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Development of Two-Shot Injection-Compression Soft Instrument Panel

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Abstract In order to reduce the cost and weight of the soft-foamed instrument-panel (IP), it was developed the new IP which is made by the two kinds of injection methods. One is the compression-injection with back-foamed foil inserted, and the other is two-shot injection with the passenger airbag door. We named it 'IMX-IP' which means that all components ('X') of the IP with different resins are made in a mold. The development procedure of this technology was introduced (1) Design of the new injection mold through TRIZ method, (2) Optimization of the injection conditions and back foamed-foil for minimizing the foam loss and thickness deviation, (3) Development of CAE for two-shot injection compression, (4) Reliability performance test and application to the mass production. The reduction of the processes through the two-shot injection with back foamed-foil inserted made it possible to enhance soft feeling on IP and reduce the cost and weight simultaneously.

요 약 자동차 소프트 인스트루먼트 패널의 비용과 중량을 줄이기 위하여 두 가지 사출을 동시에 수행하는 방법을 이용한 새로운 인스투르먼트 패널이 개발되었다. 첫 번째 사출은 뒷면 발포체 포일을 삽입하는 압축 사출을 하는 방법이고, 다른 하나는 동승석 에어백에 도어와 동시에 2샷 사출하는 방법이다. 우리는 그것을 'IMX-IP'라고 부르며, 이것은 인스트루먼트 패널의 모든 부품들이 종류가 다른 수지와 하나의 금형 안에서 만들어지는 방법인 것이다. 본 기술의 개발 과정은 (1) TRIZ 기법을 이용한 새로운 사출 금형 설계, (2) 사출 조건의 최적화와 폼의 손실과 두께 편차를 최소화하기 위한 뒷면 발포체 포일의 최적화, (3) 2샷 사출 압축에 대한 CAE 해석 검증, (4) 신뢰성 검증 시험과 양산에의 적용 순서로 이루어져 있다. 뒷면 발포체 포일 삽입을 이용한 2샷 사출을 통한 공정 감소는 개발비와 중량 절감과 함께 소프트 인스투루먼트 패널의 부드러운 느낌을 향상시키는 것을 가능하게 하였다.

Keywords : Instrument panel, Passenger airbag door, Reliability performance, TRIZ method, Two-shot injection compression

1. Introduction

Instrument panel (IP) of the compact car is generally painted (or non-painted) on the hard panel for the cost-effectiveness and the differentiated marketability with the high trim level. Recently, however, the hard IP of the compact cars sold especially in Europe cause the customer's complaints about the cheap feeling from the hard surface. Thus, the European car makers have applied the soft surface treatment (skin wrapping or PU foaming) on the IP even for the compact cars. But these soft surface treatment methods bring about the loss of the cost competitiveness and the over-investment.

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Therefore we needed to develop the soft surface IP technology to minimize the cost and investment.

In this paper, we would like to introduce the new IP surface technology that the back foamed - foil, the substrate and the passenger side airbag (PAB) door are injection-molded in a mold.

The development methodology of 'IMX IP' is arranged with (1) Through the TRIZ techniques, minimizing the foam loss from injection-pressure and stabilizing the integral molding of the PAB door, (2) Maximizing the foam recovery and the softness uniformity by the optimization of the injection-conditions and the foam types, (3) Development of the CAE analysis to realize two-shot injection (two resins injection in a mold) and compression injection and (4) Reliability performance test and application to the mass production. This technology was tested in the IP of KIA-FORTE car and was serially applied to the IP of HYUNDAI-i20.

2. Design Optimization (NVH, R&H)

'IMX IP' means all components ('X') of the back foamed-skin, substrate, and PAB door are made in a mold. In order to reduce the cost and weight of the IP with back-foamed foil, we developed the IMX IP that the surface is compression-injected with back-foamed foil inserted and the substrate (PP material) is integrally injection-molded with the PAB Door (TPO material) as shown in Fig. 1.

Previously, the soft feeling of the IP's surface was increased through the adhesion of back foamed-foil or the PU-foaming between the foil and substrate. In this technology, the back foamed foil is inserted in the cavity mold and compression-injection molded with substrate resin (plastic is injected in the open mold and then the mold become compressed), while the foam loss can be minimized. Besides, unlike attaching the separate PAB door to the substrate, the PAB door (TPO) was two-shot injection-molded with substrate resin (PP) in a mold[1]. This means the most economical technology with soft surface and the invisible PAB Door. Fig. 2 presents the IP surface value analysis and the position of the IMX technology[2].

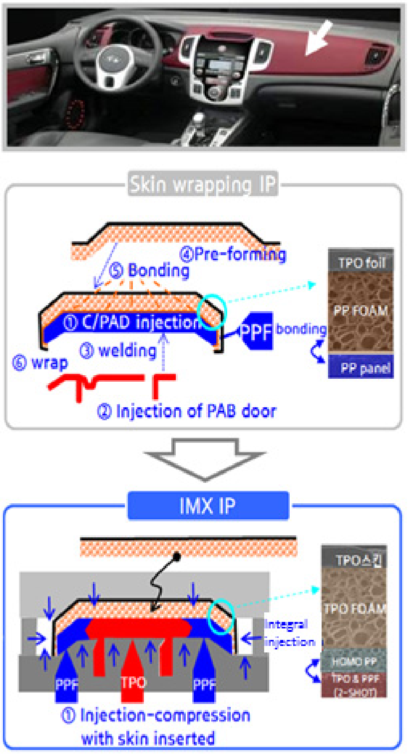

Fig. 1. IMX technology application area and back foamed foil technology comparison

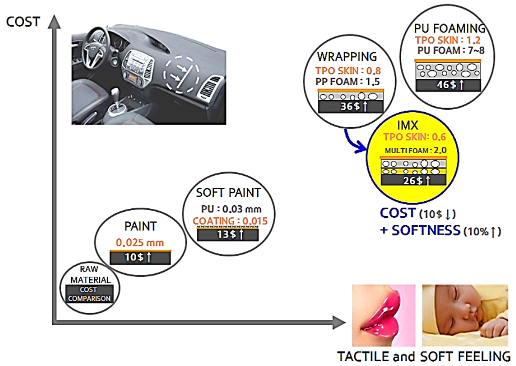

Fig. 2. IP surface value analysis

3. Verification (Stiffness, Crash, Durability)

3.1 Improvement of the integral molding of the PAB door

In order to simplify the structure of the mold, the injection gate of the TPO resin for filling the PAB door was normally placed on the side as shown in Fig. 3. In this case, however, the filling area of the TPO resin which is expensive and has the low stiffness is unnecessarily large and irregular. This contradictory relationship between the simplification of the mold structure and the quantity of TPO resin was solved using the TRIZ method as follows.

· Principle to solve the contradiction: Turn the objects ‘upside/down’
· Application of principle: Turn over the mold structure and locate the TPO gate on the center of the PAB door for minimizing the filling area of the TPO resin as shown in Fig. 3.

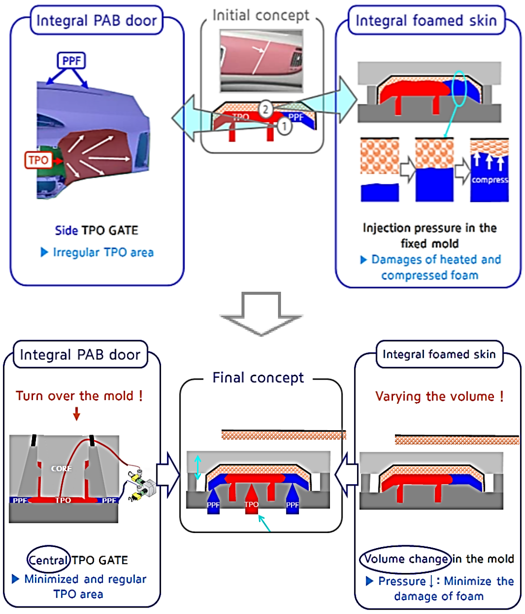

Fig. 3. Mold design concept using TRIZ method

3.2 Minimizing of foam loss (softness loss)

If the hot resin is filled in the closed mold with back foamed foil inserted, the high-pressure and temperature of resin on the back surface of the foam makes the foam damaged and its softness lose (recovery of the foam thickness is less than 20%). But, if the injection pressure is decreased for high recovery of the foam, we can get the short molded parts[3]. The contradictory relationship between the injection pressure and damage was solved using TRIZ method as follows.

· Principle to solve the contradiction: Use phenomena occurring during phase transitions (volume changes)
· Application of principle: Vary the volume in the mold for minimizing the filling pressure on the foam as shown in Fig. 3.

As described above, the final mold structure for solving the two contradictions can be summarized as follows.

(1) The TPO gate is located on the center of the PAB door for minimizing the filling area of TPO.

(2) The mold is open and closed during injection so that the volume inside mold is changed for minimizing the filling pressure on the foam as shown in Fig. 3.

4. Optimize the Recovery and Thickness Uniformity of the Foam

The concept of the mold design for softness of the foam was derived, but the detail injection conditions needed to be optimized. The objective functions for the optimization of the softness of the back foamed-foil could be (a) Foam recovery % (foam thickness ratio before / after injection) and (b) Variation of the foam thickness as shown in Fig. 4. The higher recovery of the foam (larger the better characteristics) makes the soft feeling maximized and the smaller deviation of the foam thickness (smaller the better characteristics) makes the soft feeling uniform.

First of all, the 10 kinds of initial control parameters (injection conditions, material types) were selected and needed to be reduced. For reducing the control factors, we made observation experiments by varying 10 control factors and the higher sensitivity of 4 control factors for recovery and the thickness variation of the foam were chosen as shown in Fig. 5.

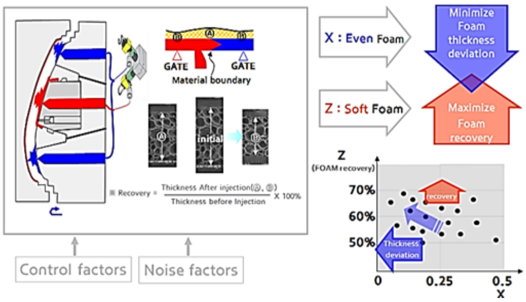

Fig. 4. System diagram and objective function of the IMX technology

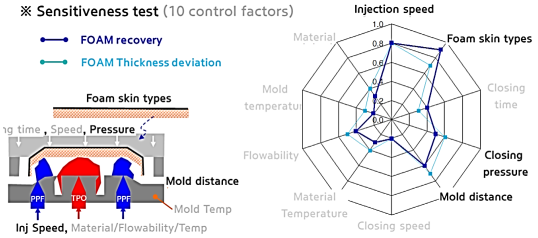

Fig. 5. The higher sensitivity of 4 control factors for recovery and the thickness variation

The optimum levels of each factors selected by experiments are shown in Fig. 6. The experimental results show same optimum levels for 3 control factors (closing pressure, mold distance, injection speed)[4].

But for the foam type (different density), each optimum level was different for the recovery and thickness variation of the foam as shown in Fig. 6. To get the same optimum level of foam types for the recovery and thickness variation, the foam needed to be more resistant to heat and higher elastic[5].

It was developed the multi-layered foam that the heat-resistant and high density foam (Homo-PP) was added between the substrate and the soft TPO foam. It makes it possible to get the elastic recovery after pressure release and the conservation of the foam from heat as shown in Fig. 7.

Finally, two goals for the recovery and the thickness variation could be achieved by applying the new multi-layer foam.

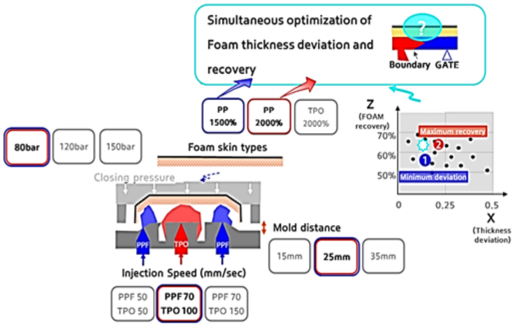

Fig. 6. 1st optimum levels of each factors selected by experiments

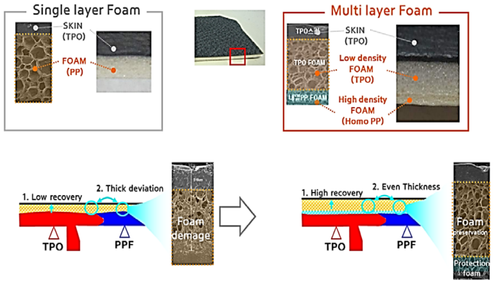

Fig. 7. Multi-layer foam for thermal and pressure blocking mechanism (Final optimization)

5. CAE Analysis for Two-Shot and Compression Injection

The conventional injection analysis program (Moldflow) can't realize three kinds of characteristics such as (1) two-shot injection (two kinds of resins are sequentially filled in a mold), (2) skin-inserted injection (the heat and pressure transfer from resin to foam need to be observed) and (3) the compression injection. To realize these complicated features of IMX injection, the hybrid 3D injection analysis program, 3D TIMON, was introduced.

This allows the prediction of the boundary of the different resins through calculating the different viscosity and cooling rate of each resin inside the mold in Fig. 8. In addition, the heat transfer from resin to foam was observed by modeling the back foamed-foil inserted in the mold as shown in Fig. 9. Fig. 10 shows the prediction of deformation with time after injection by calculating the different cooling rate of each resin.

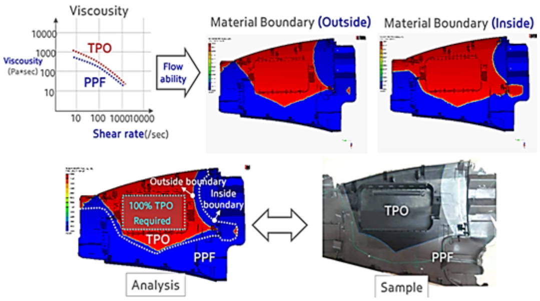

Fig. 8. The boundary of the different resins (inside /outside); Analysis result and sample

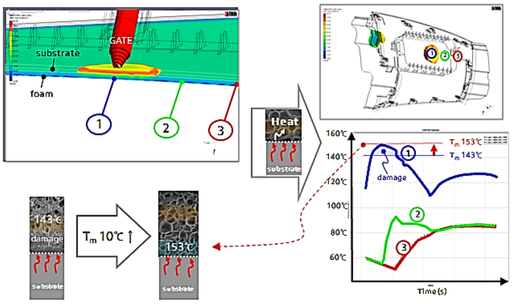

Fig. 9. Heat transfer from resin to foam with time

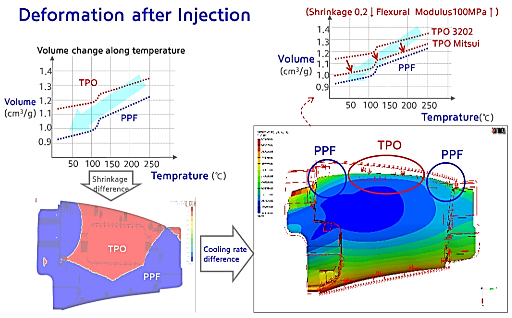

Fig. 10. Prediction of deformation after injection

6. Performance Evaluation Test and Final Sample

6.1 Airbag deployment and head impact testing

Total 9 kinds of airbag deployment tests including heat aging deployment (96 ℃400 hours → 8 hours at each temperature → airbag deployment) were satisfied[6]. The intended tearing and rotation of the airbag door was observed. And there was no sharp edge and the satisfactory deceleration results in the head impact test (ECE regulation) on the PAB door as shown in Fig. 11.

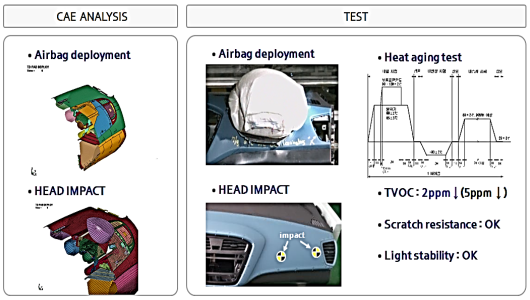

Fig. 11. Analysis and testing of the airbag deployment and head impact

6.2 Production application of IMX technology

IMX technology was applied to the IP of HYUNDAI-i20 which was mass-produced for European market as shown in Fig. 12.

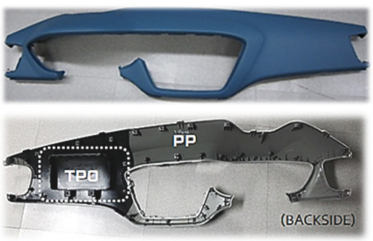

Fig. 12. IMX IP of HYUNDAI-i20

7. Conclusion

The 'IMX' IP that the surface is compression injected with back-foamed foil (TPO) inserted and the substrate (PP) is integrally injection-molded with PAB door (TPO) was developed.

To increase the softness of the foam and the stability of integral injection-molding, the TRIZ method and the design experiments were used.

The CAE analysis that realizes two-shot and compression injection was developed and compared with evaluation test results.

Finally it was mass-produced for European compact car with the cost competitiveness.

The first effect of this technology is the improvement of IP soft feeling; Shore C hardness is reduced from 70 to 62.

The second effect is the reduction of cost and weight; Processes are reduced from 6 to 1 and parts are reduced from 2 to 1.

The third effect is that TVOC is reduced from 15 ppm to 1 ppm through removal adhesive.

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