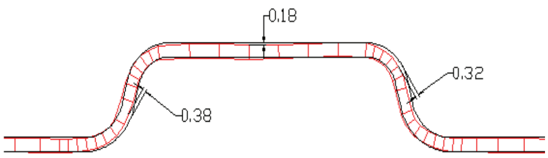

Fig. 8 Comparison of section shape

2.3 Secondary analysis results

Table 3 shows the modified analysis conditions based on the results of the primary analysis. In the secondary interpretation, the distance between the rolls was reduced from 500 mm to 450 mm and the roll rotation speed was reduced from 1rad/sec to 0.1rad/sec.

The final shape shown in Fig. 7 was obtained, and the design section and interpretation of the results section were compared. As shown in Fig. 8, the errors were within the acceptable range.

As shown in Fig. 5(a), the area of the total effective strain, longitudinal strain, and thickness of each pass of the roll forming process, and the trend of specific variations were analyzed.

Fig. 9(a) shows the total effective strain of the roll passes of the whole process. The primary interpretation

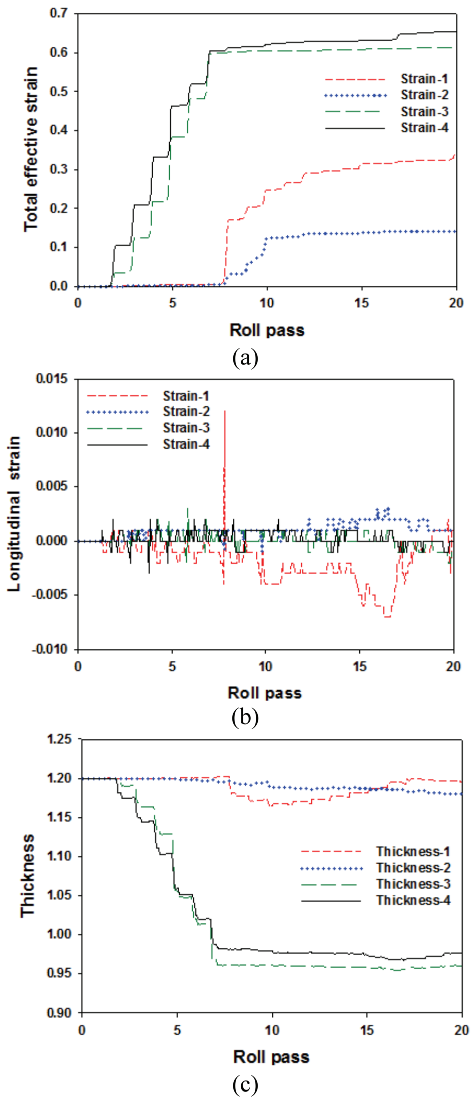

Fig. 9 Effect of roll pass on total effective strain (a), longitudinal strain (b) and thickness (c)

has almost twice the strain. In particular, the strain is higher for strain 3 and strain 4. This means that there is more deformation than there was in the primary interpretation. Through the graph, the errors of the central portion of the primary analysis period could improve.

Bending is one of the defects of residual strain after the roll forming process. These are the bow phenomenon and the camber phenomenon bending in the horizontal direction. These phenomena occur due to imbalanced strain distributions, of stretching and contraction in the length direction. Therefore, the materials were more accurately molded.

In Fig. 9(a), overall stain values are higher than the primary analysis for each pass.

Fig. 9(b) shows the distribution of each pass of the longitudinal strain. A peak appears in the area 8 roll of strain 1, but its value is low at 0.012.

Fig. 9(c) indicates the thickness of the material. Secondary result thickness value (thickness 3, 0.96mm) decreases 0.24mm more than Primary result (1.1mm). But there is no problem because the thickness variation of the width of the low and the shape design from the continuous of curvature part is difficult in an influx of material. The material was under excessive tension, and the thickness reduced continuously.

Based on the results of all analyses, better results were obtained than in the primary commentary.

3. Conclusion

The roll forming process for the production of high tensile steel as the material for automotive bumper beams was analyzed in terms of total effective strain, longitudinal strain and the thickness of material after each pass, using finite element analysis. Identified by the presence of the defect occurs have secured the roll forming process design for reliability.

Some conclusions were therefore obtained as follow.

(1) A method for car bumper beam production using the high-tensile steel sheet roll forming process has been developed.

(2) The formability of the material was improved by roll forming molding, changing the roll rotation speed and adjusting the process conditions.

(3) During roll forming, the plastic deformation was maintained for each pass to reduce the probability of bending defects.

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