급속냉각이 초미세 발포 사출 제품의 수축과 결정화도에 미치는 영향

Effect of As-Mold Rapid Cooling of Core Region on Shrinkage & Crystallinity of Injection Molded Parts Using Microcellular Foaming Process

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1. Introduction

Microcellular foaming process developed by MIT is considered a way to reduce shrinkage. This process uses inert gases like CO_2 or N_2 in the super critical fluid (SCF) state which is mixed with molten polymer in the injection molding machine barrel. This single phase solution is injected into the mold cavity by injection machine screw. Nucleation occurs as a result of pressure drop and thermodynamic instabilities which gives birth to micro cells in molten polymer. These micro cells continue to grow until the polymer is solidified Microcellular foaming process reduced the weight of the product and improved the shrinkage.[1,2]

Shrinkage of injection molded parts is a result of increased free volume of polymer upon melting and loss of this free volume upon re-solidification in mold cavity.[3] The shrinkage rate is very high in the beginning when the part is just ejected from the mold because the core region is still in molten state. Figure 1 shows molten core region and skin region of an Acetal specimen which was broken just after ejection from mold.

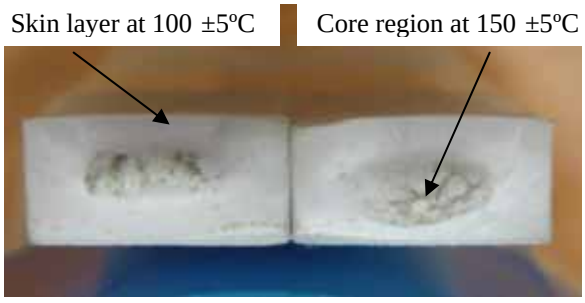

Fig.1 Cross section of core region of foamed Acetal specimen

The molten core region at 150 ±5ºC was then rapidly cooled to freeze the phases and to stop the movement of molecular chains causing shrinkage. The changes in phases then measured by using Differential Scanning Calorimeter (DSC).

2. Experimental

Acetal copolymer (F20-03) provided by KEPITAL in granular form was used to make ASTM standard samples with 127mmX12.7mmX6.4mm dimensions at increasing weight reduction under same injection molding conditions. Catalogue mold shrinkage ratio of this material is 2%. N_2 gas with 99.99% purity was used as SCF in the microcellular foaming process to make a single phase solution.

After ejection of specimens from the mold set at 25 ºC, some of the specimens were allowed to cool naturally at ambient conditions. The others were immediately immersed into ice water at 0ºC to get RC of molten core region. To get DSC thermograph, 6mg samples were made from core region of both naturally cooled and rapidly cooled specimens and % crystallinity was measured.[4]

3. Results and Discussion

Fig. 2 illustrates the effect of increased weight reduction (0~10%) on % shrinkage reduction for NC and RC samples. It is obvious from this figure that % reduction in linear shrinkage is directly related with the weight reduction for both types of samples. In the beginning when no gas was added, the observed value of linear shrinkage with respect to the size of mold cavity was 2.8% in the case of NC Acetal. When weight reduction was increased, % linear shrinkage was also decreased. At 10% weight reduction, the % linear shrinkage was reduced up to a value of 2.4%. The total % reduction in linear shrinkage from 0 to 10% weight reduction was about 14% w.r.t the mold cavity for NC Acetal samples. Similarly for RC samples, when no gas was added, the observed value of linear shrinkage with respect to the size of mold cavity was 14 %. When weight reduction was increased, % linear shrinkage was also decreased and at 10% weight reduction, the % linear shrinkage was reduced up to a value of 2.18%. The total % reduction in linear shrinkage from 0 to 10% weight reduction w.r.t mold cavity was about 22% for RC samples.

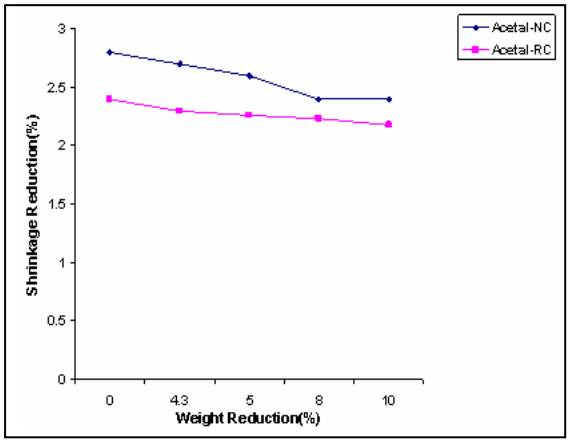

Fig.2 Effect of weight reduction on linear shrinkage

When molten Acetal is injected into mold, it starts to solidify and at the same time the growth of micro cells inside polymer melt takes place throughout the molten matrix. Upon solidification, the

long polymer chains tend to rearrange themselves into original crystalline structure resulting in shrinkage of the sample.[3] However, micro cells (entrapped gas) present in the polymer matrix try to restrict the chain movements during rearrangement/ recrystallization of long polymer chains resulting in the shrinkage reduction. Another factor responsible for shrinkage reduction is loss of % crystallinity at microcell-polymer interface which increases with weight reduction.

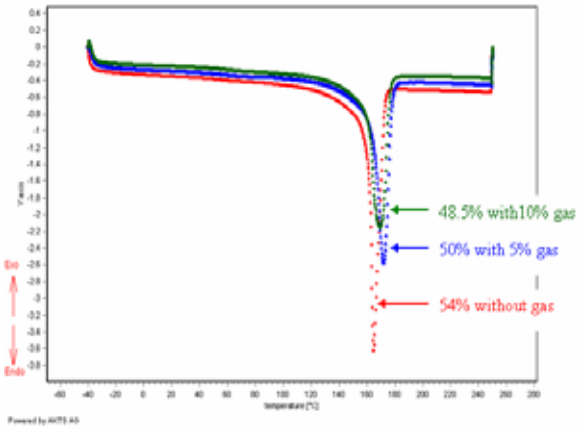

Fig.3 Effect of weight reduction on %crystallinity

Fig.3 is the DSC thermograph for NC Acetal samples and explains the changes in % crystallinity of NC samples with increased weight reduction. It is evident from this figure that without any gas, the % crystallinity is 54% which changes to 50% with 5% weight reduction and 48.5% with 10 % weight reduction.

For NC samples without any gas, the observed value of linear shrinkage is 2.8% with 54% of crystallinity while for RC samples it is 2.4% with 47% of crystallinity. The reason for this difference is the rapid freezing of molten core region when it was immersed into ice water immediately after ejection from mold. The long polymer chains were frozen at the expanded (mostly amorphous) state and free volumes created during melting could not be eliminated like NC sample. Figure 4 illustrates the effect of RC and increased weight reduction on crystallinity of the Acetal specimens.

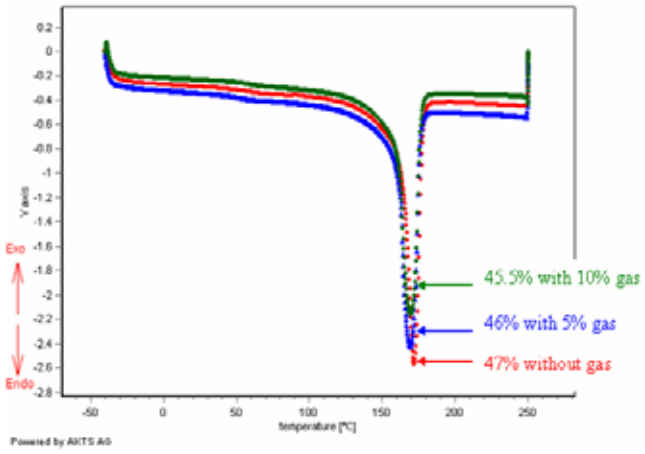

Fig.4 Effect of RC and weight reduction on %crystallinity

In the case of RC, crystallinity of core region of polymer decreases due to the combined effect of increasing weight reduction and the rapid freezing of molten polymer chains. This combined effect can be used to improve the % shrinkage of injection moulded parts.

4. Conclusion

Shrinkage and crystallinity are directly related with each other in microcellular foaming process and both are affected by weight reduction. Therefore both high weight reductions and RC can be used to decrease the % shrinkage of semi crystalline polymers. Since RC further increases the percentage of amorphous region, it must also affect on mechanical properties of the samples (Future work). RC of core region is very simple to perform on the injection moulded parts and no extra investment is needed.

References

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