Development of Hybrid Structure Outer Waist Belt Weatherstrip Using Co-Extrusion of TPV and PVC for NVH & Appearance

Cho Sung Yong 1)  Cho Eui Chan 1)  Cheong Jae Hyuk 1)  Cho Kyung Ho 1)

1) Hyundai Motor Company
150, Hyundaiyeonguso-ro, Jangdeok-ri, Namyang-eup, Hwaseong-si, Gyeonggi-do, Republic of Korea(E-mail:chosy@hyundai.com)

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ABSTRACT: The Outer waist belt is a component that has both a functional element that is a sealing with the outside of the door and an element contributing to improvement of the appearance of the outside of the door. Therefore, it is an important design factor to select a material that is favorable to permanent deformation and does not deteriorate in appearance due to external environmental conditions. In this paper, the section and production method for Hybrid structured belt which has TPV rib for good sealing and PVC skin for good appearance dealt with.

KEY WORDS: Materials, Waist belt weatherstrip, Door outside belt weather strip, PVC, TPV, Extrusion, Adhesive, Scratch

1. INTRODUCTION

The door outer waist belt prevents noise from the outside of the automobile or foreign substances from entering the vehicle interior, removes moisture when lifting and lowering the door glass to secure side view, and contributes to improving the appearance of the vehicle mounted on the outside of the door. It is a part that has all the elements that it does. Therefore, it is an important design factor to select a material that has a good compression ratio and does not deteriorate the surface of the skin due to external environmental conditions. Recently, we have applied Thermoplastic vulcanizate(TPV) materials superior to conventional Polyvinyl chloride(PVC) materials in permanent compression ratio, and TPV has already been used as an out-belt material by many OEMs. However, the out-belt section using TPV material has a 78.6% improvement in the ratio of lip load to PVC, but the material cost per unit weight is more than twice that of PVC. Due to the application of hard TPV layer to compensate for inferior scratch performance it is structurally limited to take on the problem of appearance. In this paper, we present a study on cross section and development method to fundamentally improve the problems of existing products.

2. THE MAIN SUBJECT

2.1. Problems of existing outer waist belt(section)

In the conventional TPV section (Fig.1), the permanent compression ratio of the main rib is improved than previous generation PVC section, but it is disadvantageous in the dichroism and surface scratch performance of the outer side area. (Fig.2) There is also a need to reduce costs.

2.2. Hybrid material section concept for improving problems.

To solve the fundamental problems of the Existing TPV material outer waist belt, firstly, outer waist belt should be divided into the functional area and exterior area. Secondly, Hybrid structure should be applied which has different materials...
according to the requirements of each area. In other words, the main rib that come into close contact with the door glass surface and wipe off the surface of the glass are excellent in performance, while the expensive TPV material is applied. And the low cost PVC, which has been proven in surface scratch performance and weather resistance, is applied to the skin surface. (Fig.3).

2.3. Major research topics in the development process

2.3.1. Co-extrusion of TPV & PVC

Conceptually, the hybrid belt cross section of the present study can be produced by extruding high temperature TPV first and then extruding relatively low temperature PVC. However, the length of existing extrusion line should be increased by about 1.5 to 2 times and it means high cost due to the increase of the process time will inevitably follow and the cost reduction, which is main purpose of this study becomes difficult.

Therefore, in this study, we aimed at co-extrusion of two materials, and the difference of extrusion temperature between PVC (130 ~ 150 °C) and TPV (180 ~ 210 °C) is the first problem to be overcome.

The first problem that has arisen in the process of finding the optimum mold temperature that can mold both materials at the same time is the fact that the efficiency of extrusion is drastically lowered when TPV is extruded at low temperature compared with the conventional one. This is a problem that can generally occur in polymeric materials that are molded through the extruder in a molten state. As a result, it was possible to determine the lowest moldable temperature of the TPV at a typical process speed by repeatedly experimenting with the mold temperature being lowered sequentially. (Fig.4)

The next problem is the increase in gloss of PVC surface (Fig.5). The PVC material is characterized in that the surface gloss increases when the molding temperature rises. PVC for extrusion which is commonly used in door waist belt also has the same characteristic that gloss of the skin surface increases when the temperature of the mold increases.

In this study, PVC material with matte surface was developed in optimum mold temperature (which is for co-extrusion of TPV and PVC) by adjusting the blend ratio of various additives (PVC 40~50%, Plasticizers 35~40%, Stabilizers 2~5%, Fillers 10~15%, other additives 3~5%) and main materials. (Fig.6)
Therefore, when the PVC material developed in this study is extruded at a high temperature, it is possible to make a door outer waist belt having a better skin surface characteristic\(^1\) than conventional low temperature (130~150°C) extruded PVC door outer waist belt. And also it will have equivalent skin gloss compared to existing one.

![Fig. 7 a) Divided organization and b) Clumped organization\(^2\)](image)

**Table. 1 Mechanical Properties of PVC for each temperature\(^2\)**

| Mechanical Properties                  | Extrusion Melt Temperature |
|----------------------------------------|----------------------------|
|                                        | 138°C | 149°C | 160°C |
| Tensile elongation at break (%)        | 133   | 206   | 273   |
| Tensile 100% modulus, (Mpa)            | 4.3   | 4.5   | 4.8   |
| Graves tear resistance, (KN/m)         | 9.8   | 13.9  | 19.6  |
| Britteness temperature (°C)            | -42   | -48   | -48   |
| R.T. compression set, (%)              | 18.1  | 18.1  | 16.7  |

### 2.3.2 Separate bonding method of PVC / TPV adhesive

Currently, each adhesive is separately used for bonding of the core (SUS or AL) and the TPV or PVC material. This is because the main components of the TPV adhesive and the PVC adhesive are different and it is difficult to be integrated. In addition, it is because of the lack of engineering demand for integrated adhesive and differences in the cost of the adhesive components.

The existing single material door outer waist belt need only one appropriate adhesive according as what the material is. However, this Hybrid material outer waist belt should be extruded in same core (SUS or AL) at the same time. In order to do this, it is necessary to equip facilities which can apply each adhesive to core according to a section where each polymer material is located. The facilities is normally a jig having a shape in which the ends of the application parts (brush, foam pad, etc.) are physically spaced from each other, or applicator.

The figure below shows the shape of the jig type (Fig.8) and the applicator type (Fig.9).

![Fig. 8 Jig type (with brush or foam pad)](image)

![Fig. 9 Applicator type (with roll)](image)

### 2.3.3 Research of integrated (PVC / TPV) adhesive

We have confirmed that we can produce complete hybrid material outer waist belt by the above-mentioned separate bonding method. However, if PVC/TPV integrated adhesive is developed and applied, it can contribute to stabilization of quality through advantage of production management compared with separate bonding method. Therefore, in this study, the development of the common adhesive has been studied together with the separate bonding method.

The integrated adhesive has been developed based on the adhesive strength of the TPV and PVC adhesive used in mass production products, and it is believed that the adhesive has reached the completion stage. In the future, it is expected that integrated adhesive and separated bonding method will be selectively operated according to the characteristics of production line of partner companies.

The following table shows the results of the T-peel test using UTM and the adhesive strength of the integrated adhesive developed to date.\(^3\) (Fig.10, Fig.11, Table 2)
Based on the results of the T-peeling test of the common adhesive version A and B, we proceeded production line test with different conditions in the four types of partners production line. (Fig.12) for example different number of times of high-frequency exposure, different extrusion mold temperature. (Table.3) As a result, we could find the production line setting conditions that showed similar level of performance to the test results for the specimens produced by simulating the actual products in the laboratory.

However, more general-purpose common adhesive for a wide range temperature and variable process conditions is needed. Because process sequence of the partner’s plant is variable and sometimes other conditions are different and hard to control. Separate bonding method is available, but the integrated bond will be gradually adopted from the current developed products.

| DIVISION       | MATERIAL | SUS  | AL  | Unit |
|----------------|----------|------|-----|------|
| CURRENT ADHESIVE | PVC      | 60.02| 56.51| kgf/\text{cm}^2 |
|                | TPV      | 9.95 | 18.06|      |
| COMMON ADHESIVE (VER.A) | PVC | 17.43 | 8.12|      |
|                | TPV      | 11.21| 10.15|      |
| COMMON ADHESIVE (VER.B) | PVC | 42.64 | 40.95|      |
|                | TPV      | 19.1 | 16.99|      |

2.4 Production and evaluation of prototype

The Hybrid material outer waist belt prototype (Fig.13) was made and has been evaluated the comprehensive environmental condition such as heat resistance, weather resistance, cold resistance, and the performance of door glass up and down durability, surface scratch performance, corrosion durability performance evaluation. All of the development performance criteria were satisfied.

3. CONCLUSION

The following conclusions were obtained through the development of a Hybrid material outer waist belt.

(1) Through the extrusion of different materials, TPV main ribs were maintained and PVC was applied to the outer part to improve the scratch performance and dichroism. (Table.4)
Table. 4 Scratch and appearance evaluation result

| SCRATCH PERFORMANCE | GLOSS & DICROISM |
|---------------------|------------------|
| CURRENT (TPV)       | HYBRID (PVC-TPV) |
| POOR                | GOOD             |
| BOUNDARY            | HIGH GLOSS       |
| CURRENT (TPV)       | HYBRID (PVC-TPV) |
| POOR                | GOOD             |

(2) High temperature extruding PVC (matt skin) developed and simultaneous molding temperature for TPV & PVC were set

(3) The Integrated adhesive for PVC and TPV is under development. It’s performance was not enough because many types of production line and variable circumstances. But it will be completed soon.

(4) Cost savings (6%) compared to the existing TPV door outer waist belt weatherstrip.

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