Special Issue of the 8th International Advances in Applied Physics and Materials Science Congress (APMAS 2018)

The Effects of Injection Parameters and Foaming Agent on Dimensional Accuracy of Produced Parts in Plastic Injection Molding

O.S. Kamber*
Ihlas Ev Aletleri, Istanbul, Turkey

Dimensional accuracy is an important factor for all components manufactured by plastic injection molding. This factor is more significant for functional components loaded in dynamic manner. In this study, rotatory roller of cleaning robot were produced with plastic injection molding process and the effects of temperature, pressure, cooling time, and foaming agent on dimensional accuracy of investigated pieces. Experimental findings show that measured input variables have some effect on measured outputs. Besides, this study shows that using foaming agent contributes to controlling dimensional accuracy of this component.

DOI: 10.12693/APhysPolA.135.1028

PACS/topics: plastic injection molding, dimensional accuracy, foaming agent

1. Introduction

Plastic injection molding method belongs to the most common way of manufacturing. For this reason, in our daily life many products have been made of plastic materials [1]. In plastic injection molding, like in any other manufacturing processes, many parameters of raw materials, mold, and process conditions influence the quality of product [2]. However, some of them cannot be directly controllable during process. Only few of them, such as cooling time, mold temperature, and pressure, can be precisely controlled during plastic injection molding [3]. These parameters has considerable effect on product dimensional and geometrical accuracy and quality, in particular these parameters affects the warpage and shrinkage occurs on the product these are very critical to control product quality [4].

In available literature, many studies presented the relation between these parameters and measured quality characteristics by utilizing optimization techniques [5], finite element modelling [6] and experimental studies [7]. In these studies, researchers generally focus on micro-components and thin-walled parts [8]. But no study available in the literature presents large, macro-components, in other words, components produced by plastic injection molding.

Besides, the effects of foaming agent on dimensional quality of plastic injection molded parts have not been extensively studied. Only few studies are available, with no comprehensive analysis. The presented study fills the gap, providing the systematic investigation in this area.

*e-mail: okamber@iea.com.tr

2. Experimental procedure

In this study, rotatory roller of cleaning robot is analyzed. This component is made of ABS polymer material whose mechanical properties can be found in elsewhere [2]. Basic properties of foaming agent is presented in Table I.

TABLE I

Properties of foaming agent.

Property	Value
carrier resin	polymer blend
active ingredients	40%
gas yield at 200 °C	75 ml/g
decomposition start temp. DSC (10 °C/minute)	approx. 150 °C

2-D Technical drawing and 3-D solid model of rotatory roller is presented in Fig. 1a, b, respectively. The length of roller is 322.6±0.2 mm and diameter of it is 33.7 mm, as shown in Fig. 1a. Fig. 2a, b shows 3-D modeling of plastic injection mold and fabricated plates of mold to produce components, respectively.

In experimental design, industrial applications were taken into account. Selected parameters and their levels were determined in respect of industrial applications. The variables in this study were temperature, pressure, and cooling time. For each of these parameters, five different levels were determined. To determine the effects of foaming agent on dimensional accuracy of products, five experiments were carried out. For these experiments, temperature, pressure and cooling time were kept constant as 225 °C, 120 bar, and 300 second, respectively. The rate of foaming agent used in experiments were 0%, 1.5%, 3%, 4.5%, and 6%.

Dimensional accuracy of parts produced in plastic injection molding process is measured considering diameter

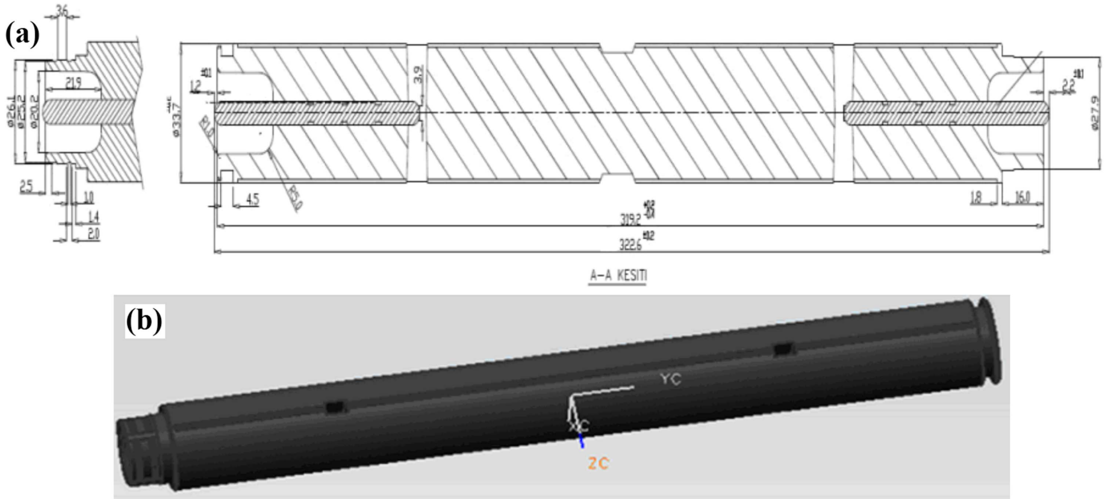

Fig. 1. (a) Technical drawing of manufactured component in plastic injection molding, (b) 3-D solid model of manufactured component.

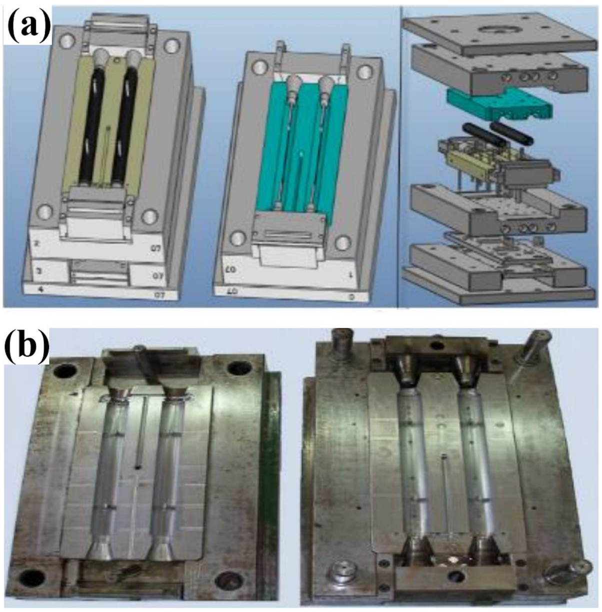

Fig. 2. (a) 3-D Modeling of plastic injection mold, (b) Male and female plate of mold.

and cylindricity. Three components were taken to measure each output so that error coming from measurements was eliminated. To make these measurements, Mitutoyo Coordinate Measurement Machine (CMM) and 3-D noncontact profilometer were used. Fig. 3a, b shows example of measurement images taken by coordinate measuring machine and example of measurement obtained with 3-D noncontact scanner profilometer, respectively.

3. Results and discussions

In production process of cylindrical components, one of the important parameters needs to be considered is deviation its diameter from nominal diameter. These deviations generally results in shrinkage and warpage [9].

TABLE II

Experimental design (T — temperature, P — pressure, CT — cooling time).

Exp. No.	T [°C]	P [bar]	CT [s]
1	200	120	300
2	215	120	300
3	230	120	300
4	245	120	300
5	260	120	300
6	230	100	300
7	230	110	300
8	230	120	300
9	230	130	300
10	230	140	300
11	230	120	200
12	230	120	250
13	230	120	300
14	230	120	350
15	230	120	400

In this study, cylindrical specimens were measured from three different points and its dimensional accuracy is evaluated accordingly.

Figure 4 shows the effects of four different parameters on dimensional deviations (diameter deviation) of rotatory roller (specimen). Figure 4a shows the relationship in between cooling time and dimensional deviation. It is an obvious that there is a strong relationship in between dimensional deviation and cooling time. When cooling time is smaller than 300 seconds, diameter of specimen shows shrinkage and diameter become much smaller than nominal diameter. Furthermore, increased cooling time also effect diameter accuracy by producing larger diameter than nominal diameter. All three specimen shows similar trend with some variation. This is mainly because

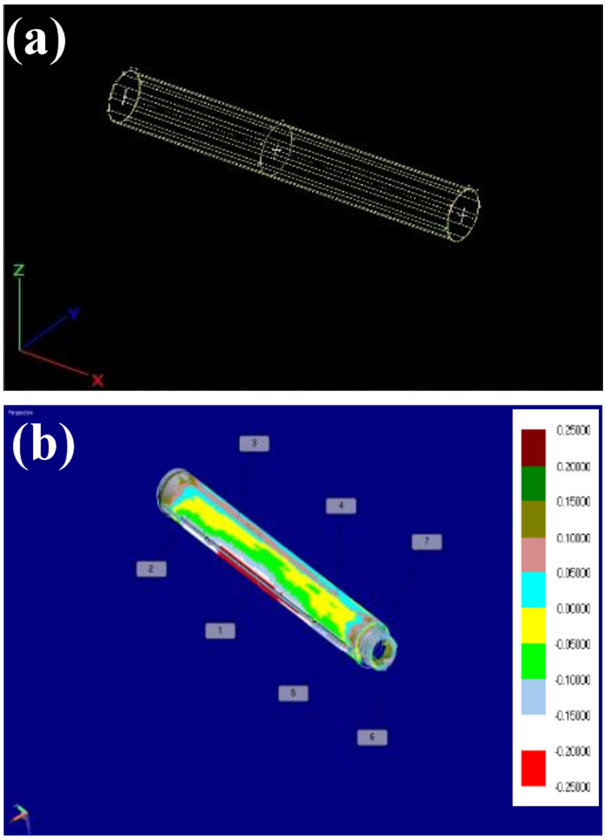

Fig. 3. (a) example of measurement images taken by coordinate measuring machine, (b) example of measurement obtained with 3-D noncontact scanner profilometer.

of cooling material quickly and extremely slow causes thermal residual stresses that affects dimensional accuracy of specimen [10]. Figure 4b illustrates the effects of various pressure on dimensional accuracy of specimens measured in this study. Low pressure generates larger error in terms of dimensional deviation and thus quality of product. Increased pressure seems to be positively influence to obtain specimens with more accurate measures.

Among all selected pressure values, minimum dimensional deviations is obtained with 130 bar. This obtained trends shows good agreement with the results reported in literature by Shen et al. [11]. The effects of temperature and foaming agent rate on dimensional deviations are presented in Fig. 4c, d, respectively. Both parameters shows similar influence on dimensional accuracy of specimens. Lower temperature and lower rate of foaming agent leads to increased dimensional accuracy of specimens; while increased values are helpful to obtain diameters that are close to nominal diameter. It should be noted that the effects of foaming agent on dimensional accuracy of ABS components are very limited [12]. Cross section of cut rotatory roller specimens are shown in Fig. 5. Figure 5a–d shows cross section photographs of product made of ABS material in different places.

As it is obvious when foaming agent is not added into the ABS material, fabricated specimens have large cavities in it that effects dimensional accuracy as well. However, adding foaming agent into to specimens remarkably increase homogeneity in cross section of specimens and thus contribute to obtain dimensional accuracy.

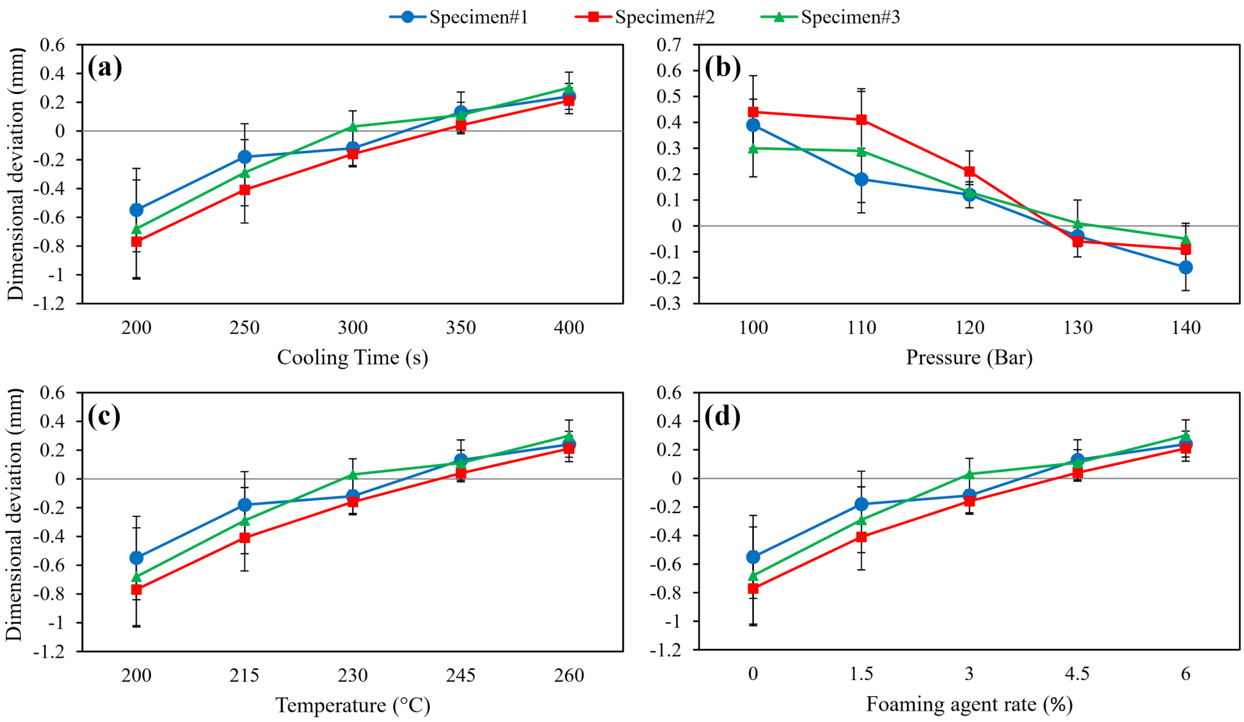

Fig. 4. The effects of various input parameters on diameter deviation of specimens.

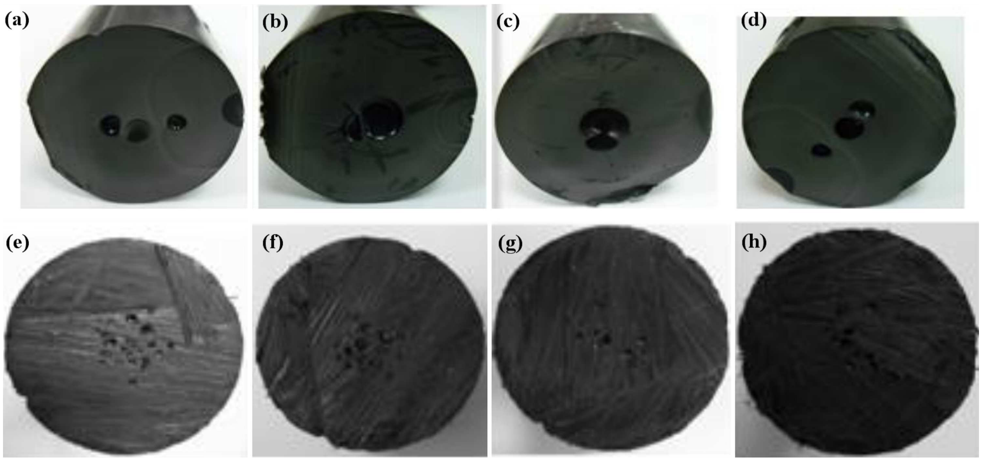

Fig. 5. Cross sections of product made of: (a)–(d) pure ABS material and (e)–(h) with foaming agent.

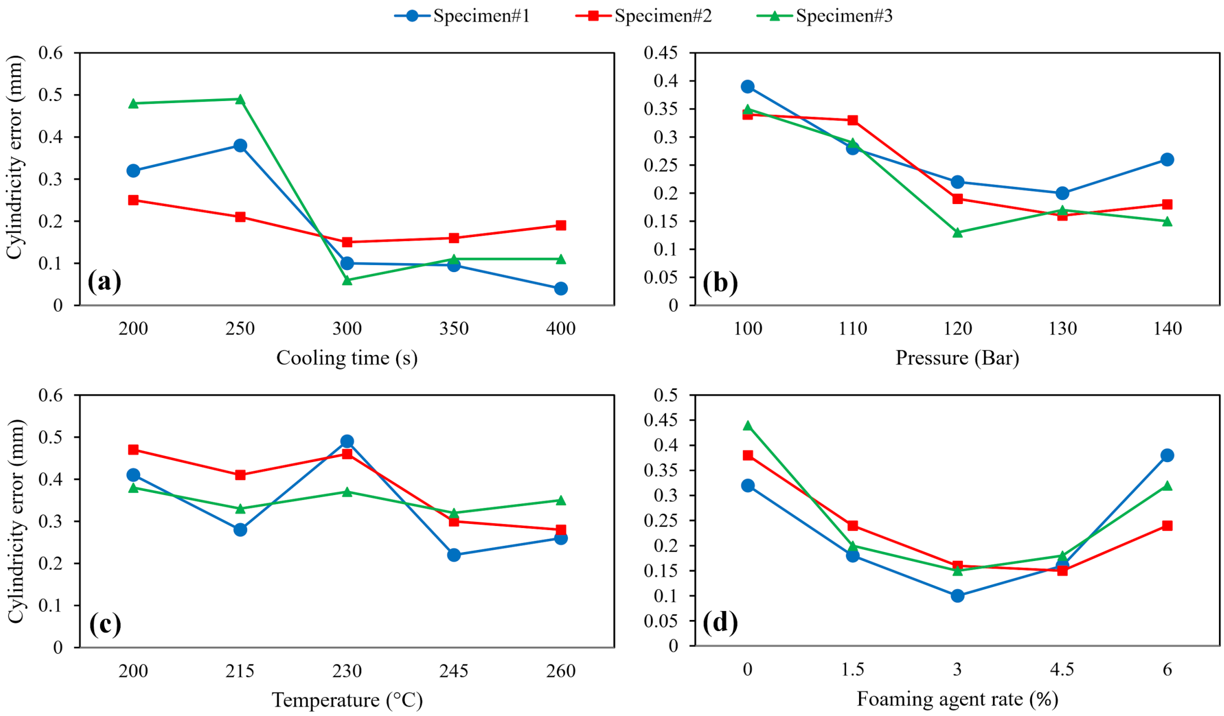

Fig. 6. The effects of various input parameters on cylindricity of specimens.

Figure 5e–h shows cross section photographs of product made by adding foaming agent in different places. Another measured output from rotatory roller parts are cylindricity error. The effects of all four input variables including cooling time, pressure, temperature and percentage of foaming agent added into raw material on cylindricity error of parts is presented in Fig. 6a–d, respectively.

Obtained data show that reduced cooling time and pressure contribute to decrease cylindricity error. Besides, lower temperature decreases the cylindricity error, but this relationship is not very predictable. The effect of foaming agent addition to the raw material on cylindricity error of parts depends on its rate. Adding 3% of the agent seems to be the reasonable contribution in respect of decreasing of this error. Overall, the reliance of plastic injection molding parameters, foaming agent contents and cylindricity error seems to be more or less similar to the influence on dimensional deviations.

4. Conclusion

This study presents the effects of injection molding parameters and foaming agent contents on dimensional accuracy of plastic injection molded parts. Our results show all selected injection molding parameters (cooling time, pressure, and temperature) affect diameter deviation of produced parts, while cylindricity error is mainly affected by cooling time, pressure and foaming agent. It is demonstrated that 3% foaming agent significantly improve dimensional accuracy of plastic injected mold parts. 300 second cooling time and 130 bar pressure ensures the best accuracy, when compared to other levels of these parameters.

References

[1] M. Kurt, Y. Kaynak, O.S. Kamber, B. Mutlu, B. Bakir, U. Koklu, *Int. J. Adv. Manuf. Tech.* **46**, 571 (2010).

[2] M. Kurt, O.S. Kamber, Y. Kaynak, G. Atakok, O. Girit, *Mater. Des.* **30**, 3217 (2009).

[3] Y. Shen, J. Liu, C. Chang, C. Chiu, *Int. J. Heat. Mass. Transf.* **29**, 97 (2002).

[4] J. Fischer, *Handbook of molded part shrinkage and warpage*, William Andrew, New York 2012.

[5] S. Mok, C. Kwong, W. Lau, *Adv. Polym. Tech.* **18**, 225 (1999).

[6] Z. Chen, L.S. Turng, *Adv. Polym. Tech.* **24**, 165 (2005).

[7] M. Mohan, M. Ansari, R.A. Shanks, *Polym. Plast. Technol. Eng.* **56**, 1 (2017).

[8] D. Annicchiarico, J.R. Alcock, *Mat. Manuf. Proc.* **29**, 662 (2014).

[9] B. Ozcelik, T. Erzurumlu, *Int. J. Heat. Mass. Transf.* **32**, 1085 (2005).

[10] X. Chen, Y. Lam, D. Li, *J. Mater. Process.* **101**, 275 (2000).

[11] C. Shen, L. Wang Q. Li, *J. Mater. Process.* **183**, 412 (2007).

[12] A.K. Bledzki, O. Faruk, *J. Appl. Polym. Sci.* **97**, 1090 (2005).