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A Study on the Optimal Conditions according to the Content of the Glass Fiber in the Resin-Automotive Motor Housing Application

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Abstract: Among the various plastic polymer molding methods, thermoplastic resins are most commonly used for mass production due to their suitability for high-volume manufacturing. However, recently, thermosetting resins have been utilized depending on product design and functionality, necessitating appropriate mold design and injection conditions to achieve suitable molded products. Therefore, resin selection must be considered not only in terms of product design but also based on functionality, taking into account the physical and mechanical properties of the resin. Additionally, since the flow characteristics of the resin are critical in injection molding, molding conditions should be set according to the thermal, physical, and rheological properties of the resin.This study focuses on the effects of filler content (glass fiber) in thermosetting fiber-reinforced plastics (FRP), specifically Bulk Molding Compound (BMC) resin, which is crucial for thermal deformation in automotive motor housing products. The resins used in this study include Generic BMC1 resin, BMC1 with 15% glass fiber, and BMC1 with 30% glass fiber. The research employs CAE (Computer-Aided Engineering) to investigate strain under basic conditions for the BMC resin and the strain variations with the addition of glass fiber. It also examines the impact of filler content on injection molding conditions, specifically mold temperature and curing time. Experimental results indicate that mold temperature has the most significant effect among the injection conditions, while the impact of curing time was relatively minor.

Key Words: Plastic Polymer Molding Method, Thermoplastics, BMC, Glass fiber

1. Introduction

Recently, electric vehicles are being commercialized, and accordingly, the need for research on improving and developing problems in motors and motor housings, which are key components, is emerging. Kim et al. (2011) studied that a lot of heat is generated when the motor is driven, a coolant for cooling it is stored inside/outside the motor housing, and the motor housing must have high strength to protect motor parts while blocking the outflow of cooling oil inside. At the same time, thermal conductivity must be good to minimize the temperature increase inside the motor. Usually, automobile motor housing uses cast iron or aluminum die casting. However, aluminum materials have low thermal conductivity, a risk of corrosion, and furthermore, there is a problem that multiple processes such as welding are required in the manufacturing process of the motor housing. To replace this, plastic materials such as GFRP and FRP are used. Through this, companies are making the material lighter by using plastic and composite materials, while developing aimed at maintaining and further improving physical properties. Thermosetting resins, thermoplastic resins, and plastic composite materials are used as the materials, and composite materials such as FRP (BMC) resin and sheet molding compound (SMC) resin are mainly used for motor housing. BMC resin has excellent insulation, high thermal deformation temperature, and excellent mechanical strength, so it is suitable as a material for motor housing. However, for better physical properties, the synthesis of additives is required. Glass fiber, styrene, and radial initiator are added to Recently, electric vehicles are being commercialized, and accordingly, the need for research on improving and developing problems in motors and motor housings, which are key components, is emerging.

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2. Materials and methods

Among the BMC resins currently provided by Moldflow, Generic's General BMC1 resin was used as the resin used in the experiment, and Glass fiber was used as a filler.The physical properties and injection conditions of the Generic BMC1 resin used in this experiment are shown in Tables 1 and 2. The resin used in the experiment consisted of three types of resins: 0% additive, 15% additive, and 30% additive to measure the difference in deformation according to the glass fiber content. In order to measure the deformation amount of the molded product by mold temperature of the BMC resin, the temperature was set to 150°C, 155°C, and 160°C under the molding conditions of Moldflow, and the deformation amount of the three types of resins was measured and compared. In order to measure the deformation amount of the BMC resin according to the curing time, the curing time was set differently to 30sec, 45sec, and 60sec under the same conditions based on the previous measurement results, and the deformation amount of the three types of resins was measured and compared. In addition, the deformation amount of the molded product according to the presence or absence of the glass fiber under each condition was measured and compared.

Table 1 Material Properties for BMC (GENERIC BMC1)

Specific Gravity	1.86 ±0.05
Tensile Strength (Mpa)	29.42
Elongation at Break (%) D638	2.8
Flexural Strength (Mpa)	647.24
Flexural Modulus (Gpa)	10.3
Notched lzod (J/m) D256 lmpact Strength	30
DTUL (°c)	226 (°c)
Coeff.of Linear Expansion (x10-^{5}/°c)	1.7
Mold Shrinkage (%) Factor	0.02
Dielectrical (Kv/mm) Breakdown Strength	10<

Table 2 Injection Molding Conditions employed

Molding condition			
Mold temperature (℃)	150	155	160
Curing time (sec)	30	45	60

3. Result and discussion

3.1. Deformation amount according to mold temperature

In order to measure and compare the amount of deformation of the molded product according to the change in the mold temperature, the mold temperature was set differently at 150℃, 155℃, and 160℃, and the injection time and curing time were applied equally at 1sec and 30sec.

When compared with the presence/absence of the glass fiber, the difference in the amount of deformation between the resin with and without the glass fiber was clearly found. In the case of the glass fiber-free resin, the amount of deformation was 0.3724mm when the mold temperature was 150°C, 0.4386mm when the mold temperature was 155°C, and 0.5375mm when 160°C. In the resin to which 15% of the glass fiber was added, the amount of deformation was 0.2553mm when the mold temperature was 150°C, 0.2603mm when it was 155°C, and 0.2880mm when it was 160°C. In the resin to which 30% of the glass fiber was added, the amount of deformation was 0.3525mm when the mold temperature was 150°C, 0.3592mm when it was 155°C, and 0.3994mm when it was 160°C. Therefore, when the glass fiber content was 15%, the amount of deformation of the resin was the least. In general, the higher the glass fiber content and the longer the glass fiber length, the greater the injection pressure. High injection pressure helps fill, improve glass fiber dispersion, and reduce product shrinkage, but it is easy to cause distortion deformation and demolding due to increased shear stress and direction, requiring an appropriate glass fiber content. The amount of deformation according to the mold temperature can be summarized in the order of 0%, 15%, and 30% of the glass fiber. When the mold temperature is 150°C, it is 0.3724mm, 0.2553mm, 0.3525mm, and when it is 155°C, it is 0.4386mm, 0.2603mm, 0.3592mm, and when it is 160°C, it is 0.5375mm, 0.2880mm, and 0.3994mm. Based on this, it can be seen that the high content of the glass fiber in the range of 150~160℃ does not reduce deformation, but the content of about 15% is appropriate. It can be seen that when the temperature is gradually increased from 150°C to 160°C by 5°C, the amount of deformation increases as the temperature increases. In addition, it was found that the lower the mold temperature, the lower the amount of deformation.Data on figures are shown in Tables 3, 4, 5, and Fig. 1, 2, and 3 below.

Table 3 Deformation of Glass fiber 0%

	Glass fiber 0%		
Temp (℃)	150	155	160
Deformation	0.3724	0.4386	0.5375

Table 4 Deformation of Glass fiber 15%

	Glass fiber 15%		
Temp (℃)	150	155	160
Deformation	0.2553	0.2603	0.2880

Table 5 Deformation of Glass fiber 30%

	Glass fiber 30%		
Temp (℃)	150	155	160
Deformation	0.3525	0.3592	0.3994

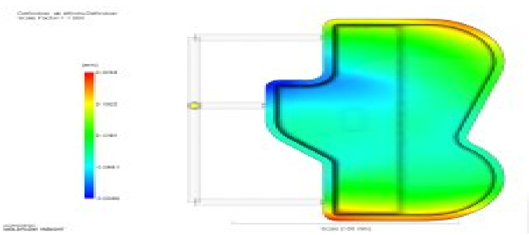

Fig. 1 Mold temperature 150℃ -> Mold temperature of 150℃

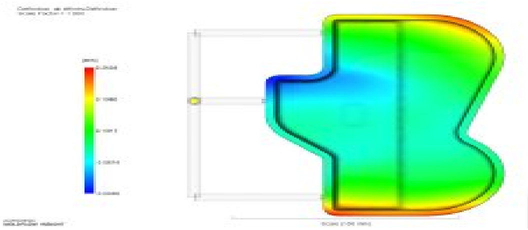

Fig. 2 Mold temperature 155℃ -> Mold temperature of 155℃

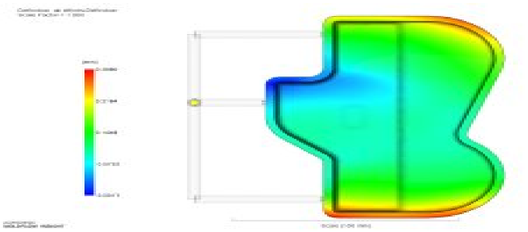

Fig. 3 Mold temperature 160℃ -> Mold temperature of 160℃

3.2. Deformation amount according to curing time

Experiments were conducted to measure and compare the amount of change in the molded product according to the curing time. The basic curing time was set to 30 sec, and then 45 and 60s of curing time were applied at 15 sec intervals, respectively. The results were summed up by curing time, mold temperature, and glass fiber content and summarized. Data on figures are shown in Tables 6, 7, 8, 9, Fig. 4, 5, and 6 below.

According to this, in the resin with a glass fiber content of 0%, the values at 30sec and 45sec were 0.3724mm, which showed no difference, but at 60sec it was 0.2866mm, which rather reduced the amount of deformation. In the resin with a glass fiber content of 15%, the amount of deformation at 30sec was the least at 0.2553mm, 0.2603mm, and 0.2880mm, and at 60sec, the amount of deformation was 0.2558mm, 0.2599mm, 0.2884mm, and 45sec, 0.2694mm, 0.2999mm, and 0.3199mm, increasing the amount of deformation in the order of 30sec, 60sec, and 45sec. In the resin with a glass fiber content of 30%, the amount of deformation according to the curing time did not show a significant difference. When comparing by glass fiber content, it was confirmed that the section showing the highest quality deformation was 15% with a glass fiber content. In general, when the mold temperature was 150°C at the curing time of 30 sec, which had the best result value, the amount of deformation was 0.3724mm, 0.2553mm, 0.3525mm, 0.4386mm, 0.2603mm, 0.3592mm, and 0.537580mm when the mold temperature was 160°C. Finally, it was found that the amount of deformation according to the difference in glass fiber content was not regular, and the amount of deformation decreased when the intermediate glass fiber content of 15% was added under the experimental conditions. In addition, it was confirmed that when the curing time was 45 sec, the amount of deformation tended to increase compared to when it was 60 sec. As a result, it was confirmed that the amount of deformation according to the curing time also did not exhibit regularity.

Table 6 Deformation of Curing time 30s

	Temp (℃)	Glass fiber 0%	Glass fiber 15%	Glass fiber 30%
30s	150	0.3724	0.2553	0.3525
	155	0.4386	0.2603	0.3592
	160	0.5375	0.2880	0.3994

Table 7 Deformation of Curing time 45s

	Temp (℃)	Glass fiber 0%	Glass fiber 15%	Glass fiber 30%
45s	150	0.3724	0.2694	0.3533
	155	0.4386	0.2999	0.3589
	160	0.5375	0.3199	0.3995

Table 8 Deformation of Curing time 60s

	Temp (℃)	Glass fiber 0%	Glass fiber 15%	Glass fiber 30%
60s	150	0.2866	0.2558	0.3533
	155	0.3618	0.2599	0.3585
	160	0.4505	0.2884	0.4000

Table 9 Deformation of Glass fiber 0%, 15%, 30% for Curing time 30s, 45s, 60s

	Glass fiber 0%		Glass fiber 15%		Glass fiber 30%	
Curing time: 30s	150	0.3724	150	0.2553	150	0.3525
	155	0.4386	155	0.2603	155	0.3592
	160	0.5375	160	0.2880	160	0.3994
Curing time: 45s	150	0.3724	150	0.2694	150	0.3533
	155	0.4386	155	0.2999	155	0.3589
	160	0.5375	160	0.3199	160	0.3995
Curing time: 60s	150	0.2866	150	0.2558	150	0.3533
	155	0.3618	155	0.2599	155	0.3585
	160	0.4505	160	0.2884	160	0.4000

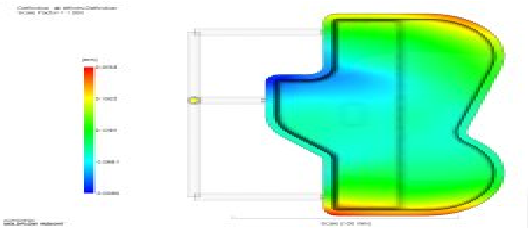

Fig. 4 Curing time 30s -> Curing time of 30s

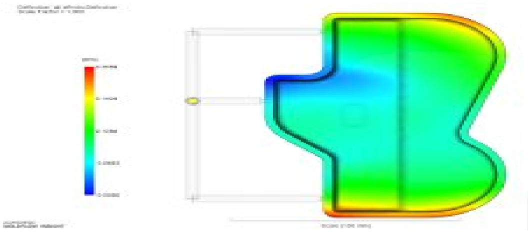

Fig. 5 Curing time 45s -> Curing time of 45s

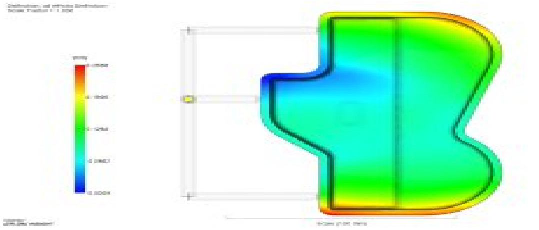

Fig. 6 Curing time 60s -> Curing time of 60s

4. Conclusion

Through this study, it was not only possible to find the improvement condition value of the bulk molding compound (BMC) resin deformation amount used in automobile motor housing but also to find out how the effect occurs through each different condition. As a result of the study, the following conclusions were drawn on the amount of deformation of the injection molded product due to the mold temperature and curing time according to the glass fiber content.

1. The distribution of deformation according to the glass fiber content is relatively good at 15%, and the average value is 0.2774mm, which is smaller than 0% of 0.4218mm and 30% of 0.3705mm.

2. The deformation of the automobile motor housing was maximized at 0.5375mm, which is 44% larger than 0% to 150℃ by content at 160℃, 0.2880mm, which is 13% larger at 15%, and 0.3994mm, which is 13% larger at 30%, regardless of the glass fiber content.

3. The amount of deformation according to curing time decreased by 31.8% on average at 0% of the content compared to the lowest value, but increased by 10.6% on average at 15% and 0.19% at 30%. When the glass fiber content was 30%, there was little effect on curing time, but a significant difference in result values was found at 0% and 15% of the content.

4. Comparing each of the different conditions, such as mold temperature and curing time, it was found that the difference in the amount of deformation caused by the mold temperature was the largest, and this resulted in the highest quality automotive motor housing being molded at a low temperature of about 150°C.

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Reference

1) Sanders. M.S. and Mc Cormick. E.J., “Human Factors in Engineering and Design”, Seventh Edition, Mc Graw-Hill Inc., New York, pp. 87-92, 1992.
2) Hyundai Motor Co., Ltd, 10-2012-0116079, Korean Intellectual Property Office, 2011.
3) Thomason, J.L. The Influence of Fibre Length and Concentration on the Properties of Glass Fibre Reinforced Polypropylene, 1996.
4) Abdulkadir Gullu. Experimental investigation of the effect of glass fibers on the mechanical properties of polypropylene(PP) and polyamide6(PA6) plastics, 2006.
5) Park, J.Y., Yoon. G.S., Lee. J.W., Choi. J.M., A Study on Deformation of LSR Injection Moldings Having the Runners with Same Flow Distance, Journal of the Korea Society of Die & Mold Engineering, Vol.7:1 60-63, 2013.
6) Kim Young-man, & Kim Yong-hwan. A Ductility Analysis Study with Digimat to Implement Mechanical Behavior of Glass Fiber Reinforced Plastic. Journal of the Korean Society of Computer Structural Engineering, 32(6), 349-358. 2019.
7) Im Hwan-seong, Ryu Ha-woong, Kim Jung-ho, Kwan Ki-jung, Kim Bong-gue, Moon Ji-hoon, 10-2015-0001408, Korean Intellectual Property Office, 2013.
8) D.T.Kim and S.R.Han,“A Study on the Design of Door Module PNL Using CAE and Inverse Compensation for Warpage”, KSDME, Vol. 12, No. 2,pp.27-33, 2018.
9) Park, N.G. and Kim, S.K., “Coating die design and analysis”, Proceedings of Korean Society of Manufacturing Technology Engineers 2019 Spring Meeting, pp.184-184, 2019.

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