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# Development of the Compound Die Forming Technology United between Semi-Progressive and Transfer Die

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# 세미 프로그레시브 금형과 트랜스퍼 금형기술을 융합한 복합 자동화 금형 제조기술에 관한 연구

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## ABSTRACT

To enhance the productivity and quality of the compound process of progressive dies and transfer dies, the semi-progressive method is applied in the material supply step to produce blanks, and then the transfer method is applied. Parts are transferred among processes by means of the finger and transfer bar in the transfer die, and the final seat cushion panel is produced. The main challenge in the current study is how to deform a seat cushion panel while meeting the design specifications without any defects. In order to obtain this technology, a sheet metal-forming simulation and die forming of the seat cushion panel were adopted; as a result, a compound die-forming technology for the automotive seat cushion panel, combining both semi-progressive die and transfer die for continuous production, was successfully developed.

**Keywords :** Compound Die(복합금형), Forming Technology(성형기술), Semi-Progressive Die(세미프로그래시브 금형), Transfer Die(트랜스퍼 금형)

## 1. Introduction

When it comes to sheet metal forming methods for passengers' cars, press forming methods of single process are mainly used to minimize the initial investment on the level of small/medium size companies. However, this type of methods relies too much on the technicians and the quality may be varied, which makes the technological competitiveness inferior. Recently, as car seat parts are modularized and standardized, parts for small and medium sized passengers' cars are standardized and the use of uniform parts is induced. As a result, there is an urgent need for parts forming automation and productivity-related technology development. In the automobile industry of Japan, for instance, sheet metal forming methods of seat-related parts are classified to progressive forming methods, transfer forming

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methods for automatic transportation of raw materials, etc. As a result, they are dominant in global competition with such edges as higher productivity, low prime cost, and quality improvement. Since car seats affect the driver's comfort and safety quite significantly, safety matters in seat manufacturing are one of the primary factors to be taken into account when it comes to the marketability of automobiles. Car seat frames are the basic structure of seats. As a satisfactory level of strength and rigidity are secured and ultra-light materials are used, the general weight of a car can be reduced with better fuel efficiency. In addition, the need for light-weight car body technology, high added values, and automation in application of new technologies is ever increasing, core technology with great potentials is required in both domestic and global markets.

As part of an automobile seat frame, a seat cushion panel requires 8 workers and 8 units of dies and presses each as the tandem process progresses from procedure 1 to procedure 8. In other words, 8 workers are designated for the die and press processing steps each, which inevitably affects the production of other items and the general productivity as the production lines may be irregular depending on each worker's performance. In the manual transportation and loading of goods, the quality may deteriorate, and there might be a problem of workers' safety. The manual production of single dies also may affect the quality of products since each worker has a different level of know-how[1-9].

Hence, this study aims to develop a compound automation die forming technology in application of the major process forming simulation of press dies as well as the die design manufacturing for seat cushion panels in order to secure the compound automation tooling design and forming technology in combination of the semi-progressive die and transfer die technology.

# 2. Material Property Test

## 2.1 Tensile test

The material used in the test is SPCC whose thickness is 0.8mm. Sheet materials were processed with the wire cutting method and used as specimen. To get the mechanical properties, a tensile test was implemented. The tensile specimens were collected at 0 degree, 45 degree, and 90 degree to the direction of rolling. During the tensile test, the speed of the crosshead was maintained constant at U.T.M and it was tensed up to the point of fracture. The mechanical properties of SPCC found through the tensile test are as follows: Fig. 1 shows the actual image of the standard tensile test specimens. Table 1 shows the result of the SPCC tensile test.


**Fig. 1 Tensile test specimen (SPCC)**

**Table 1 Mechanical properties of SPCC(0.8mm)**

| Direction | | Yield strength [MPa] | Tensile strength [MPa] | Elongation [%] |
|---|---|---|---|---|
| 0° | 1 | 318 | 490 | 38 |
| | 2 | 322 | 494 | 38 |
| | 3 | 329 | 492 | 39 |
| 45° | 1 | 346 | 488 | 37 |
| | 2 | 332 | 482 | 37 |
| | 3 | 338 | 495 | 36 |
| 90° | 1 | 341 | 504 | 38 |
| | 2 | 346 | 506 | 38 |
| | 3 | 338 | 496 | 37 |

## 2.2 FLD test

The grid analysis method is designed to easily make the modification of a die based on the flow of materials and strain on the deforming spot during the mold tryout and used to scientifically predict the forming severity or FLD (Forming Limit Diagram). As for deformation measurement, a circular grid or rectangular grid of 2.54mm(0.1″) or 5.08mm(0.2″) in diameter goes through an electrochemical etching on a steel sheet to measure the grid strain. Fig. 2 shows the circular grid images before and after strain while Fig. 3 shows the forming product after etching. Since the deformation of a grid may be varied, the measurements are analyzed to calculate the strain rate. To reduce the measurement error, an image processing apparatus is adopted to measure the values in addition to computers.

A forming limit diagram indicates the extent of deformation upon fracture over the area of sheet fracture. In a forming test to obtain an FLD diagram, the universal sheet metal forming tester shown in Fig. 4 may be used. Fig. 5 and Fig. 6 show the specimen before and after an FLD test. An FLD diagram shows the upper limit of material deformation wi

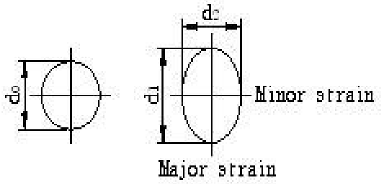


**Fig. 2 Circle grid before and after strain**

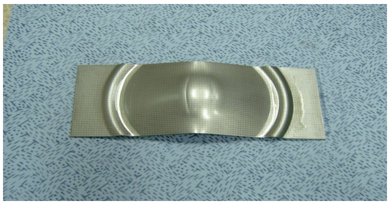

**Fig. 3 Circle grid after strain**

thout necking or crack. In the case of cold-rolled steel sheets, when the minor strain is 0, the major strain is called FLDo. The value of FLDo may be varied depending on the material, and it is possible to calculate the value through parallel movement along the axis of major strain rates. If the values of FLDo of each material and the form of the forming limit diagram are known, the forming limit diagram of that material can be predicted.

After drawing forming, there may be three different deformation modes of major minor strain rates: As for the plane strain mode, the major strain is positive while the minor strain is 0 on the basis of the grid size before deformation; as for the stretch mode, the major and minor strain rates are all positive; and as for the draw mode, the major strain is positive while the minor strain is negative.

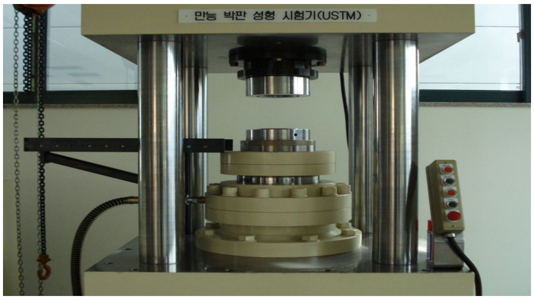


**Fig. 4 Universal sheet metal forming test machine**

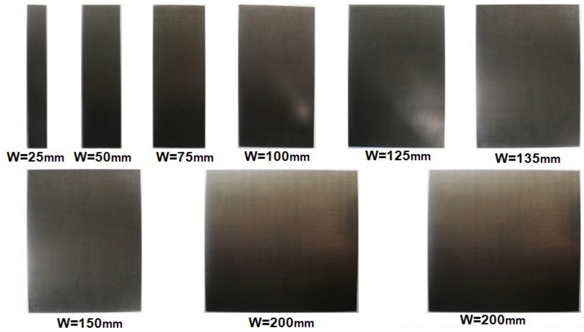


**Fig. 5 Specimens before FLD test(rolling direction)**

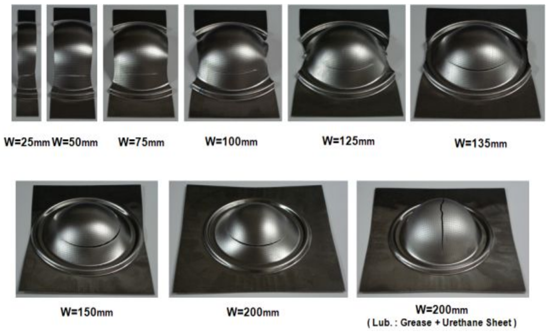


**Fig. 6 Specimens after FLD test(rolling direction)**

The punch head of seat cushion panel drawing parts shows the plane strain mode, the corner section shows the stretch mode, and the sidewall portion shows the draw mode respectively. Deformation in the draw mode is an alternative cycle of elongation and compression in the sidewall portion. For this deformation to be easy, it is better to minimize the drawing force. The stretch mode is to expand the surface area of a forming product through elongation. In this case, the uniformity of the stress and deformation distribution of the forming product is of importance. Fig. 7 shows the FLD diagram in the rolling direction of SPCC while Fig. 8 shows the FLD diagram at 90 degrees of the rolling direction. As shown in Fig. 9, the FLD diagram in the rolling direction is a bit higher than the FLD diagrams at 90 degree. In other words, the formability is enhanced in the rolling direction[10, 11].

## 3. Sheet Metal Forming Simulation

### 3.1 Experiment model for sheet metal forming simulation

Blank material properties acquired from the tensile test were referred to the sheet metal forming simulation. Table 2 shows the material properties

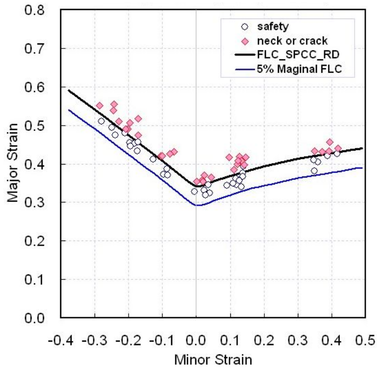


**Fig. 7 Forming limit diagram of SPCC(rolling direction)**

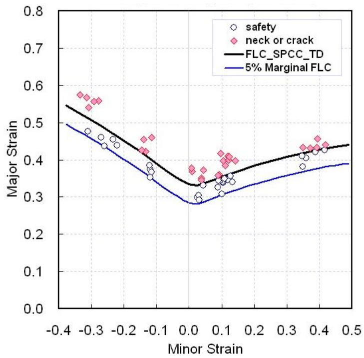


**Fig. 8 Forming limit diagram of SPCC(transverse direction)**

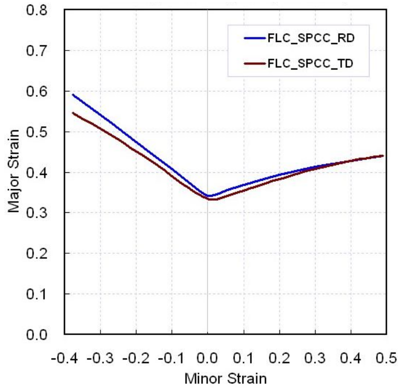


**Fig. 9 Forming limit diagram of SPCC depending on rolling direction**

**Table 2 Experimental conditions**

| | |
|---|---|
| Material density | 7.8e-06 kg/㎣ |
| Young's modulus | 206 Gpa |
| Poison's ratio | 0.3 |
| Material thickness | 0.8 mm |
| Stamping velocity | 5 m/sec |
| Anisotropy coefficient | R0=1.09, R45=0.79, R90=1.29 |

**Fig. 10 Blank size of seat cushion panel**

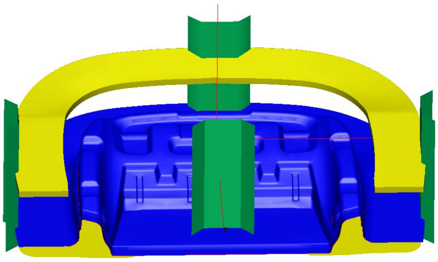

**Fig. 11 Die model of seat cushion panel**

**Fig. 12 Drawing process of seat cushion panel**

based on the tensile test. It is necessary to enter the processing conditions for the press and die such as blank holding force. Since the blank and die, the blank and punch, and the blank and blank holder are in contact in the forming process, the roughness of the contact surfaces and friction coefficient are important factors. In general, the friction coefficient is under 0.1 upon lubrication, but 0.12 is applied here. Fig. 10 shows the size of the blank shape of the seat cushion panel. The final blank shape was decided after many trials and errors to obtain the optimal blank shape in the semi-progressive forming process. Fig. 11 shows the die model for simulating the sheet metal forming of the seat cushion panel while Fig. 12 shows the drawing product of the seat cushion panel.

## 3.2 Results of sheet metal forming simulation

Fig. 13 shows the result of sheet metal forming simulation of a seat cushion panel when the blank holding force(Blank Holding Force; BHF) is 10 ton. Fig. 14 shows the result when the blank holding force is 30 ton. It is expected that two spots at the upper corners of the seat cushion panel will involve necking. As the blank holding force increases from 10 to 30 ton, the thinning rate increases in general and especially at the corners. The thinning rate where crack occurs is over 30%. When the blank holding force is 30 ton, the thinning rate reaches 25% and necking on the product becomes severe. The thinning rate increases at both corners up to 25% or higher, which increases the possibility of fracture too. Based on the forming simulation result above, it was expected that necking would occur in two spots at the upper corners of the seat cushion panel. Accordingly, the curvature adjustment at the upper corners was repeated in the tryout after die forming. As a result, the necking problem was significantly solved. In order to get the drawing products of a seat cushion panel, the experiment was performed as shown in Fig. 12 when the blank holding force was changed. The product quality was better as the curvature of both corners was increased or the roughness on the surface was improved.

## 4. Results and discussion

To enhance the productivity and quality in the compound process of progressive dies and transfer dies, the semi-progressive method is applied in the step of material supply to produce blanks, and then the transfer method is applied.

Parts are transferred among processes by means of the finger and transfer bar in the transfer die, and the final seat cushion panel is produced. In the initial stage of the production, coil materials are used and pass through the uncoiler, leveler, and roll feeder. When they are transferred to the 1,400 ton transfer press, a blank is produced in the progressive blanking die and rotated at 90 degree. After the parts are transferred among processes by means of the finger in the transfer die, the final seat cushion panel is produced. Fig. 15 shows the final product of a seat cushion panel. As shown in Fig. 16, the existing processes included the single die of 8 steps and involved manual loading and unloading, which hindered the improvement of quality and productivity. As shown in Fig. 17, the compound automation tooling design and forming technology was developed in combination of the semi-progressive die and transfer die, and the problem of productivity and quality was satisfactorily solved. Coil materials continued to be supplied from the developed semi-progressive die to produce blank parts. The developed transfer die processes consisted of 8 steps as shown in Fig. 18, and the final product is illustrated in Fig. 19.

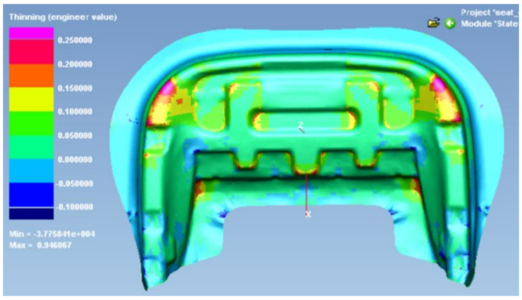


**Fig. 13 Simulation result of seat cushion panel (BHF= 10ton)**

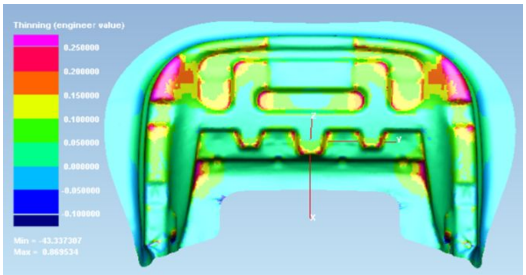


**Fig. 14 Simulation result of seat cushion panel (BHF= 30ton)**

**Fig. 15 Final product of seat cushion panel**

Although there were trials and errors due to the imbalance of the 90 degree reversal device of the blank and sensor malfunction that led to panel duplication, the 1,400Ton transfer press operation contributed to producing items of superior product and precision. The conveyor belt pulley was replaced in order to link with the finger transportation device, which improved the productivity from 10 SPM to 20 SPM.


**Fig. 16 Conventional press die processes**

**Fig. 17 Drawing process of developed transfer die**

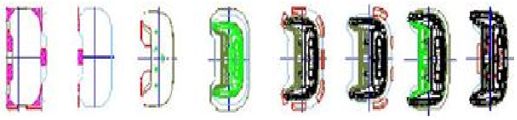

**Fig. 18 Developed transfer die processes**

**Fig. 19 Press line of semi-progressive die and transfer die**

## 5. Conclusion

This study is to develop a compound die forming technology in combination of the semi-progressive die and transfer die technologies. In order to get this technology, sheet metal forming simulation and die forming of the seat cushion panel were adopted, and as a result, the compound automation die forming technology was successfully developed. The results of this study are as follows:

(1) In the development of the compound automation die forming technology for automobile seat cushion panels, an advance simulation was conducted after die design to complement expected problems. As a result, the test period was shortened.

(2) In combination of the semi-progressive die and transfer die technologies, the possibility for producing automated production by means of the compound die forming method was verified. In other words, the development of the compound die processing technology has enhanced the competitiveness by securing safety, better productivity, and saving of prime costs.

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