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QUALITY STABILIZATION OF BALL SEAT IN AUTOMOTIVE SUSPENSION PARTS

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ABSTRACT−Recently, many solution have been suggested to development of plastic products. Among many manufacturing technologies for plastic parts, the injection molding process is very attractive because of its low production cost and short cycle time. In this paper, the plastic ball seat of a ball joint, one of the essential components for automotive suspension or steering system, was studied to enhance its mechanical performance and durability by using PA66 that is reinforced polymeric plastic resin. But ball seat has some trouble in manufacture process. And strength of molded part is not enough to use. For the quality stabilization and reliability of injection molded parts, we designed the mold cavities through analytical simulation software and tested the mechanical performance for the injection molded ball-seat parts. After modification, tensile strength increases by about 13.5%. Strength and quality stabilization is improved.

KEY WORDS : Ball-seat, Ball joint, Injection mold, Tensile test

1. INTRODUCTION

In modern industry, a lot of research on the new material is widely required. In view of these trends, polymeric plastic materials are considered as the revolutionary and substitutive materials compared with the conventional ones like steels and their alloy. Also the applying areas of plastics are to be widened and diversified.

Based on the prominent properties like lightweight, minimized shrinkage effect, electric insulation and corrosion resistance, the demands of plastic molded parts are increasing and new mass-production methods are introduced in many aspects.

Among the various production technologies like sheet molding compound (SMC), resin transfer molding (RTM), pulltrusion, autoclave, injection molding process, the injection molding technology is considered as one of the best choices due to the lower production cost and mechanical performance.

More complicated injection molding process has been researched due to the development of new polymeric plastics having higher physical and chemical performances. Since 1970, one dimensional resin flow analysis has been presented, and now two dimensional flow analysis is developed.

Tadmar introduced the flow analysis network method by assuming the resin flow as the equivalent Newtonian viscous flow with constant temperature. Kamal and Kenig obtained the distribution of pressure and density by using the power-low and Spencer-Gilmore state equation. On the other hand, Freidel investigated the crystallizing process and its effect on the mechanical performance of the injected parts. Sherbelise researched the relation between shear rate and temperature sensitivity in the state of injection and packing pressure. Wang researched the shrinkage and weight according to the injection velocity, resin temperature, and packing pressure.

Based on these analytical researches, packaged program softwares are introduced, and they reduce the number of try and error in designing the die-mold and injection process. Also, due to this software, standardization and optimization are acquired for the quick development of relatively complicated injection molded parts.

In this paper, the plastic ball seat of a ball joint, one of the essential components for automotive suspension or steering system, was researched to enhance its mechanical performance and durability by using PA66 that is reinforced polymeric plastic resin. The main function of ball-seat is minimizing the friction reaction between ball and socket to transmit the adequate force in the

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suspension or steering system of automobiles.

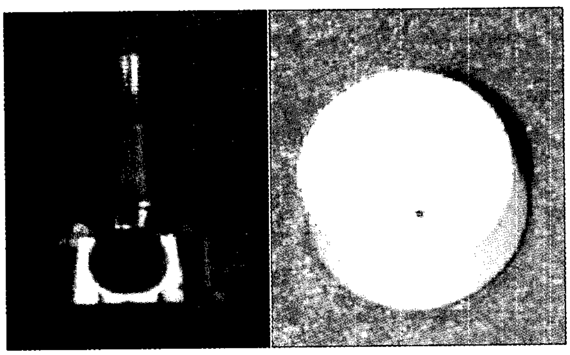
In assemble process, 10% of ball seats are broken out. For the quality stabilization and reliability of injection molded parts, we designed the mold cavities through analytical simulation soft ware and experimented the mechanical performance for the injection molded ball-seat parts.

2. EXPERIMENT

In case of symmetrical shape such as ball-seat, flow pattern of melted plastic is very important. To find a suitable mold designs and process conditions, injection process and molded part are analyzed by using computer simulation program (C-Mold). Base on the results, mold and gate location was designed. Injection molding experiment and tensile test are repeatedly attempted.

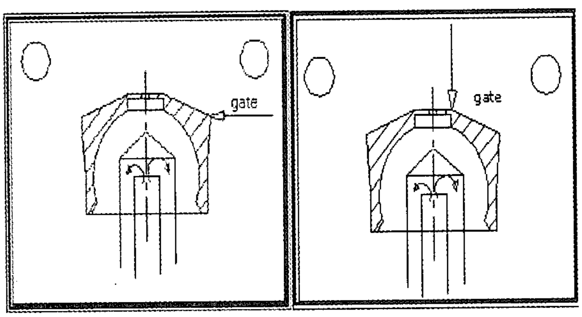
2.1. Injection Molded Part

The ball seat is one of automotive suspension parts and protect the ball stud from impact. Figure 1(a) shows an assembly of ball-joint and ball seat is shown in Figure 1(b).



(a) Ball-joint (b) Ball-seat

Figure 1. Assembly of ball joint and Injection molded ball-seat.



(a) Before modification (b) After modification

Figure 2. Schemetic diagram of gate location.

2.2. Analysis of Injection Flow

Injection molding simulation was attempted at unmodified cavity shape shown in Figure 2(a) and modified cavity shape in Figure 2(b). Analysis simulation soft ware for this aim is C-mold. This program gives results with 3 steps of result. First is pre-step of the injection, next step is related to an injection process. In this step, a user can check the result about pressure state, temperature, and flow of melted resin. The final step is cooling process. The ball seat has a symmetrical sphere shape and it must define the balanced flow and idle injection conditions. It can be defined in melt front advancement, It shows melted resin flow in cavities by time step. Core orientation shows vector of flow direction in cavities.

The flow balance during filling cavities is achieved in melt front advancement. The result of unmodified mold shape is shown in Figure 3, and modified shape is shown in Figure 4. Both of melted resin Flow is well balanced. In case of unmodified design, two directions of melted resin flow meet at opposite side of gate. Weld lines refer to weaker regions formed by the impingement of two separate flow fronts. Weld line may be formed also by splitting and rejoining of flow fronts around inserts. In case of modified design, flow direction is cylindrically

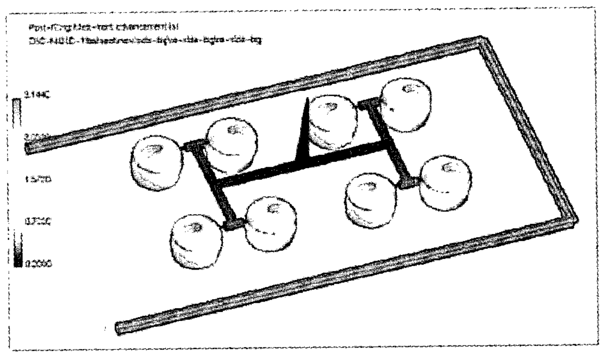


Figure 3. Flow analysis of Melt front advancement of unmodified mold.

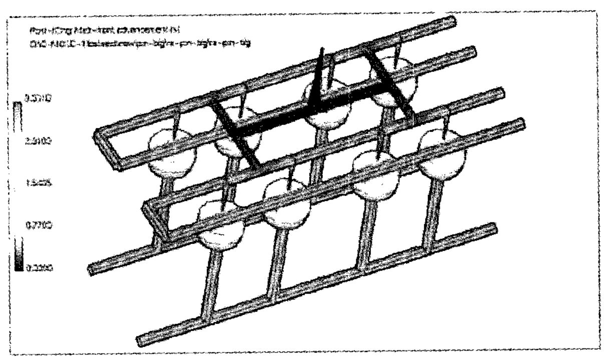
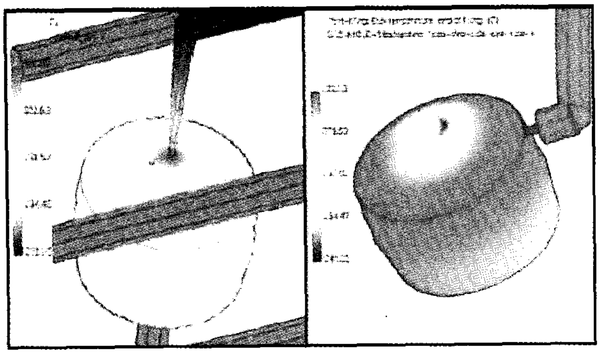
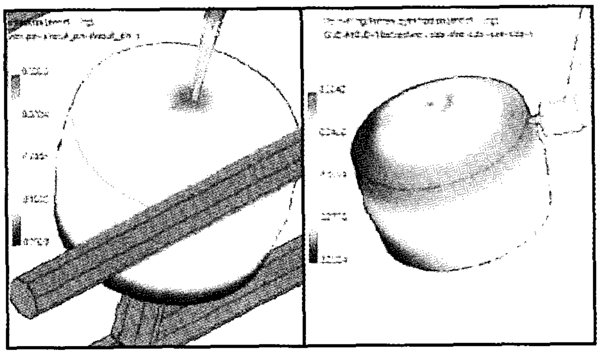


Figure 4. Flow analysis of Melt front advancement of modified mold.



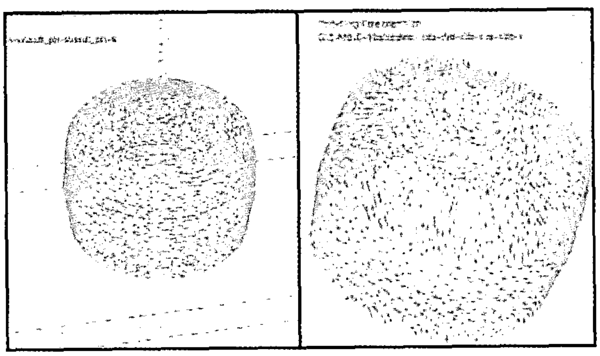
(a) After modification (b) Before modification

Figure 5. Bulk temperature distribution.



(a) After modification (b) Before modification

Figure 6. Frozen layer fraction.



(a) After modification (b) Before modification

Figure 7. Rresult of core orientation.

symmetric. The best values for tensile and impact strength are achieved in direction of flow while perpendicular to it, reduced toughness and increased tendency to stress cracking can be expected. In result of Modified gate location, the better result is expected in Modified gate system.

The steep temperature gradient causes a frozen skin to develop during the flow stage and this restricts the cross section of the flow channel to increase the pressure drop. Figure 5 is the result of the temperature distribution after filling. In most of the cases, the temperature distribution has a tendency to melt front advancement. But it has an effect on shrinkage. This result requires careful consideration with frozen layer fractions in Figure 6. Some distortions are the result of anisotropy shrinkage. Different thermal expansions dependent on directions can lead to distortions of the desired geometry. Such results as Figures 5, and 6, can bring on distortion caused by different temperature and frozen layer distribution.

Figure 7 is core orientation after filling. Ball seat is under high load at the assembly process. Therefore balanced strength and orientation of circumference direction are very important. We can see the unbalanced flow at the unmodified product, flow hesitation is occurred in opposite side of gate.

Different shrinkage and flow directions occur to weld line. The weld line is one of serious troubles for injection molding. After modification, flow direction and shrinkage rate are well balanced.

2.3. Injection Test

All test materials were supplied in pellet form and dried according to manufacture specifications prior to the manufacture of the ball seat, which were produced using a injection molding machine (LG, 140 ton) with a general purpose screw of diameter 45 mm. All the ball seats were allowed to condition under ambient conditions for a minimum of 48 hours prior to testing. An average result of 10 ball seats was used for all of the following test procedures.

Mold was made according to the result of computer simulation. It has 8 cavities shown in Figure 8.

In case of unmodified mold design, ball seat is break at assembly process. By the report from manufacturing line, the breaking trouble of about 10% occurs in assembly. Therefore we analyzed melted resin flow in mold by CAE program. Weld line can be occur in unmodified mold design. After change the gate location, weld line is disappeared.

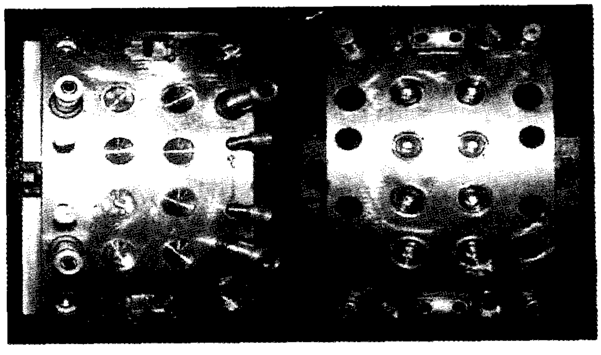


Figure 8. Injection mold for ball seat.

Table 1. Material properties of PA66 (3189 HSL NC010).

	Unit	Standard (ASTM)	Value	
Specific gravity	-	D 792	1.10	
Melt Temperature	°C	D 798	255	
Shrinkage	%	D 955	Flow	21
			Crossflow	24
Tensile strength	kN/m^2	D 638	67077	
Flexural strength	kN/m^2	D 790	73549	

Table 2. Injection conditions.

	Unit	Value
Melt temperature	°C	290
Mold temperature	°C	60
Injection pressure	% of 152003 kN/m^2	40
Holding pressure	% of 152003 kN/m^2	40
Cycle Time	second	8.5

Material for injection test is PA66 produced in Dupont Zytel, and grade number is 3189 HSL NC010. Material properties are shown in Table 1. Before injection, material is dried in oven drier at 80°C for 4 hour. Temperature of injection room is 15°C and relative humidity is 40%. Holding time is 3 second, injection time is 8.5 second, and cooling time is 15 second. Injection pressure and holding pressure are 40% of 152003 kN/m^2. Mold temperature is 60°C, and melt temperature is 290°C. All of injection conditions are standard specifications from material manufacturers. Injection conditions are shown in Table 2.

In injection process, when they are ejecting from mold, some parts break at unmodified gate system. Because they are under stress by core like ball shape, inferior products are also reduced in modified mold.

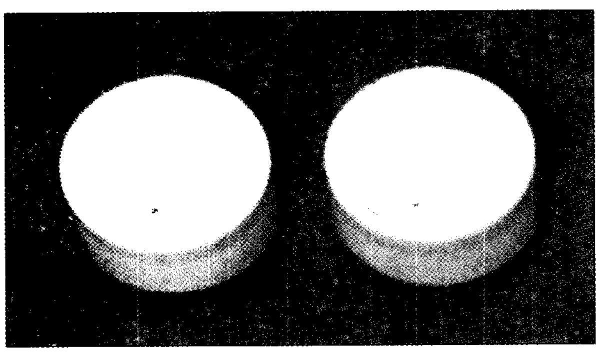


Figure 9. Injection molded part.

2.4. Tensile Test

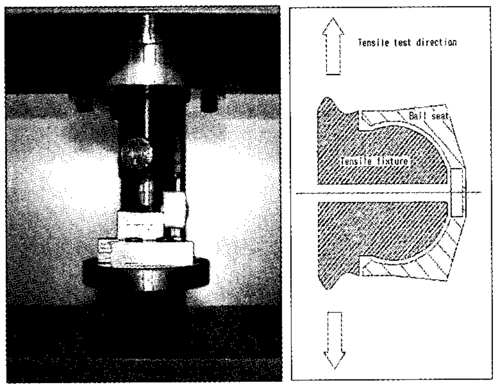
Tensile test is attempted for the checking the basic mechanical properties. The tensile property tests of the samples were performed using an Instron 4102 universal test machine, fitted with a 5 kN load cell. The tensile tests were carried out in accordance with ASTM D638M standard, using a cross head speed of 200 mm/min.

This test is to get the basic information before another test. Tensile strength test is performed at UTM machine, Head speed for test is 3 mm/min. The tensile test was attempted 10 days after injection. And tested over 20 times, Figure 10 shows the test machine and test diagram.

A tensile test of unmodified design is attempted to two kinds of directions. First direction is gate side and second direction is cross direction of gate side.

In unmodified design system, breaking point is 2340.436N in the gate direction, 2364.25N in the cross of the gate direction. Maximum tensile strength of modified design system is 2634.044N. These values are balanced for all of test direction.

The results show an overall increase in modified gate location. The modified mold design effects a quality



(a) Testing (b) Test diagram

Figure 10. Front view of tensile test

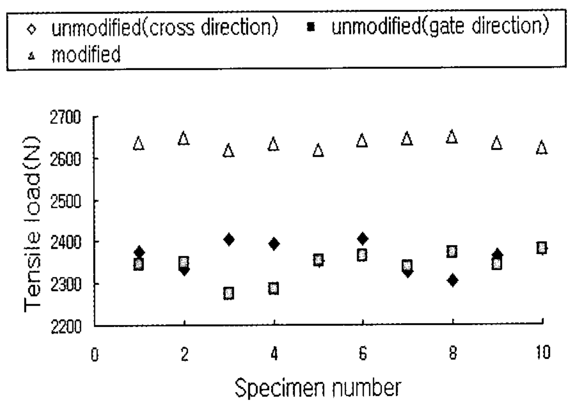


Figure 11. Result of tensile load.

stability of molded part. Result of unmodified part is largely scattered. Result is shown in Figure 11.

3. CONCLUSION

For the quality stabilization and reliability of ball seat, we designed the mold cavities through analytical simulation software and tested the mechanical performance for the injection molded ball-seat parts.

In the filling process of unmodified side gate system, the flowing plastic is obstructed by the core, splits its stream, and surrounds the core. The rejoining of the split streams forms a weld line that lacks the strength properties that exist in an area without a weld line. Gate location is changed to bottom center of ball seat. It made balanced flow distribution. And it removed a weld line.

Modified gate system had a balanced flow with uniform temperature distribution.

Tensile strength of unmodified product is 2345N. All specimens had broken in opposite side of gate.

After modification, tensile strength is about 2642N. Strength and quality stabilization is improved.

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