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Development of Automotive Seat Rail Parts for Improving Shape Fixability of Ultra High Strength Steel of 980MPa

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980MPa 초고장력 강판의 형상 동결성 향상을 통한 자동차 시트레일 부품 개발

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ABSTRACT

This paper aims to ensure describe the a spring-back prevention technique for improving shape fixability by using an ultra-high strength steel sheet with 980 MPa to develop a lightweight seat rail parts. Ultra-high strength steel gives a potential for considerable weight reduction and a cost-effective way to produce energy efficient vehicles. The influence of a spring-back of seat rail parts on the shape fixability in forming processes was investigated to be solved by an adjustment of the appropriate tool design and process parameters. The computed results for improving shape fixability were in good agreement with the experimental results.

Keywords : Automotive Seat Rail(자동차 시트레일), Shape Fixability(형상 동결성), Ultra High Strength Steel Sheet(초고장력 강판), Spring-back(스프링백), Lightweight Parts(경량 부품)

1. Introduction

Shape fixability of a sheet metal refers to a degree of maintaining a formed shape close to the shape of a die during sheet metal forming process. Shape change is a phenomenon that cannot be avoided in all the sheet metal forming processes, and is affected by various factors[1]. The largest problems faced during actual sheet metal forming process are fracture and spring-back. These problems can be resolved by designing an appropriate die and adjusting process parameters. Especially, prediction of spring-back can be the most important factor in order to obtain a desired shape of the product during sheet metal forming process. spring-back is a partial deformation of shape by elastic recovery during press forming and is affected by process parameters such as geometrical shape and materials of the formed product. Process parameters are affected by combination of product

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shape, bending strength, yield strength, modulus of elasticity, and materials thickness, thus it is difficult to predict an accurate spring-back[2-8].

Recently, several researches about shape fixability are carried out in Korea. Choi et al. discussed the effect of non-linear kinematic hardening model that affects prediction accuracy of the spring-back during analyzing the press forming for the seat rail which is formed with high strength steel sheets having 590 MPa and 780 MPa grade[9]. Park et al. predicted the spring-back of martensite steel with a grade 1,470 MPa by using a moving hardening model based on the Yoshida-Uemori model[10]. Kim compared accuracy of the spring-back analysis result, considered Bauschinger effect while developing a running reinforce center pillar die with actual formed product through the shape comparison after forming the actual products[11]. Jung performed quantification for the spring-back characteristics generated in the seat rail formed product for the steel sheet for the automobiles having various tensile strength[12].

Generally, if cars are clashed and driver's seat is broken away, first of all, seat rail is broken which would cause casualty[13]. Therefore, ultra-high strength steel sheet is applied to reduce weight of car frame by reducing material's thickness and to improve strength at stability view point[14-20]. This research is aimed to secure spring-back control technology to improve a shape fixability through an optimum process design of the seat rail die where ultra-high strength steel sheet with 980 MPa is applied.

2. Tests for Physical Characteristics of Materials

2.1 Tensile strength test

Thin steel plate having thickness 1.6mm of ultra-high strength steel sheet CR980DP was used after wire cutting. Tensile strength test was carried out in order to investigate mechanical property of the steel sheet. Specimens for tensile strength were collected at 0°, 45°, and 90° towards rolling direction. The test specimens for tensile strength was elongated until it is ruptured after maintaining crosshead at constant speed in the universal sheet forming testing machine. Fig. 1 shows the test specimen after the tensile strength test, while Fig. 2 shows the stress-strain diagram obtained from the tensile strength test.

Fig. 1 Specimens after tensile test

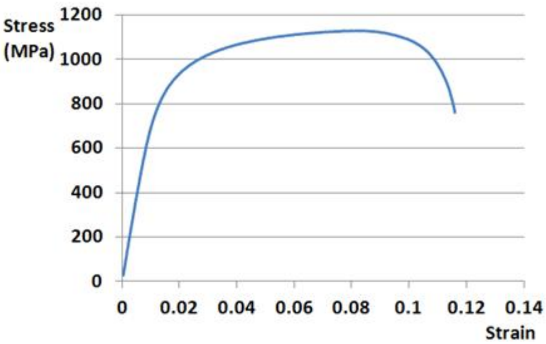


Fig. 2 True stress-strain curve of CR980DP

2.2 FLD test

FLD (Forming Limit Diagram) refers to a forming limit diagram, and makes die modification easy by finding out materials flow and strain at the strain concentrated part during die try out. That is, it

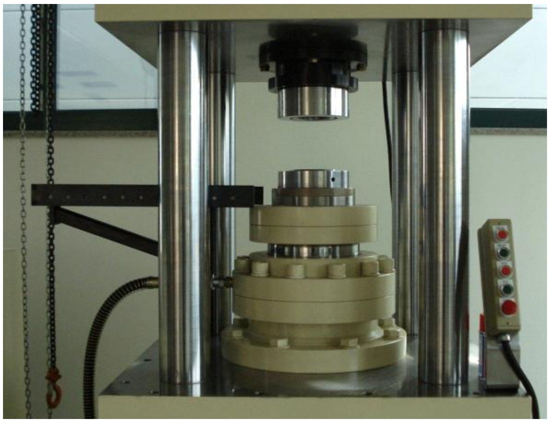


Fig. 3 Universal sheet forming test machine

Fig. 4 Specimens before FLD test

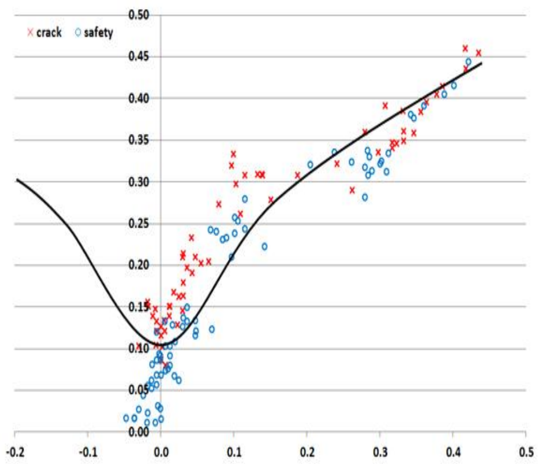


Fig. 5 Forming limit diagram of CR980DP (rolling direction)

can be used as means to predict difficulty of strain scientifically. Forming limit diagram is an index representing an amount of strain during breakage for the strained area where breakage can be occurred in the steel sheet. Universal sheet forming testing machine was used for the forming test to obtain FLD stress-strain curve as shown in Fig. 3. Fig. 4 shows FLD testing specimens, while Fig. 5 shows FLD curve of the material CR980DP. FLD curve displays a maximum limit for strain of materials without necking or crack.

3. Forming Analysis and Testing

3.1 Forming analysis model

The data obtained by the tensile strength test were used for to investigate physical characteristics of the blank materials to analyze steel metal forming. Roughness and coefficient of friction at the contact face are important in analysis since forming is executed while blank and die, blank and punch, and blank and blank holder are contacted. Generally, if lubrication is implemented, co-efficient of friction lower than 0.1 can be given. Friction conditions at the die-material interface greatly influence metal flow, formation of surface and internal defects, stresses acting on the dies[17]. In this study, the coefficient of friction of 0.12 was applied to forming analysis of the seat rail die. Table 1 shows the forming analysis condition of the seat rail die where ultra-high strength steel sheet was applied. Fig. 6 shows a blank shape size of seat rail die. In order to produce an optimum product shape, blank shape was finally decided after several trials and errors using laser cutting and machining. Fig. 7 shows a die model for the forming analysis of the seat rail sheet material, while Fig. 8 show the seat rail product.

Table 1 Simulation conditions

Plastic material	CR980DP
Blank size	95.4 × 405 mm
Material thickness	1.6 mm
Rigid die	STD11
Friction coefficient	0.12
Stamping velocity	30 SPM(stroke per minute)

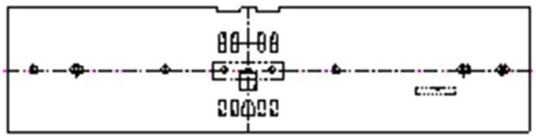


Fig. 6 Blank size of seat rail product

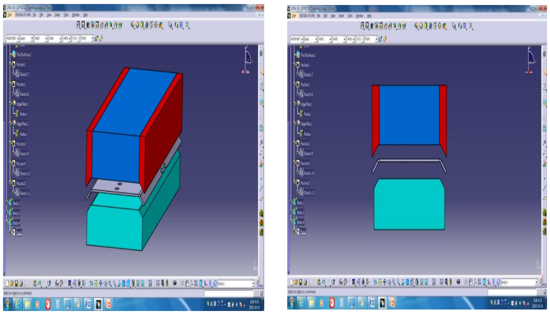


Fig. 7 Seat rail die model of 2nd stage bending

Fig. 8 Seat rail product after stamping

3.2 Results of the seat rail forming analysis

Ultra-high strength steel sheet material has a superior strength as compared with a general steel sheet, but its elongation rate is not that superior. Therefore, formability is low, while elastic recovery is

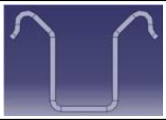
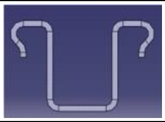
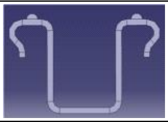
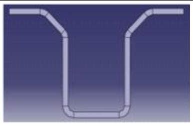
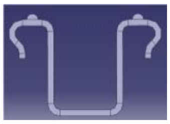
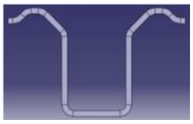
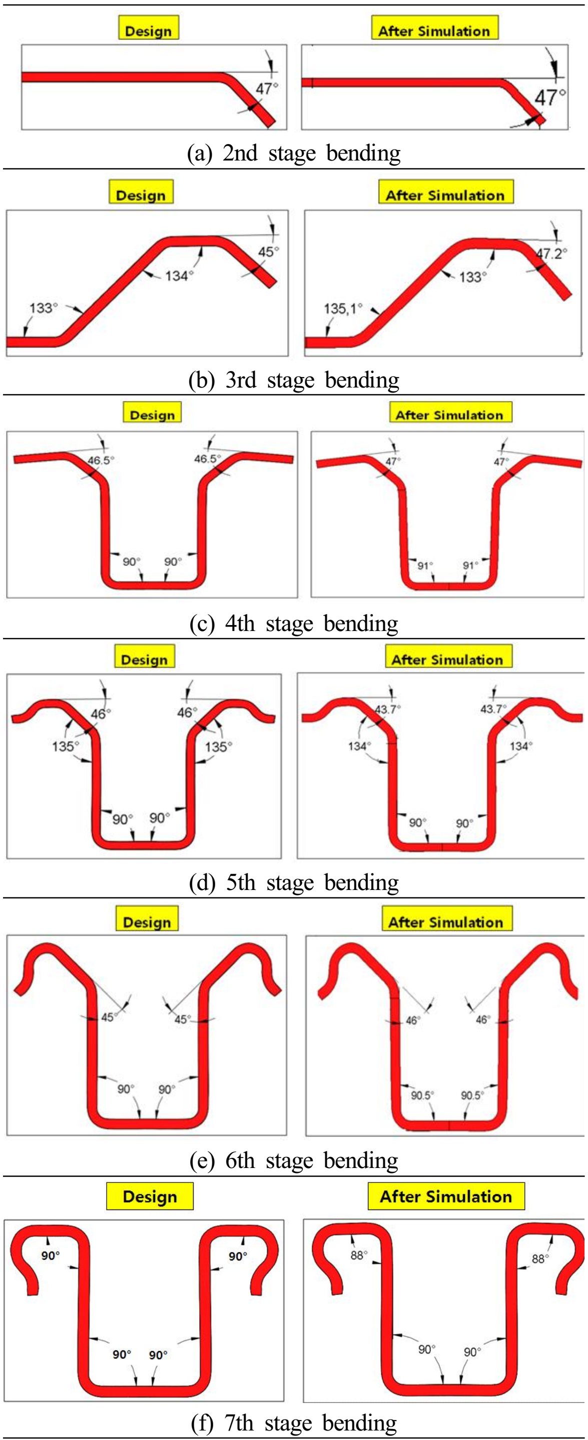
1 Stage Semi-Pro		6 Stage Bending	
2 Stage Bending		7 Stage Bending	
3 Stage Bending		8 Stage Embossing	
4 Stage Bending		9 Stage Restriking	
5 Stage Bending			

Fig. 9 Process design of seat rail die

high which leads high possibility of spring-back. The shape fixability improvement technique in this study is a process design technology of the seat rail die in order to restrict spring-back of ultra-high strength steel sheet. Fig. 9 shows process design of seat rail die. In the process design technology, process balancing is important for smooth flow between each process in order to form a final product after going through several processes. Therefore, a die process design was executed with a total of nine stages to improve shape fixability of seat rail die on which ultra-high strength steel sheet was adopted. For a smooth flow production between processes, a process balancing technique was applied rather than imposing an abrupt strain. A commercial finite element program Simufact Forming S/W was used to proceed the forming analysis by entering physical properties data of the ultra-high strength steel sheet. For punch and die, alloy tool steel STD11 was used, and materials thickness was made to 1.6 mm. Fig. 10(a) shows the forming analysis result in second stage bending, while Fig. 10(b) shows the forming analysis results with third stage bending. Forming analysis results of second stage bending showed that from the initial design value at 47°, same value of 47° was displayed after analysis. The reason why spring-back does not occurred is because concentrated load is transferred to 47° bending portion. At the third stage bending, the initial design value 133° became 135.1°. This might be due to the large spring-back by elastic recovery as an adverse bending process. Fig. 10(c) ~ Fig. 10(f) show forming analysis results from fourth stage bending until seventh stage bending. Fig. 11 shows the effective plastic strain from the seven stage bending. The forming analysis result and initial design value showed a similar trend. It might be due to designing of process not to impose a concentrated load in the particular process during forming. The eighth stage is embossing, and the ninth stage is restriking to get the final seat rail product.



(a) 2nd stage bending

(b) 3rd stage bending

(c) 4th stage bending

(d) 5th stage bending

(e) 6th stage bending

(f) 7th stage bending

Fig. 10 Simulation results of seat rail die

3.3 Testing method

Forming process was designed as the total nine stages to improve shape fixability of the seat rail die wherein ultra-high strength steel sheet was applied. The reason why process was designed as a total of nine stages was to consider balancing of process so that concentrated load would not be imposed on the particular process to disperse the load. Also, design was carried out to disperse concentrated load which disturbs flatness in a particular process, and processes were divided in order to minimize the spring-back since the material is an ultra-high strength steel sheet with a high repulsive force. Fig. 12 shows the seat rail die of each process. Process parts were placed on the lower die and press ram was moved till the bottom dead end to check the die spot. Red lead was coated on the die spot and formability was checked by adjusting die height per each process according to condition of the red lead adhered on the contact face after forming.

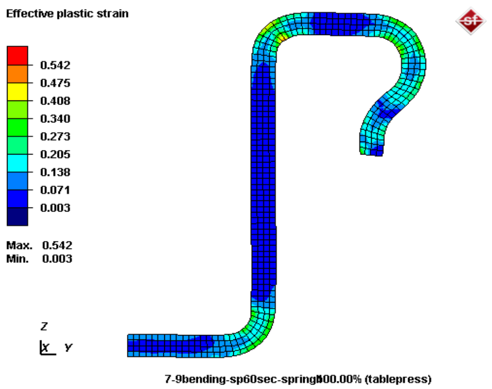
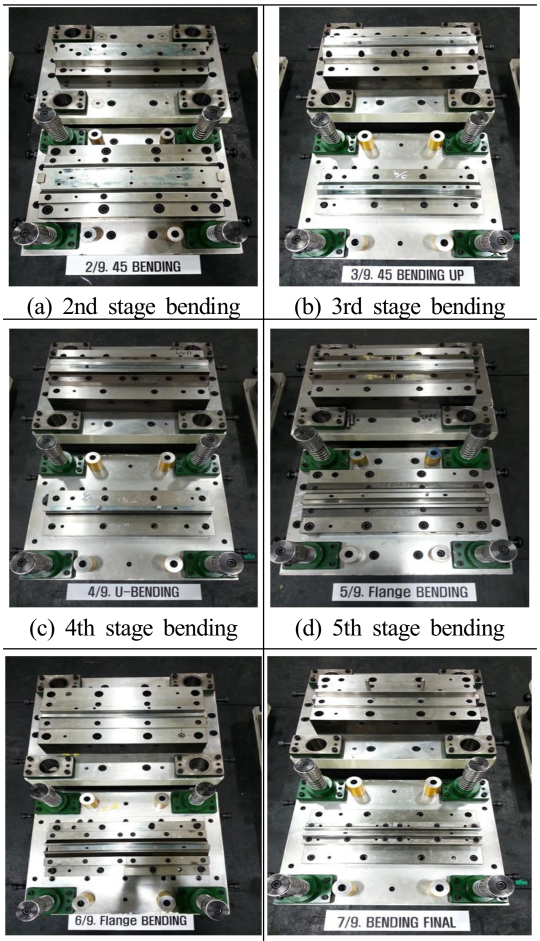


Fig. 11 Effective plastic strain of 7th stage bending

4. Test Results and Discussion

Try-out was carried out with the seat rail die by using a capacity 500-tons mechanical press. Process subject material used for the try out was a blank by cutting coil material of the ultra-high strength steel sheet CR980DP with laser. Blanking was performed under lubricant-free condition. Table 2 shows the spring-back results for seat rail die. At design value 47° with the 2nd stage bending die, analysis result was 47° which was different by 0.5° from testing result 47.5°. At the 3rd stage bending die with design value at 133°, analysis result value was 135.1°, which is different by 0.6° from the testing result 135.7°. This result might be due to the large spring-back caused by the adverse bending. At the 4th stage bending die with design value 90°, analysis result and test result became same with value 91°. However, adverse slope of 0.5° was given on the punch in this process, which yielded the prevention effect of spring-back. The reason why the difference was existed between analysis and testing result in the sixth stage bending die might be due to minor effect by working condition at press and die shop. It might be possible to improve shape fixability of body part since flange was formed while forming the body part



(a) 2nd stage bending (b) 3rd stage bending
(c) 4th stage bending (d) 5th stage bending
(e) 6th stage bending (f) 7th stage bending

Fig. 12 Seat rail die of each stage

of set rail under the 5th stage and the 7th stage bending die.

From the data of Table 2, experiment results agree well with the analysis results. Fig. 13 shows parts per each process of seat rail die. Fig. 14 shows a seat rail die which is under forming stage with attached to the press. It was found that improvement of shape fixability through spring-back control was possible with an optimum process design for the seat rail die wherein ultra-high strength steel sheet with 980 MPa was applied. It was also confirmed possibility of

Fig. 13 Seat rail sample of each stage

Fig. 14 Seat rail die during forming

Table 2 Spring-back results of seat rail die

Stage	Design	Simulation	Experiment
2nd bending	47°	47°	47.5°
3rd bending	133°	135.1°	135.7°
4th bending	90°	91°	91°
5th bending	90°	90°	90°
6th bending	90°	90.5°	90°
7th bending	90°	90°	90°

forming the ultra-high strength steel sheet by securing size accuracy for the seat rail parts.

5. Conclusions

This study was conducted by developing light-weight seat rail parts in order to secure a spring-back control technique for the improvement shape fixability using ultra-high strength steel sheet with 980 MPa. The results obtained through the study are as follows;

(1) The stress by strain during tensile strength test for the ultra-high strength steel sheet material, and FLD curve to investigate the forming limit could be obtained.

(2) Effective plastic strain by coefficient of friction was confirmed through forming analysis for the seat rail parts where in ultra-high steel sheet was applied, and optimum product could be manufactured through testing for the seat rail die of ultra-high strength steel sheet.

(3) Possibility of shape fixability was confirmed through the optimum process design of seat rail die wherein ultra-high strength steel sheet with 980 MPa was applied, and formability was also achieved by securing size accuracy for the seat rail parts.

(4) It was confirmed that not only light-weight effect but also cost reduction and productivity improvement could be achieved by developing the seat rail parts with ultra-high strength steel sheet.

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