

A Study on the Impact Resistance of Plastic Underbody Parts

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ABSTRACT

Impact resistance of plastic underbody parts was studied using simulated injection-molded specimen which can be tested according to different types of material used, injection molding variants like position and number of injection molding gates, and features of ribs. Material applied was glass fiber reinforced polyamide which can be used in underbody parts. Test was performed using several combinations of injection molding gates and rib types. From the test result, optimal design guide for plastic underbody parts was determined. Also, new high impact resistant plastic material made of glass fiber reinforced polyamide 66 (PA66) and polyamide 6 (PA6) alloy was developed and the material properties useful for CAE were determined. As a case study, oil pan and muffler housing were designed following the optimal design guide and CAE. And the reliability of the sample muffler housing designed was verified.

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INTRODUCTION

The increased demand to improve vehicle fuel efficiency and to reduce weight is forcing automotive industry to replace some under hood components made of metal with plastic. Parts such as engine cylinder head cover, air intake manifold and thermostat housing are already replaced from metal to plastic [1,2,3]. Recently, parts which are located in the underbody region like engine and transmission oil pans, muffler housing, and fuel system protector are also beginning to be replaced by plastic. In this case, impact resistance performance is very important to obtain major protection of the parts against splatting of rocks or impact of hump. Figure 1 shows possible stone impact case of transmission oil pan.

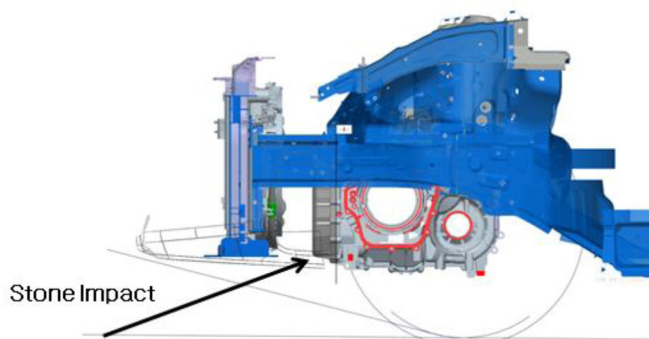


Figure 1. Possible stone impact case of transmission oil pan

For underbody plastic parts, glass fiber reinforced polyamide can be the most suitable material. Glass reinforced polyamide has an advantage in physical properties such as tensile strength, impact

strength, heat resistance and chemical resistance over other materials. Also injection molding is very suitable to produce underbody plastic parts because it allows for mass production and cost reduction. Another advantage of injection molding is its design flexibility. Many complex ribs can be applied when injection molding is used. The ribs generally improve structural strength and stiffness of the parts, but they also prevent underbody parts from crash when stones collide.

Several design variants of underbody parts like material formulation method, thickness of the part, and type of ribs can be considered regarding their performance. Injection molding conditions like position and number of injection molding gates can also be a design variant. For glass fiber reinforced plastics, glass fiber orientation which affects its mechanical property is the direction of polymer melt flow through injection gate position in figure 2. Glass fibers are usually oriented in the same direction as melt flow, and mechanical property of glass fibers oriented in melt flow direction is better than that of transverse direction [4,5,6].

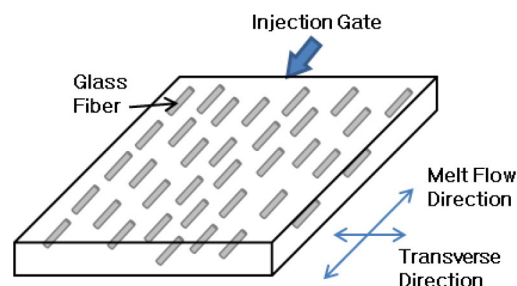


Figure 2. Relationship of injection gate position and glass fiber orientation

In this research, the impact resistance was studied to develop reliable plastic underbody parts. Results of impact performance were analyzed for each design variant such as type of material, injection molding variant like position and number of injection molding gates, and feature of ribs. Simulated injection- molded specimens were created and impact test was performed for each design variant. From the test result, optimal design guide for plastic underbody parts was determined. Also, new high impact resistant plastic material made of glass fiber reinforced PA66 and PA6 alloy was developed and the material properties useful for CAE were determined. As a case study, oil pan and muffler housing cases were designed by the plastic material following optimal design guide and CAE. And the reliability of oil pan and muffler housing designed was verified.

DEVELOPMENT OF SPECIMEN MOLD TO SIMULATE STONE IMPACT

To achieve the purpose of this research, stone impact specimen mold to test various factors that can affect impact performance was developed. The specimen was made to simulate plastic part in reality. It is possible to change its type of rib, and the position and number of injection gate. Figure 3 shows four types of ribs (no rib, uniaxial ribs parallel to melt flow, uniaxial ribs perpendicular to melt flow, square rib pattern)

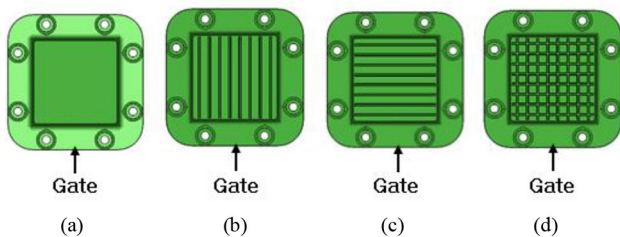


Figure 3. Types of ribs in specimen: (a) No rib (b) Uniaxial ribs parallel to melt flow, (c) Uniaxial ribs perpendicular to melt flow, (d) Square rib pattern

The mold was made to choose the number of injection gates. Figure 4 (a) shows single-gate injection molding and Figure 4 (b) shows double-gate injection molding to create a weld line which is a major factor in low impact resistance.

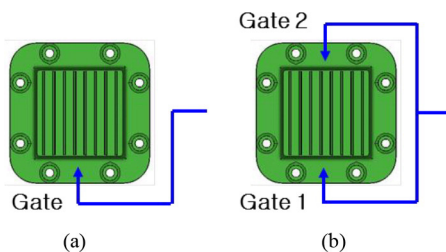


Figure 4. Types of injection molding gate; (a) Single gate (b) Double gate

To simulate stone impact in reality, aluminum sphere ball was chosen. Aluminum has similar density with road stone (density of aluminum : 2.7, density of stone (common) : 2.5). For sphere ball's size, Small Stone and Large Stone were considered as depicted in figure 5. For small stone case, weight is 6.5 g and diameter is 17 mm. For Large stone case, weight is 1 kg and diameter is 100 mm. Though impact

angle of 90 degree does not follow the actual condition of vehicle, it was chosen because severe test condition provides reliability to specimen or parts.

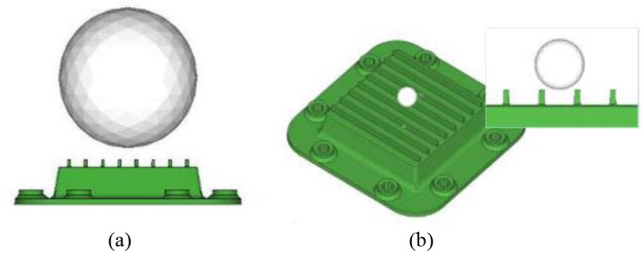


Figure 5. Stone impact test: (a) Large stone (b) Small stone

IMPACT PERFORMANCE ACCORDING TO TYPE OF RIBS AND NUMBER OF INJECTION GATE

Impact test of the developed specimens was performed as type of ribs and number of injection gate varies. Material applied was 35% glass fiber reinforced PA66, a possible candidate for underbody parts like oil pan and muffler housing. Figure 6 shows the test result of maximum impact energy with no crack on specimen.

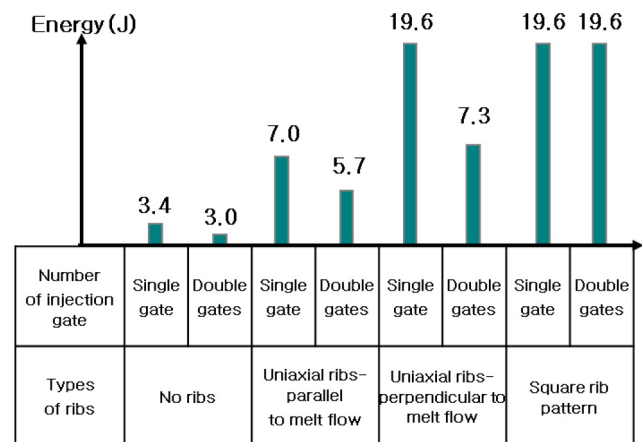


Figure 6. Impact resistance test of developed specimens

In the test result, specimen made with single gate has higher impact strength compared to specimen made with double gate. As specimen made with double gate has a weld line on the impact area, it is easy to generate crack. Figure 7 shows features of crack growth of specimen without any rib. Crack growth of specimen molded with double gate followed weld line, but crack growth of specimen molded with single gate had irregular growth direction following glass fiber orientation.

In case of rib type, square rib pattern showed the best impact strength. Square rib pattern provided excellent impact strength even with the specimen that had a weld line. Plastic parts that require multiple gates because of their large size or complex shape can utilize square rib pattern to minimize the effect of weld line.