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Design, Analysis and Manufacturing of Plastic Parts Made from Bio-Added Polymers

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Abstract: Bio-reinforced materials are plastic parts that can be produced by adding general-purpose polymers in certain proportions, where their important contributions to human and environmental health are stored. This study covers the design, analysis and manufacturing processes of food product insertion compartments of tea and coffee machines, which are kitchen products, by plastic injection method. For this purpose, first of all, the plastic parts and mold design of the food compartments in tea and coffee machines were made in CAD (Computer Aided Design) software. The most appropriate injection parameters were determined, trial and error. Based on the results obtained, a series of plastic products were performed in the mold using two bio-added polymers such as Polypropylene (PP) and Acrylonitrile butadiene styrene (ABS) to check the accuracy and quality of the injected products. Finally, after injection a metallic plastic mold of bio-added polymers, selected errors are determined in advance with the help of CAD/CAM/CAE programs and are applied to minimize cost, durability and time. Additionally, the manufacturability of kitchen utensils with bio-added polymers was tested using the plastic injection method.

Keywords: Bio-added polymers, Plastic injection, Design and analysis, Coffee and tea machines, Plastic products

Introduction

In today's mold industry, many plastic materials are widely used in industrial and household appliances. For these purposes, general purpose engineering polymers are preferred (Akyuz, 2006; Atasimsek, 2006). Plastic products are highly preferred due to advantages such as low cost, high dimensional accuracy, lightness, ease of production and mass production (Beamunt et al., 2002). Polypropylene (PP) polymer and Acrylonitrile butadiene styrene (ABS) are polymers with two different properties close to these mentioned properties (Kayalı, 2022). PP is a crystalline thermoplastic consisting of a mixture of different polypropylene monomers. It is known for its durability and hardness. It is a versatile material with various applications due to its unique properties such as high strength, excellent chemical resistance and good thermal stability (Seyhan, 2023). ABS polymer is a hard, rigid and tough material at low temperatures. Additionally, it has good tensile, impact, dimensional stability, rigidity and chemical resistance properties. Since ABS is an amorphous polymer, the dimensional accuracy of printed plastic products is quite high (Bitirgic, 2010).

The use of plastic products is especially important in designs developed for home appliances. Polymers such as Polypropylene (PP) polymer and Acrylonitrile butadiene styrene (ABS) are used extensively in kitchen utensils. (Campo, 2008). By reinforcing glass fibers with engineering polymers such as PP and ABS, higher strength

plastic products can be produced (Wyzgoski et al., 2004). In another study, authors stated that by reinforcing glass fiber to PP polymer material, they achieved an increase of at least 2-3 times in the mechanical properties of plastic parts (Fu et al., 2001). It can be stated that reinforcing glass fiber into harder materials such as concrete provides a significant increase in strength in concrete (Jan et al., 2022).

Important strategies are created for model design of plastic products, analysis of the model, mold design and manufacturing, and selection of injection parameters for injection of plastic product. In the design of a product to be injected in plastic injection, cold-hot runners, holes on the plastic part, ribs, wall thickness, slope and rounding of the part are important factors to be taken into consideration. All these factors are now realized with advanced computer-aided programs (Topcu, 2010). Before injection of plastic products, the polymer should be effectively planned and designed to enter the cold and hot runner while it is molten. If the flow length is short and the product volume is low, cold runners are preferred; if the flow length is long and the product volume is high, hot runners are generally preferred (Ozturk & Ozkan, 2015; Wang et al., 1996). Another group of researchers examined the effects of injection parameters on injected plastic products using the same type of polymer materials. It can be concluded that parameters such as temperature, pressure and injection speed are effective on both the strength and geometric change of the parts (Farotti &Natalini, 2017), (Oktem &Erzincanlı, 2012). In this study, Gonullleroglu (2015), examined the distortion analysis, experimental and theoretical results of the plastic product (refrigerator door profile part) after injection. The researcher tried to eliminate the defects of the plastic product by improving the design parameters based on flow analysis.

Plastic products used in household appliances are expected to have superior properties in terms of strength and will not have a negative impact on human health and the environment. In order to minimize these negative effects, it is necessary to develop plastic products with higher strength and better cosmetic appearance. For this reason, some researchers have examined the effect of process parameters during hot runner injection of plastic products such as garbage containers and bottles by adding bio-additives to Polyethylene Terephthalate (PET) polymer. They examined the effects of injection temperature, mold temperature, packing pressure and cooling time on volumetric shrinkage (Srikhumsuk et al., 2024).

This study focuses on examining the necessary design, manufacturing, analysis and dimensional accuracy control stages during the production of kitchen appliances using the plastic injection method. For this purpose, the product design and mold design of the coffee machine spoon and tea machine body handle cover model were made. Then, molds were manufactured and the plastic products of the models were injected on an injection machine. During injection, the dimensional accuracy of the plastic products was checked by a 3D optical scanner by making several attempts at three different temperature, pressure and injection speed parameters.

Materials and Method

In this study, coffee powder for the coffee spoon and tea fiber for the tea machine body handle cover were added to PP and ABS polymer materials as bio-additives. Coffee spoon and tea machine body handle cover samples from PP and ABS polymers were injected by injection molding method with three different injection parameters. Experiments have been carried out by adding certain proportions of glass fiber and bio-added materials to PP and ABS polymer materials.

Design and Manufacturing

The plastic product design of the coffee spoon and tea machine body handle cover was carried out in NX Siemens CAD program. The mold design required for printing both plastic products was made in the same program. Then, the designed molds were manufactured on the CNC machine. Using the manufactured molds, plastic products were injected on an injection machine. Figure 1 shows the coffee spoon used in the coffee machine. Figure 2 shows the design of the tea machine body handle cover. Figure 3 shows the female mold half required to inject the plastic product of the coffee spoon. Four coffee spoons can be pressed at a time in the mold half. In similar way, four tea machine body handle cover can be injected.

Figure 1. The design of coffee spoon model

Figure 2. The design of tea machine body handle cover model

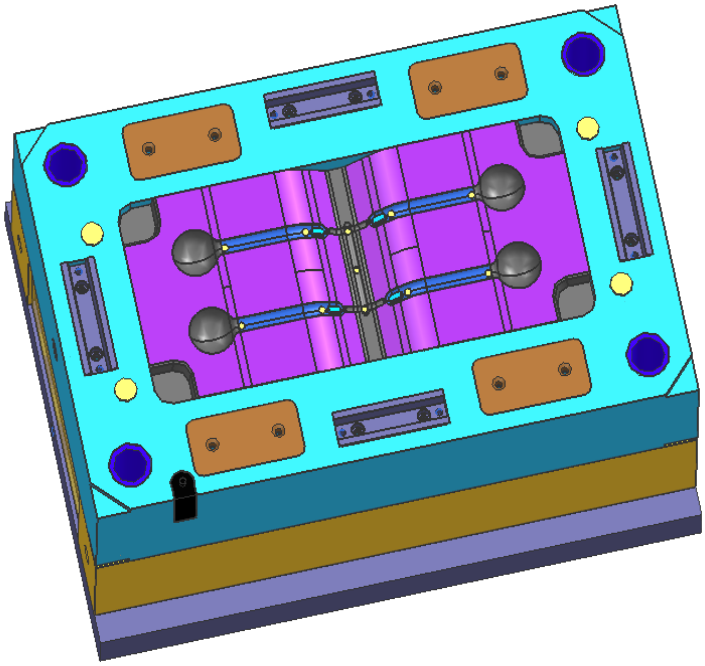

Figure 3. The design of coffee spoon model

Controlling of Dimensional Errors of Plastic Products

Figure 4. The check of dimensional accuracy of plastic products with 3D optical scanner

Figure 5. The injected of coffee spoon

A 3D optical scanning system was to check the dimensional accuracy of plastic products (coffee spoon and tea machine body handle cover) injected by combining glass fiber and bio-additives reinforced with PP and ABS polymers. Figure 4 shows the measurement process with the VYLO Rapotor3DX brand FOV 300 model three-dimensional scanning device. Figure 5 shows the plastic product model of the measured coffee spoon model.

Results and Discussion

In this section, CAD data and dimensional errors of the actual dimensions of the plastic products of the bio-added coffee spoon and tea machine handle cover made of PP and ABS polymers were determined. Figure 6 and 7, dimensional errros of coffee spoon and tea machine body handle cover. From Figure 6 is examined, it is seen that there is a maximum deviation of -1.88 mm at the bottom end of the handle of the coffee spoon and -0.22 mm at the top. From Figure 7, it is seen that there is a deviation of +0.15 mm near the bottom end of the tea machine body handle cover and -1.68 mm to the right edge of the bottom end.

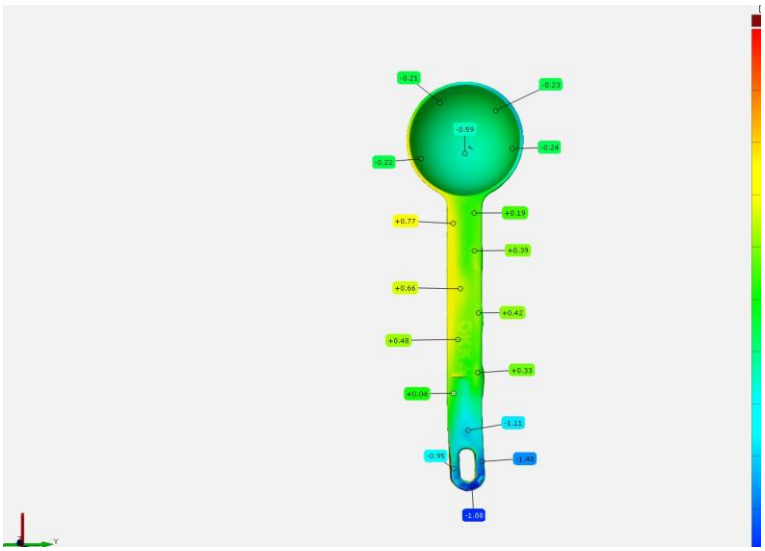

Figure 6. The control of coffee spoon

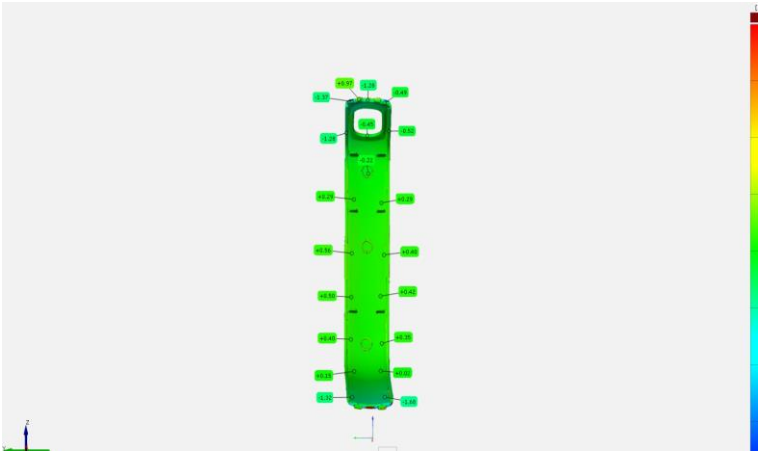

Figure 7. The control of tea machine body handle cover

Conclusions

In this study, glass fiber reinforced plastic products were produced by injection method by adding bio-added materials to PP and ABS polymers. A 3D optical scanner was used to check the dimensional accuracy of plastic products. Reverse engineering was performed by finding the difference between the CAD model of plastic products and the real model. It was observed that the measured error results were within tolerance values. As a result of this study, the negative effects on human health were tried to be eliminated by adding coffee powder and tea fiber to polymers such as PP and ABS. In addition, glass fiber reinforcement prevents the decrease in strength in plastic products that require weight under the influence of heat.

Recommendations

In future trends, plastic products will conduct mold flow analysis, mechanical properties and optical measurement.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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