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Process Design of Automobile Seat Rail Lower Parts using Ultra-High Strength, DP980 Steel

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980MPa급 초고장력 강판을 이용한 자동차용 시트 레일 로어 부품의 성형공정 설계

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ABSTRACT

The purpose of this study is to develop a process for forming a MPa ultra-high strength steel sheet to reduce weight and improve product strength. To do this, we performed the initial process design based on empirical formulas in a handbook and experience of skilled engineers, and researched the effects of major process variables on spring back by analyzing the forming analysis and experimental results. This paper suggests an optimal process design of the seat rail lower parts, using a MPa ultra-high strength steel sheet. This satisfies the dimensional accuracy and strength requirements for the product.

Key words : Seat Rail Lower(시트 레일 로어), Shape Fixability(형상 동결성), Ultra-high Strength Steel(초고장력 강판), Process Design(성형공정 설계), Spring Back (스프링 백)

1. Introduction

Recently, as regulations on environment and fuel efficiency have been strengthened, weight reduction of automobiles has become a major issue. On the other hand, the weight of automobiles is continuously increasing due to high performance and various convenience devices. When the steel sheet has a high strength, the rigidity of the vehicle body is increased and safety is improved. The strength of the vehicle body can be maintained even if the thickness of the steel sheet is reduced, and the weight of the vehicle can be reduced. In general, when the strength of the steel sheet is increased, the elongation rate is lowered; consequently, the workability is lowered. In the method of forming an ultra-high strength steel sheet, there are press forming and roll forming methods[1]. The ultra-high strength steel sheet has a further lowered elongation and is less formable than a general steel sheet[2]. The biggest problem in the sheet metal forming process is spring back. This problem can be solved by proper die design and

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control of process parameters. Inparticular, spring back prediction is the most important for obtaining a desired product's shape after forming in the sheet forming process. The spring back is affected by process parameters such as the geometrical shape of the formed parts and the material due to partial shape deformation due to elastic recovery during press forming. Process parameters are affected by the shape of the product, bending strength, yield strength, modulus of elasticity, and material thickness, and it is difficult to predict accurate spring back[3~5].

Several studies have been conducted on spring back prediction in Korea. Bang et al. conducted a stamping process design for a center pillar component which was formed with a high strength steel sheet of 780MPa[6]. In the case of ultra-high strength steel sheet, which is being applied to reduce vehicle weight and improve fuel economy, process design technology is important because of the large spring back compared to mildsteel. Accordingly, many researches are being developed[7~16]. The purpose of this study is to develop a process for forming an ultra-high strength steel sheet with a thickness of 1.6mm and strength of MPa to reduce the weight of the car body and to improve the strength of the product. To do this, one can proceed with an initial process design based on empirical formulas and experiences of seasoned engineers in the handbook, and analyze the effects of major process parameters on the spring back by comparing the forming analysis and experimental results. Through the analysis of process design, one can set up the process parameters and propose the optimal forming process for the seat rail lower parts using MPa ultra-high strength steel sheet material which satisfies the dimensional accuracy and strength of the product, and confirm the feasibility through an experiment.

2. Material Property Test

Fig. 1 Wear testing machine

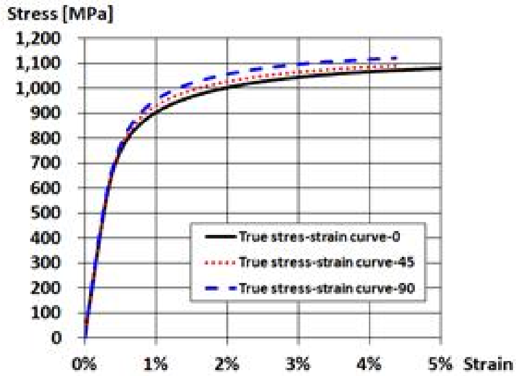


Fig. 2 True stress-strain curve of CRDP

2.1 Tensile strength test

The material used for the tensile test was an ultra-high strength steel sheet by wire cutting a thin plate material having a thickness of 1.6mm and it was used as a specimen. Tensile test was carried out to investigate the mechanical characteristics of the specimen. Tensile strength test specimens were collected at 0, 45, and 90 degrees to the rolling direction. The tensile test was carried out in a universal material tester after holding the crosshead at a constant speed and then pulling it until fractured. Fig. 1 shows the specimens after tensile test, and Fig. 2 shows the stress-strain curve obtained from the tensile test results.

2.2 FLD test

Forming Limit Diagram (FLD) refers to the forming limit diagram, which is used to identify the material flow during the mold try-out process and the amount of deformation at the deformation center

Fig. 3 Universal sheet forming test machine

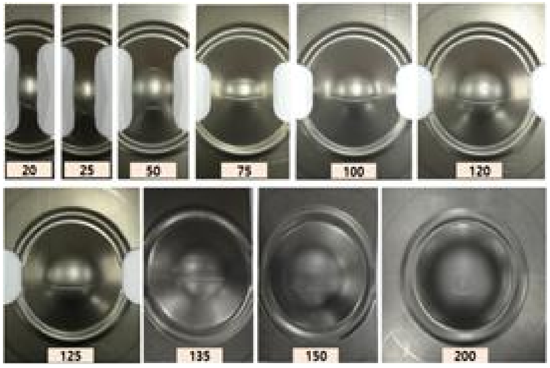


Fig. 4 Nakajima specimens after FLD test

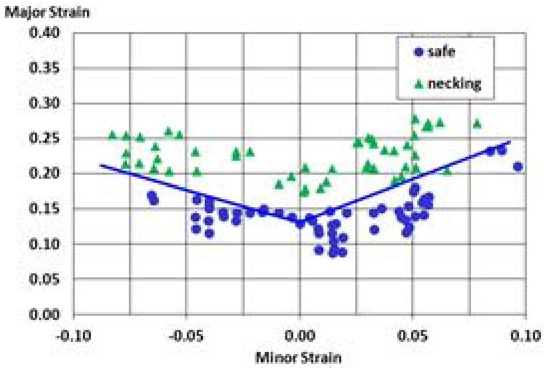


Fig. 5 FLD curve of CRDP

to facilitate mold modification; that is, the forming limit diagram is an index indicating how much deformation occurs at the deformation region where the sheet material is likely to be fractured. For the forming test to obtain an FLD curve, a universal sheet metal forming tester is used as shown in Fig. 3. Fig. 4 shows the Nakajima specimens after the FLD test, and Fig. 5 shows the FLD curve of the MPa ultra-high strength steel sheet material. The FLD diagram shows the maximum limit where a material can be deformed without necking or cracking. FLD_0, which has a minor strain of 0 in the FLD diagram, shows the major strain 0.13 in the MP a ultra-high strength steel sheet as shown in Fig.5.

3. Forming Analysis and Experiment

3.1 Forming analysis model

The physical properties of blank material for sheet metal forming analysis were obtained by the tensile test. Since the blank and the die, the blank and the punch, and the blank and the blank holder are formed in contact with each other, the roughness and the friction coefficient of the contact surface are important. Generally, the friction coefficient would be set lower than 0.1 for lubrication; however, one has applied the friction coefficient 0.12 for non-lubrication. In this study, the coefficient of friction was applied 0.12 for non-lubrication. Table 1 shows the forming analysis for the seat rail lower die using an ultra-high strength steel sheet. Fig. 6 shows the blank of the seat rail lower die. The shape of the blank was decided after several trials and errors to produce an optimal product shape, while the blank was used after cutting with the laser. Fig. 7 shows the die model for forming the analysis of the seat lower product, and Fig. 8 shows the seat rail lower product.

Table 1 Simulation conditions

Plastic material	CRDP
Blank size	110.4mm×450mm
Material thickness	1.6mm
Rigid die	STD11
Friction coefficient	0.12
Stamping velocity	30 SPM

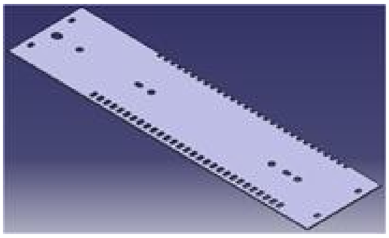


Fig. 6 Blank size of seat rail lower product

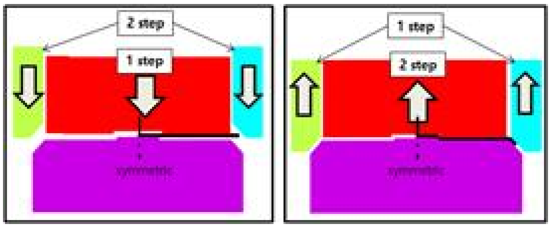


Fig. 7 seat rail lower die model of 2nd stage bending

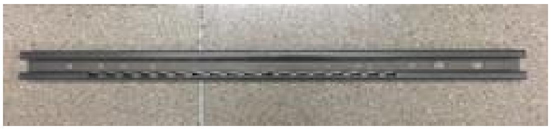


Fig. 8 Seat rail lower product after stamping

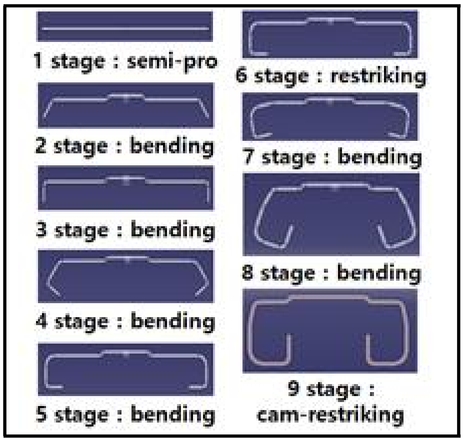
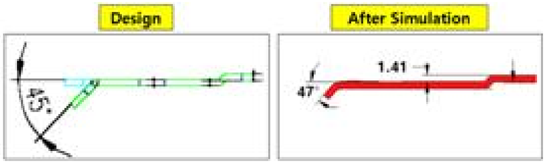


Fig. 9 Process design of seat rail lower die

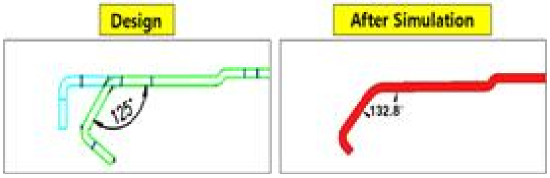
3.2 Forming analysis results

Although the ultra-high strength steel sheet material is superior in strength to general steel sheet, it has low elongation and low formability, and the elastic recovery is high, resulting in a large spring back occurrence. The spring back prevention technology of this study is a technique to improve the shape fixability of ultra-high strength steel sheet and to develop the optimal process design of the seat rail lower die. Fig. 9 shows the process design of the seat rail lower die. The processes of the seat rail lower die are comprised of several stages, and a process balancing is important for smooth flow production between each process to form a final product; that is, in order to prevent the spring back of the seat rail lower die with the ultra-high strength steel sheet, the die process design was performed with a total of nine stages. In order to produce smooth flow between processes, a process-balancing technique that provides a moderate change rather than a rapid deformation was done, and a restriking process to shape the final product was added. The physical properties data of MPa ultra-high strength steel sheet was entered to proceed with the forming analysis using a commercial finite element program called Simufact Forming S/W. For the punch and die, an alloy tool steel STD11 was used, and the material thickness was 1.6mm. Fig. 10(a) shows the forming analysis results in the 2nd stage bending, and Fig. 10(b) shows the forming analys is results in the 3rd stage bending. According to the forming analysis results of the 2nd stage bending, the initial design value of 45° was appeared to 47° after forming analysis. In the 2nd stage, the spring back occurred due to the elastic recovery of the 45° bending as shown in Fig. 11. As the analys is results of the 2nd stage bending are enlarged, the bending occurs at the end of the top face and the spring-go appears to be generated, but actually the spring back occurred. In the 3rd stage bending, the initial design value and the analysis result were coincided. Fig. 10(c) to Fig. 10(g) show the results of the forming analysis from the 4th stage to the 9th stage, and Fig. 12 shows the effective plastic strain of the 9th stage. In the

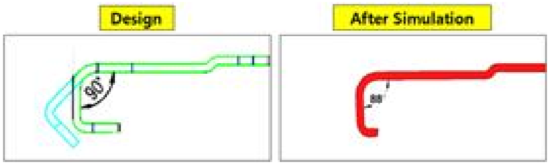


(a) 2nd stage bending

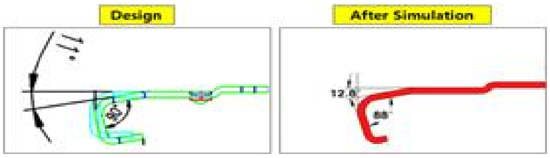
(b) 3rd stage bending



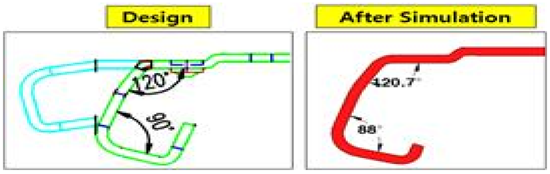
(c) 4th stage bending



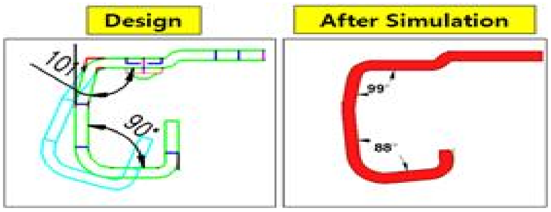
(d) 5th stage bending



(e) 7th stage bending



(f) 8th stage bending



(g) 9th stage cam-restriking

Fig. 10 Simulation results of seat rail lower die

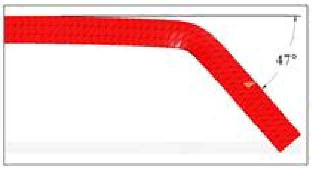


Fig. 11 Detailed enlargement of simulation results of 2th stage bending

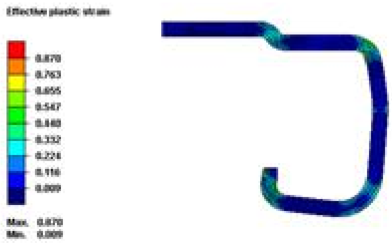
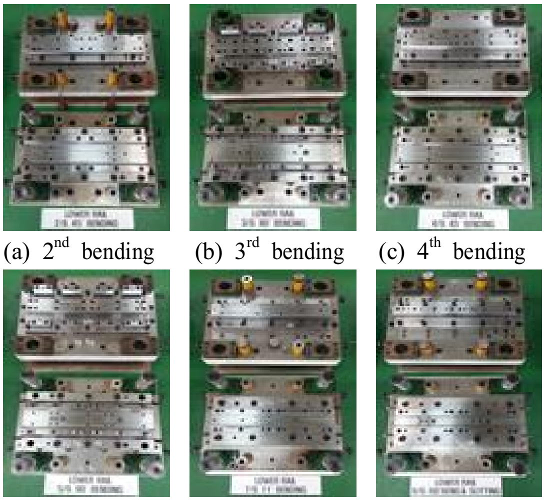


Fig. 12 Effective plastic strain of 9th stage cam -restriking

4th stage, the initial design value of 125° became 132.8° after analysis and the spring back was somewhat higher at 7.8°. The reason for this would be a normal spring back of ultra-high strength steel sheet by the high elastic recovery attributable to the obtuse angle. In the remaining bending processes, the spring back and the spring-go appeared alternatively. This could be due to process design, considering the process balancing not giving concentrated load on the specific process stage during forming.

3.3 Experimental method

The forming process was designed in nine stages in order to prevent the spring back of the seat rail lower die using the ultra-high strength steel sheet. The reason for designing a total of nine stages was that balancing among stages was considered so that the load was distributed without imposing a concentrated load to a specific stage. Furthermore, it was designed to distribute the concentrated load that hindered the flatness in a specific stage in order to control the flatness. Since it was an ultra-high



(a) 2nd bending (b) 3rd bending (c) 4th bending

(d) 5th bending (e) 7th bending (f) 8th bending

Fig. 13 Seat rail lower die of each stage

strength steel sheet with high repulsion force, the process was divided and designed to minimize spring back. Fig. 13 shows the seat rail lower die in each process stage. The workpiece was placed on the lower die and the press ram was operated until the bottom dead center for combining between upper and lower die. The combination was carried out by coating a red lead on the workpiece and the formability was checked by adjusting the die height per process stage according to the condition of the coated red lead on the contact face after forming was done.

4. Results and Discussion

The mold try-out was carried out for the seat rail lower die using a 500-tons capacity mechanical press. The workpiece material for forming was a 980MPa ultra-high strength steel sheet, which was used as a blank by laser cutting the coil material. The experiment was performed without lubrication. Table 2 shows the spring back experimental results for the seat rail lower die. In the 2nd stage bending die, 42.9° in the 1st die try-out at design value 45°,

Table 2 Experiment results of spring back of seat rail lower die

Stage	Design	Experiment		
		1st T/O	2nd T/O	3rd T/O
2nd bending	45°	42.9°	44°	45°
3rd bending	90°	90.5°	90°	90°
4th bending	125°	126.5°	125.5°	125°
5th bending	90°	90.5°	90°	90°
7th bending	11°	8°	8.7°	10.6°
8th bending	120°	124.5°	123.2°	120.5°
9th cam-restriking	101°	-	101.5°	101°

Table 3 Spring back results of seat rail lower die

Stage	Design	Analysis	Experiment
2nd bending	45°	47°	45°
3rd bending	90°	90°	90°
4th bending	125°	132.8°	125°
5th bending	90°	88°	90°
7th bending	11°	12.8°	10.6°
8th bending	120°	120.7°	120.5°
9th cam-restriking	101°	99°	101°

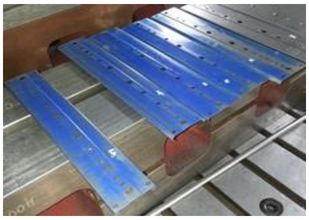


Fig. 14 Red lead samples of seat rail lower

44° from the 2nd try-out, and 45° from the final 3rd try-out could be obtained. The combination between upper and lower die was carried out by placing the workpiece on the lower die and operating the press ram until the lower dead center during die try-out. During combining, the red lead was coated on the workpiece, and the contact points on the workpiece were identified so that die could be modified and the position of the bottom dead center could be adjusted. Fig. 14 shows the red lead samples of the seat rail lower die. In the 9th stage of cam

Fig. 15 Seat rail lower samples of each stage

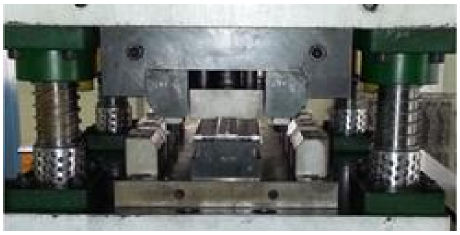


Fig. 16 Seat rail lower die during forming

restriking, a good product could be prepared with the bending angle 101° by experiment. Table 3 shows the spring back results of the seat rail lower die. When the analysis results and experimental results were compared, the spring back and spring-go appeared alternatively in each process stage in the forming analysis. Meanwhile, spring back mainly occurred in the experiment. In the 2^{nd} stage bending die, the analysis result was 47° with the design value being 45° and the experiment value being 45°, showing a difference of 2°. This might be because the end portion of the top face was bent, indicating spring-go as shown in Fig. 11. However, it was spring back caused by bending. In the 4^{th} stage bending die, the analysis result was 132.8° with the design value of 125°, while it was 125° from the experiment, showing a difference of 7.8° from the experimental result. In addition, in the 7^{th} stage bending die, the spring-go was displayed in the analysis result, while spring back occurred in the experiment. There as on for the difference between the experiment and the analysis result is that the input condition of the analysis is different from the experiment, and the working conditions such as worker, press, and die were affected minutely. Fig. 15 shows the workpieces in each stage for the seat rail lower die, and Fig. 16 shows the seat rail lower die installed on the press during forming. It was found that the optimum forming process of the seat rail low die with 980MPa ultra-high strength steel sheet can improve the shape fixability by preventing the spring back. Furthermore, it is possible to secure the dimensional accuracy for the seat rail lower parts and confirm the formability of the ultra-high strength steel sheet.

5. Conclusions

This study was carried out to develop the lightweight seat rail lower parts using the 980MPa ultra-high strength steel sheet and to secure the spring back prevention technology through the optimal process design. The obtained results are as follows:

1. In the tensile test of the ultra-high strength steel sheet, the stress due to the strain was confirmed, and the FLD diagram was obtained in order to understand the forming limit.
2. The effective strain of each process stage was confirmed through the forming analysis of the seat rail lower parts using the ultra-high strength steel sheet material, while the optimum product was manufactured through three repeated experiments on the seat rail lower die with the ultra-high strength steel sheet.
3. It was confirmed that spring back prevention was possible through the optimal process design of the seat rail lower die using the 980MPa ultra-high strength steel sheet material. Formability was also confirmed by securing dimensional accuracy for the seat rail lower parts.
4. The developed seat rail lower parts with the ultra-high strength steel sheet not only reduced the weight, but also reduced the cost and improved the productivity.

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