TPO Dynamics In Automotive: The Development of Soft TPO for Better Recycle

Seong-Min Cho, Dong-Myung Shin, Chang-Gyou Kim

Honam Petrochemical Corp., Daeduk Research Institute, Daejeon, Korea
rdkcg@hpc.co.kr

Introduction

TPOs based on polypropylene have firmly been used for years in hard automotive parts such as in bumper fascia, instrumental panel and door trim panel owing to their variety of advantages compared to engineering plastics: low density, similar properties, good cost performance, good safety performance, long service life and good recyclability by replacing steels and engineering plastics. More importantly, recently as environmental regulations related to recycle have been strengthened, the use of TPOs in soft automotive parts such as instrument panel skin and door trim skin is being required much more to replace PVC. Therefore, soft TPO has emerged as a dominant material in automotive skin materials.

In this study, we'd like to give an overview of soft TPO and introduce soft TPO material requirement and preferable material composition by vacuum thermoforming and powder slush molding, respectively.

Figure 1. Soft TPO in instrument panel and door trim skin

The necessity of soft TPO for better recycle

In terms of the conventional soft parts in automobile interior such as instrument panel and door trim, there are vacuum thermoforming-molded materials made of PVC resin and ABS(Acrylonitrile-Butadiene-Styrene copolymer) sheets, powder slush-molded materials made of PVC resin and plasticizer, sol-molded materials made of paste PVC resin and plasticizer through emulsion polymerization [1-2]. However, recently, with regard to environmental preservation, environment-friendly materials are highly required that can be recycled and don't generate pollutants during incineration. The materials including the PVC resin are not easily recyclable and generate hazardous substances, such as dioxins, during incineration. Therefore, EU strengthened environmental regulations that total recovery ratio should be reached to 85% including reuse, recover, recycle. Furthermore, PVC produces harmful odor due to the presence of a large amount of plasticizers. Another driver for TPO materials is the long-term durability of thermal resistance and capability of low temperature airbag deployment. The long-term durability of thermal resistance and capability of low temperature airbag deployment are being the most important requirements for the invisible (seamless) Passenger-side Airbag(PAB). Therefore, most of automotive makers have searched for some substitutes of PVC and are promoting the soft TPO for the substitute of PVC. [3-4]

As a result of these situations, in Korea, the skin materials of instrument panel and door trim are being moved to TPO materials and the principal processes of producing of TPO materials are vacuum thermoforming and powder slush molding.

Requirements for soft TPO

***Vacuum thermoforming process**

The vacuum thermoforming process has been preferred over powder slush molding method due to its high processability and low manufacturing cost. However, it is difficult in this process to fabricate the products of complicated shapes having embossed patterns on the surface. Therefore, vacuum thermoforming process is generally being used in mid-sized car and recreational vehicles.

Elongational Behavior. Soft TPO for vacuum thermoforming process should have high melt strength because high melt strength of TPO plays a key role to the stable calendar sheet production and the grain retention of sheet during vacuum thermoforming process.

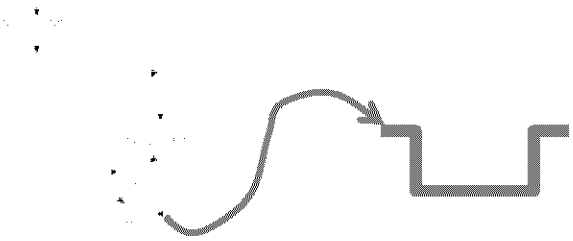

Figure 2. Schematic of vacuum thermoforming process

Therefore, high melt strength polypropylene (HMS-PP) with long chain branch and high molecular weight is generally used as the base resin. As well known, HMS-PP is commercially being made from irradiation process by electron beam, polymerization or reactive extrusion. Recently, HMS-PP from reactive extrusion has been known preferable owing to its low cost[5-7].

Physical Properties. As for the skin materials, the hardness should be at least below shore 80A for soft touch, the tensile strength should be at least above 90 Kgf/cm^2 and elongation at break should be at least above 300 % for stable usage in car interior.

Thermal Resistance. For long term guaranty for customers, thermal resistance is highly required. As can be seen Figure 3, PVC exhibited the residual elongation below 20% only after 200hrs. On the other hand, soft TPO shows the above 90% even after 500hrs. This more stable thermal resistance of TPO is another driver for its using TPO in automotive skin materials.

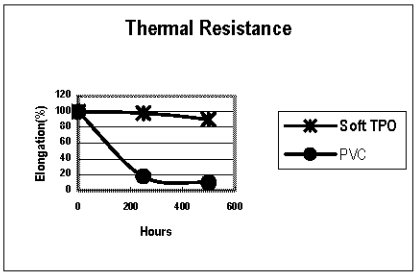

Figure 3. Thermal Resistance comparison in Soft TPO vs PVC

Low Temperature PAB Deployment. As the invisible (seamless) Passenger-side Airbag(PAB) becomes a new trend to satisfy a variety of consumers' needs, all skin materials should pass low temperature PAB deployment test. As can be seen Figure 4. and 5., PVC was fractured with fragments. On the other hand, soft TPO was fractured with the knit (seam) line clearly. It showed the typical ductile fracture behavior

Figure 4. Fracture Surface of PVC from vacuum thermoforming process after –30℃ Deployment

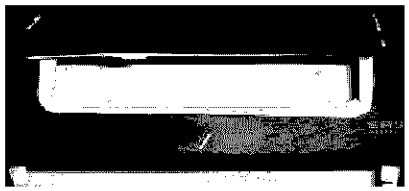

Figure 5. Fracture Surface of soft TPO from vacuum thermoforming process after –30℃ Deployment

***Powder slush molding process**

The skin sheets from vacuum thermoforming process do not have a good finishing and soft touch due to low surface hardness. Therefore, patterns like embossing are easily effaced. Also, it is difficult to make sheets of complex shape which are used in luxury class cars. In addition, the materials may be deformed with time due to the residual stress during vacuum thermoforming process. Therefore, powder slush molding is generally being used in luxury class cars.[8~9]

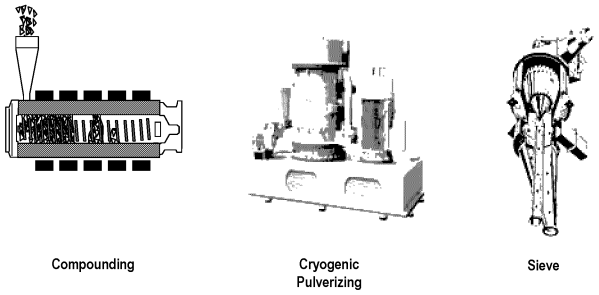

Figure 6. Schematic of powder manufacturing process

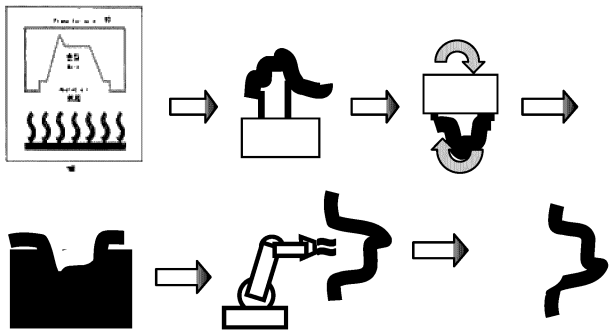

Figure 7. Schematic of powder slush molding process

Powder Size Distribution. It's very important for ground powder to have good size distribution. It's known well that as the powder size becomes smaller it has the faster melting speed. However, in case the powder size is too small below 100 μm, there is the agglomeration in powders which causes pinholes on the surface of the sheet after powder slush molding. These pinholes lead to bubble creation which is very serious problem during painting process. Therefore, the normal distribution of powder size where the mean size is around 300~400 μm is preferable. As a result, the technology of controlling the powder size distribution is another key technology to have good powder slush moldability.

High Melt Fluidity. High melt fluidity of the powder is also highly required to remove pinholes on the surface and have good flatness of back surface. In terms of good flatness of back surface, it's very important to let laser carving process go well to make the invisible (seamless) passenger-side airbag(PAB). Therefore, in order to have good powder slush molded sheet with no pinholes and good flatness of back surface, some amount of low molecular weight materials having high melt fluidity are required.

Thermal Resistance. As the same case as in vacuum thermoforming process, thermal resistance is highly required. As the material has higher thermal resistance it has worse melt fluidity. In case of using too small amount of low molecular weight materials for high thermal resistance, it results in worse melt fluidity of the sheet. Therefore, the amount of low molecular weight material should be controlled under a certain level.

Low Temperature PAB Deployment. As the same case as in vacuum thermoforming process, all powder slush molded skins should pass low temperature PAB deployment test. As can be seen Figure 8, soft TPO from powder slush molding process was fractured with the knit (seam) line clearly.

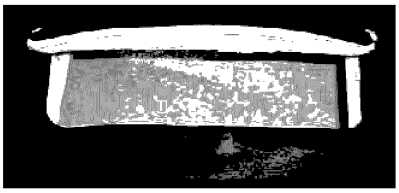

Figure 8. Fracture Surface of soft TPO from powder slush molding process after –30℃ Deployment

New Technologies to Make Soft TPO

Since the cost of soft TPO is much higher than that of PVC, car makers and material makers are searching for new technologies to make soft TPO with low cost which reduce or consolidate the steps of process. One of them is to make soft TPO powder directly from extruder without pulverizing. Another is to make skins from injection molding process.

Conclusions

Soft TPO requirement and preferable material compositions by two manufacturing processes which are vacuum thermoforming process and powder slush molding process were introduced in this paper. In vacuum thermoforming-molded TPO, excellent elongational properties for vacuum thermoforming process are highly required. Therefore, it is desirable to use HMS-PP and rubbery materials having long chain branch. In powder slush-molded TPO, high melt fluidity without pinholes and good flatness of back surface of sheet are highly required, therefore, it is desirable to use low molecular weight materials. However, for the balance between high melt fluidity and thermal resistance, the amount of low molecular weight materials should be controlled under a certain level.

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