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Quality and geometry optimisation for products manufactured by means of blow moulding method

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In the article, features which characterize quality of products manufactured by means of blow moulding have been defined. Some measurements for weight, thickness and crystallisation degree in critical points of the bottle have been taken. After analysis of measurements optimal thickness of product which enables to fulfil all quality requirements and the geometric profiles of extrusion tube has been assessed.

1. INTRODUCTION

The plastic type, method, processing conditions and processing capacity of machine are the main elements to determine the product. All these factors influence directly or indirectly the final dimensions and product shape and all the processing, material and surface anomalies which are important from product user point of view [1,2,3].

The purpose of the investigations is evaluation of product manufactured by blow moulding method, basing on certain criterion and definition of optimal geometrical parameters of extrusion tube and finished product cross-section. Main criteria of quality evaluation are weight and wall thickness measurement and definition of crystallisation degree [4].

2. COURSE OF INVESTIGATION

For research purposes, 60 bottles have been made (shape shown in the Fig. 1) out of low density polyethylene (commercially known as “Malen E”) for six different thicknesses of extrusion tube: 2.6, 2.3, 1.9, 1.7, 1.5, 1.1 [mm], 10 pieces of each thickness.

Weight measurements for each manufactured bottle have been made by means of CP 225 Sortorius semi-microchemical balance with the weighing range 0-220g and with the accuracy of ±0.1 mg. After container weighing arithmetical mean has been evaluated for each series and then, on the basis of this evaluation, bottles with weight similar to counted mean have been taken for further investigations.

Product thickness measurements have been made by means of VIS electronic micrometric detector of Sylvac type with measurement range of 0-25mm for bottles with weight close to the average value.

In a view to define crystallisation degree out of the bottles in critical points of the bottle shown in the Fig. 3, samples used for definition of crystallisation degree have been cut off. The test has been accomplished by means of Differential Scanning Calorimetry (DSC, DSC 200 PC *Phox®* by Netzsch).

Fig. 1 View for a bottle received during blow moulding process.

3. ANALYSIS OF RESEARCH RESULTS

Extrusion tube wall thickness influences in direct proportion on weight of finished product (Fig. 2).

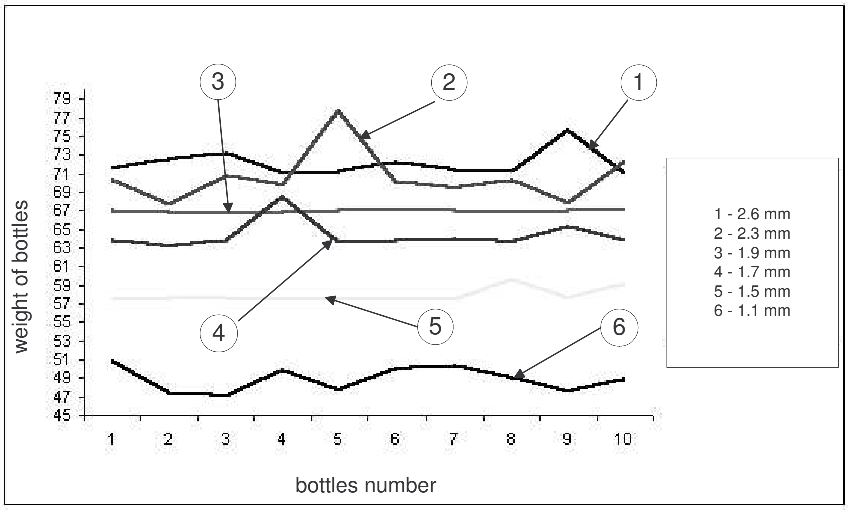

Fig. 2. Chart of wall thickness influence on a weight of manufactured bottles

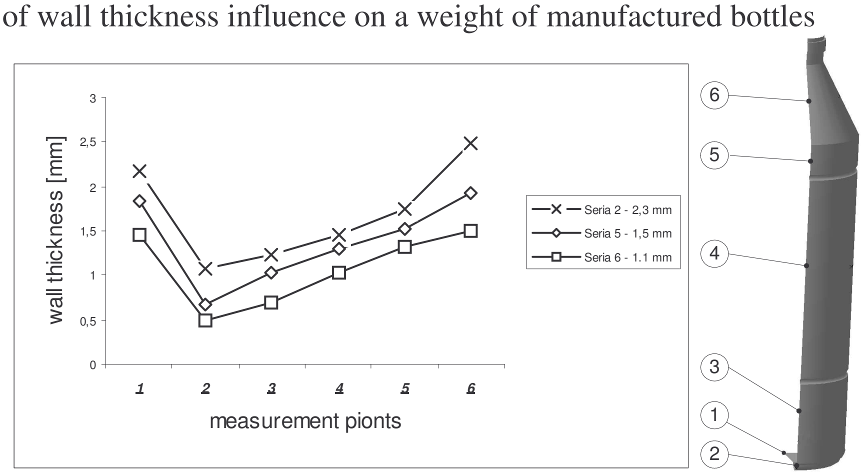

Fig. 3. Chart of wall thickness distribution at the edge A for the bottles of each series

In order to illustrate wall thickness distribution for bottles with different dimensions of extrusion tube, wall thickness in different measurement points has been presented (Fig. 3). After analysis of above mentioned dependencies one can assume that wall thickness profiles are similar to each other. Bottles for each series have the highest and the lowest thickness in the same points, differing only in wall thickness value.

Considerable decrease in wall thickness visible in point **2** of the chart (Fig. 3) is caused by the fact that this is the point where the most intensive stretching during blowing process appears.

Remarkable thing is that rise in wall thickness in the region of bottle-neck is, in this case, caused by increase of material amount, caused by blow mould clamping and necessity to lead compressed air through the mandrel situated in the bottle-neck.

Tab. 1 Comparison of crystallisation degree and wall thickness in each measurement points

Measurement point	Wall thickness	Crystallisation degree
Bottle No 6 out of 1st series (output hose diameter 2,6 mm)		
1	2.146 mm	46.3 %
2	0.625 mm	41.4 %
3	1.164 mm	42 %
4	1.466 mm	45.1 %
5	2.468 mm	52.9 %
Bottle No 10 out of 6th series (output hose diameter 1,1 mm)		
1	1.659 mm	47 %
2	0.52 mm	39.1 %
3	0.898 mm	44.9 %
4	1.197 mm	45 %
5	1.81 mm	48.5 %

According to Table 1 for the lowest wall thickness (2) crystallisation degree value is the lowest. However, in the point which characterize with the highest thickness (5) crystallisation degree is the highest. This situation is caused by the fact that thinner walls transfer heat faster as the result of transferring it to the mould walls, which is connected with shorter times of crystallisation. This is the reason why bottles with low wall thickness are characterized by lower concentration of crystalline phase and, what follows, lower crystallisation degree value.

Opposite phenomena could be observed in places where wall thickness is the highest. After the blowing stage only exterior surfaces are rapidly cooled while temperature in wall core drops much more slowly. It determines the formation of morphologies with highest values of crystallisation degree.

Taking economy of manufacturing process and crystallisation degree into consideration and analysing thickness of the finished goods and extrusion tube, optimal geometry of the wall profiles has been found; it should be 1.5mm. This value is an optimal one; increase in wall thickness does not result in sudden crystallisation degree increase but it only increases material consumption.

In order to receive the same and optimal product wall thickness in critical areas extrusion tube thickness must be different. Desirable thicknesses of extrusion tube in each region have been compared in Tab. 2.

Tab. 2. Optimal geometrical dimensions of extrusion tube

Measurement points	Extrusion tube diameter [mm]
1	1.1
2	2.3
3	2.3
4	2.3
5	1.1
6	1.1

4. CONCLUSIONS

The investigation enables to form the following conclusions:

- product thickness profile (Fig. 3) is characteristic for each blowing process and depends on constructional solutions for moulds applied;
- extrusion tube thickness does not change the thickness profile shape and only influences the product wall thickness value;
- product is the thinnest in points of the most intensive stretching i.e. in the corners of bottle bottom and the thickest in points of material surplus;
- analysis enabled to define optimal product thickness at the value of 1.5 mm which enables to obtain optimal mechanical properties; it has been proved by crystallisation degree measurements,
- in order to obtain products with suitable quality and equal wall thickness it seems to be justified to apply the device for automatic extrusion tube thickness regulation and, in points of the most intensive stretching to enlarge extrusion tube thickness according to Tab. 2.

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