잔류 응력에 의한 사출성형물의 변형

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Deformation of the injection molded part due to residual stress

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Introduction

Injection molding is one of the most common operations in polymer processing. Good quality products are usually obtained and major post-processing is not required. However, residuals stresses which exist in plastic parts after ejection affect the final shape and mechanical properties. Residual stresses are caused by polymer melt flow, pressure distribution, non-uniform temperature field, and density distribution. After release of eventual constraints, final product dimensions may differ considerably from the initial ones. Injection molding introduces residual stresses that exist in the final product. It is important to predict and measure the residual stresses the final part in order to predict its performance. Depending on the situation, residual stresses can be either detrimental or beneficial. Compressive residual stress on the surface can prevent the initiation of cracks, thereby increasing the fatigue life. Conversely, when stresses due to external loads are added to the residual stress, plastic yielding will begin at a lower load. An asymmetric mold wall temperature distribution will cause asymmetric residual stresses and if the part is not stiff enough, it will warp after its ejection from the mold.

The aim of this study is to predict deformation experienced by the injection molded part after ejection(out-of-mold) from the cavity by numerical methods using Moldflow™ and ABAQUS™. Deformation of the molded part caused by the residual stress is measured by the 3 Dimensional Scanner. Measurement of the deformation is compared with the viscoelastic stress analysis conducted by ABAQUS™. The results can be utilized to improve injection molding conditions and to predict the durability of the part.

Experimental

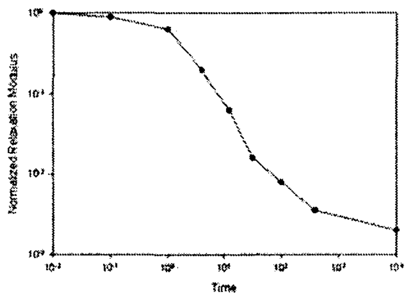
After Moldflow™ analysis has been carried out for the injection molded part, In-mold data is imported by ABAQUS™ [Table.1] and deformation of the part is computed by considering viscoelastic properties obtained by the relaxation test [Figure.1] with DMTA.

To determine properties and deformation of the part, numerical analysis is commonly used. The accuracy of the numerical results should be examined by comparing with the measurement results scanned by the 3D Scanner (Exyma; 3D NEXTUS) can be compared with numerical analysis results. The 3D Scanner is adopted the method of geometric superposition. Analysis results are compared with CAD raw data and the measurement data acquired before and after the annealing test which is conducted in a convection oven at 80 °C for 60 hrs.

Property	
Elastic modulus	1.385E+9 Pa
Poisson's ratio	0.408
Thermal conductivity	0.11 W/m°C at 220°C
Specific heat	2723 J/kg°C at 220°C
Solid density	906.95 kg/m3
Melt density	741.25 kg/m3
Viscoelastic	Relaxation Test by DMTA

Mesh	Tetra	Hex
Type	C3D10MT	C3D20T
Amount	66,862	7,200
IC	20 °C , Fixed one side	
Load	Pressure : 1000 Pa (Viscoelastic) at upper side	
BC	17532 hrs (2 year)	
Part Size	120 * 30 * 2 mm	

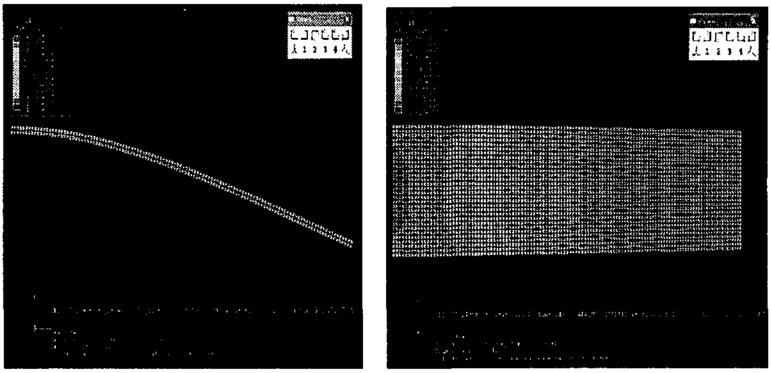
[Table.1] Input data for ABAQUS analysis



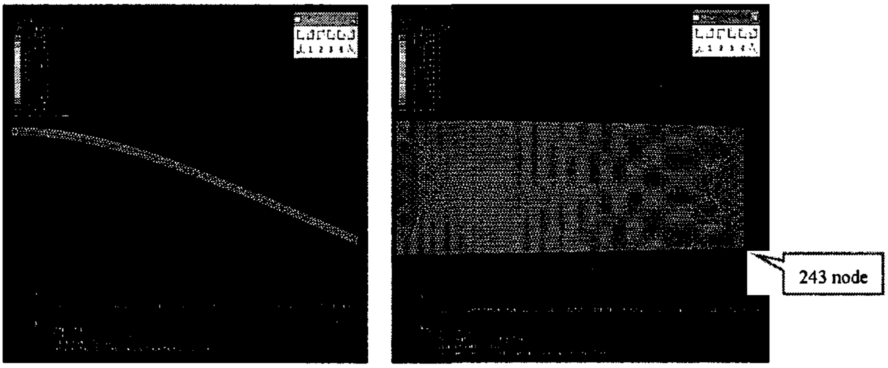
[Fig.1] Relaxation modulus of polycarbonate varying with respect to time (Mercier, 1965).

Results and discussion

To consider more realistic properties of the injection molded part, a numerical analysis is performed to conduct the viscoelastic stress analysis with the relaxation modulus data. The numerical results are shown in Figure 2 and 3. Viscoelastic deformation of a simple polymeric plate is shown as a function of time in the figures. For application of more accurate numerical analysis, geometry of the injection molded part was measured by the 3D scanner. Through the measured data, boundary conditions can be determined to produce precision parts by the numerical analysis

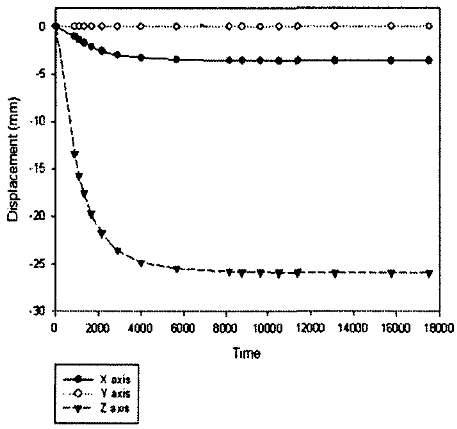


(a) Viscoelastic deformation obtained by using the finite element mesh (Hex) after 2 years.



(b) Viscoelastic deformation obtained by using the finite element mesh (Tetra) after 2 years.

[Fig.2] Comparison of viscoelastic analysis results obtained by using different type of elements.



[Fig.3] Displacement of the 243[rd] node vs. time (maximum deflection = 26.1684mm).

Conclusion

Residual stresses and deflection of the injection molded parts were predicted by using numerical analysis software. Deformation of the part due to its viscoelastic properties was also predicted and measured. Long-term performance of the molded part that contains residual stresses was measured by the 3D scanner using the relaxation modulus data.

Acknowledgement

This work was financially supported by the Korea Science and Engineering Foundation through the Applied Rheology Center (ARC) at Korea University

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