Analysis of The Manufacturing Process Using Polyproplene by Plastic Injection Molding Method

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Abstract

Polypropylene is the most widely used type of polymer material. It is widely used in many areas from food to textile. Plastic injection molding is one of the most common methods used in the production of plastic parts. Many products in different sizes and shapes can be produced with plastic injection molding. In our study, carved furniture was produced from polypropylene raw material by plastic injection method and the parameters suitable for production were specified. Factors such as pressure, temperature, time, and speed are factors that directly affect the production and end product quality. For this reason, it is very important that the parameters are optimized well. The total cycle time of the production is determined as 40 seconds, and the final product is a product with 170 grams and 0.9 mm wall thickness. At the end of the study, the cost expenses of the sample firm were specified.

Keywords: Plastic injection, Injection molding, Polypropylene, Plastic injection machine.

Plastik Enjeksiyon Kalıplama Yöntemi ile Poliproplen Kullanarak Üretim Sürecinin Analizi

Öz

Polipropilen en yaygın kullanılan polimer malzeme türüdür. Gıdadan tekstile bir çok alanda kullanımı oldukça yaygındır. Plastik enjeksiyon ile kalıplama yöntemi, plastik parçaların üretiminde kullanılan en yaygın yöntemlerden bir tanesidir. Plastik enjeksiyon kalıplama ile farklı ebatlarda ve şekillerde bir çok ürün üretilebilmektedir. Çalışmamızda, plastik enjeksiyon yöntemi ile polipropilen hammaddeden, oymalı mobilya üretimi yapılmış ve üretime uygun parametreler belirtilmiştir. Basınç, sıcaklık, zaman ve hız gibi faktörler üretimi ve son ürün kalitesini doğrudan etkileyen faktörlerdir. Bu sebeple, parametrelerin optimizesinin iyi olması oldukça önemlidir. Üretimin toplam döngü süresi 40 saniye olarak belirlenmiş olup, son ürün 170 gr ve 0.9 mm et kalınlığına sahip bir üründür. Çalışma sonucunda, örnek firmaya ait maliyet giderleri belirtilmiştir.

Anahtar Kelimeler: Plastik enjeksiyon, Enjeskiyon kalıplama, Propilen, Plastik enjeksiyon tezgahı.

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1. Introduction

Plastics are materials used in a wide variety of fields due to their lightweight, durable and easy formability. In addition to their low cost, they can be transformed into many valuable parts, which makes plastics unique. It is also called polymer and plastics consisting of different polymer chains exist in almost every part of our daily life in different forms and structures.

Plastics are among the most preferred materials with many advantages they offer to users. One of the qualifications sought in today's technology is to obtain high quality products at low cost. For this reason, one of the production methods of plastic parts obtained by different methods is plastic injection. In the literature, there are many studies to increase productivity (Oktaç et al., 2021) (Timur and Kılıç, 2021). There are parameters that affect efficiency improvement. The most important issue to increase productivity in injection molding; The time spent in mold changes is that the subsequent stages of production will be planned well. In the context of plastic injection systems, it is possible to handle lot-size and scheduling problems with some techniques and to design a mathematical formulation. These formulas, which were produced in the experimental stage, can provide optimal and applicable solutions by considering them commercially. Cervantes et al., found better and comparable solutions with a two-step sequential approach. In the approach they suggested, they aimed to improve the quality and calculation time (Cervantes et al., 2020). Aslaner et al., have done research that will help future studies for machine scheduling problems to be created by establishing a mathematical modeling in their work. In this study, they consider machine constraints, transaction sequences and processing times and deadlines in multi-order situations (Aslaner et al., 2021). In another study, a new approach is presented to train a machine learning-based model, and includes simulation data to minimize the amount of physical experiments. For this purpose, melt temperature, flow rate, packaging pressure and mold temperature and all these data of an injection molding process; It is intended to correlate with the weight and thickness of the product. The deviations in the thickness of the desired sample and the average thickness of the produced part are minimized by this simulation (Finkeldey et al., 2020). Maulidina et al., aimed to determine the optimum maintenance time interval for critical components and the total maintenance cost of the injection molding machine. A more appropriate figure has been obtained and this study may lead to more optimal maintenance and cost calculations in the future. In one study, it was predicted that the corrosion caused by the water hardness used in the cooling channels slows down the cooling in the channels, and a study has been done to improve this. The recommendation given in this study is to change the water hardness. In this way, it extends the life of the plastic injection mold, the timing factor that causes rusting is removed (Maulidina et al., 2019).

In the literature, some comparisons have been made using the rapid cooling system technology that will work integrated with the conventional refrigerated plastic injection process. According to the results of the study, more successful results were obtained with the rapid cooling process compared to conventional cooling, both visually and in terms of brightness of the product. For this reason, it is aimed to reduce the cost of painting and to complete the production without the need for a second process (Özgüven, 2020).

There are processes in plastic injection production method such as receiving raw materials, heating and melting, injection into the mold with pressure, cooling and removing parts, surface smoothing and cutting waste. As in all production planning, productivity is very important in production with plastic injection method (Kılıç and Timur, 2021). Due to reasons such as high product variety, rapidly changing customer demands, appropriate production plans and experimental designs are tried to be created. In one study, some research was done into a real problem happening in a plastic injection factory. With the literature reviews, the planning of the manufacturing companies has been examined and it is aimed to increase the efficiency with these comparisons (Erkut, 2019). In one study, they investigated the effects of cooling water on polypropylene material produced by changing the flow rate. During this examination, all parameters were kept constant and only the flow rate of the water was the variable. As a result of the study, the melt in the mold cooled faster with the increase in flow rate (Kızılöz, 2019).

With the developing plastic production, the plastic injection method has been used more widely in mass production. Fuzzy logic method has been used in order to save material, reduce cycle time and increase mold life. Experimental and theoretical knowledge base has been created with information such as injection parameters and manufacturing rules. With this database, the optimization of the parameters is provided by using the fuzzy logic method (Tunçer, 2019).

2. Material and Method

The study was carried out under the headings such as raw material, production, mold and machine properties, consumption.

2.1. Plastic Raw Material-Polyropylene

Polypropylene material has been used as a raw material with its low fragility, resistant to heat and chemical acids, high strength, and its cost-effectiveness among plastic types.

Fig. 1 Polypropylene raw material

Each supplier company has technical characteristics of its raw materials. Technical characteristics of our raw material Table 1 also shown.

Table 1. Properties of polypropylene

Properties	Polypropylene
Density (g/cm³)	110
Melting temperature (°C)	223
Transition to glassy temperature (°C)	197
Thermal conductivity (10⁻⁴ cal/s.cm.°C)	134
Specific heat (Cal/g°C)	202
Thermal transmittance (10⁻⁴ cal/s.cm.°C)	24

2.2. Production

Firstly, polypropylene melt temperatures are entered. After adjusting the injection temperatures, the screw material distance is adjusted. This varies according to the weight of each piece. The amount of melt covered by that distance is transferred to the mold. Then the speed settings of the injection are entered. Entering the injection speed settings gradually will give better results as it is adjusted according to the melt temperature of the product.
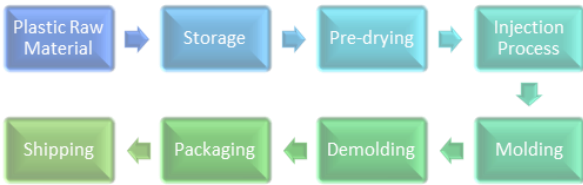

Fig. 2 Production flow chart

Optimum injection temperatures and pressures and times were entered as shown below in Table 2 and Table 3.

Table 2. Injection settings

Parameters	Value				
Zone	5	4	3	2	1
Pressure (bar)	60	65	70	75	80
Speed (%)	30	30	30	30	30

Table 3. Holding settings

| Parameters	Value		
Zone	3	2	1
Pressure (bar)	60	60	60
Speed (%)	65	65	65
Time (second)	1	1	1

2.3. Injection Mold and Injection Machine

The mold design shown and the features of the finished part are shown in the Table 3. Features have the desired product characteristics.

Fig. 3 Mold design for carved furniture leg

Table 4. Properties of final product

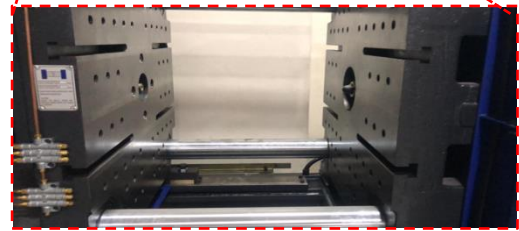| Properties	Value
Length (cm)	14
Height (cm)	12
Wall thickness (cm)	0.9

a)
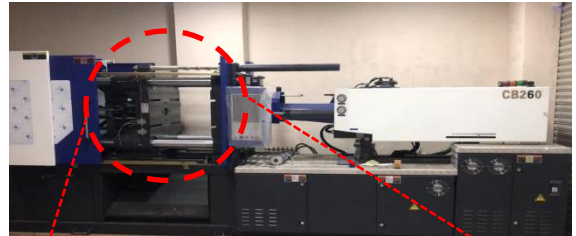
b)

Fig. 4 a) Plastic injection machine, b) Mold unit

The technical specifications of the HAITAN-CB260 branded plastic injection molding machine purchased from Fakiroğlu plastic.

2.4. Chiller Cooling System

In the system, we reduce the cooling water from 35°C to 17°C to cool the molds. The mold will perspire below 17°C. The cooling water chiller enters the system at 35°C and comes to the mold at 17°C. A cooling system with two compressors was used while performing the cooling process.

Fig. 5 Cooling system with two-compressor

In the system, mass flow rate of water is 250 kg in hour (kg/h) and specific heat of the water is 1 cal/g°C. T_{end}=17 °C, T_{first}=35 °C and using specific heat capacity formula;
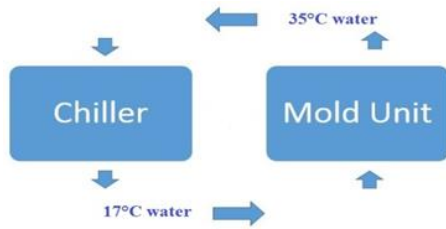

Fig. 6 Systematic of the cooling system

2.5. Electricity Consumption

Energy consumption classes and monthly energy consumption costs in the production process are summarized in Table 5.

Table 5. Cost estimation of electricity for monthly

Parameters	Plastic Crushing Machine	Plastic Injection Machine	Chiller System
Piece	1	1	1
Power (kW)	15	31.3	50
Daily Operating (hour)	8	12	12
Monthly Operating (hour)	8*26	12*26	12*26
Consumption (₺/kWh)	0.48	0.48	0.48
Cost (₺)	1.497,60	4.687,49	7.488,20
Total Cost (₺)	13.673,09		

2.6. Factory Plan

Production-related activities such as transportation, storage, quality control must be coordinated as a whole in terms of their physical location. The main purpose of the factory arrangement is to minimize the amount of movement of living and non-living things. A poorly placed factory layout causes energy loss, chaos, delay, control and management difficulties. In addition, it is a factor that directly affects costs. The factory planning of the enterprise is shown in the Fig. 7.
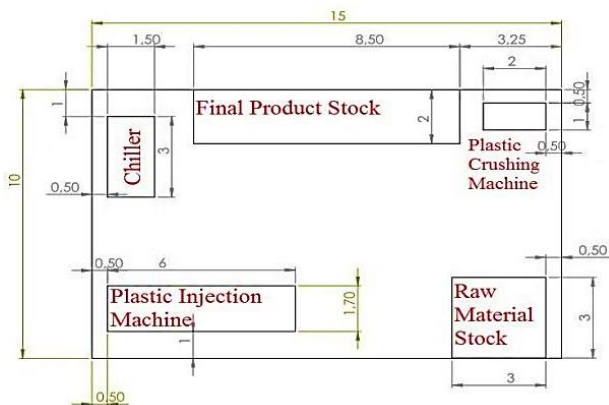

Fig. 7 Planning of factory (lengths are specified in meters)

3. Results and Discussion

Cost is all of the costs incurred, directly or indirectly, to make and sell a product or a service. Cost analysis is used to make these calculations. One of the most important points in plastic injection production is cost. There are many factors affecting the cost. In plastic injection design and production, there are 6 main topics and these are raw material cost, mold design and production cost, production cost, marketing cost, employee costs and factory fixed costs. The main factors that make up the production cost are raw material cost, mold cost, injection machine cost, operational costs. The main factors that make up the cost of raw materials are costs such as transportation and storage. Factors such as machine maintenance and repair costs and machine depreciation constitute machine costs. Energy consumption, maintenance and repair, calibration, packaging and transportation costs are the factors that create operational costs. Personnel expenses are composed of factors such as premium, employee wages, service and catering services. After all, extra expenses are incurred for the promotion and marketing of the product. Costs such as market research, magazine and brochure printing, website design, advertising and fairs also occur. The Table 6 indicates the costs of the factory.

Table 6. Cost estimation

Cost types	Price (monthly)
Raw Material and Machine Expenses	
Product and mold design	70.000 ₺
Raw material	45.000 ₺
Transportation	5.000 ₺
Injection machine	280.000 ₺
Machine maintenance and repair	1.250 ₺
Mold maintenance and repair	625 ₺
Electricity consumption	13.673 ₺
Packaging	10.000 ₺
Personal Expenses	
Bonus	1.200 ₺
Service	1.000 ₺
Meal	2.000 ₺
Working	12.000 ₺
Other Expenses	
Website design	500 ₺
Advertising	500 ₺
Fair	5.000 ₺
Magazine and brochure printing	1.000 ₺
Total	448.748 ₺

4. Conclusions

The main purpose of our study is to obtain a quality product with suitable parameters, as well as to eliminate the factors that will increase the cost by optimizing the parameters. When it comes to production, minimum cost - maximum quality is always more advantageous. Plastic injection machine settings were determined as optimum values and shown in the study. The wall thickness is in the appropriate range recommended for polypropylene material and this value is 0.9 mm. For carved

furniture legs; the product was measured as 12 cm in height and 14 cm in length. The strength and solidification of the product were better when sufficient cooling was achieved in the mold. Water arriving at 35 °C is sent to the mold at 17 °C in the chiller cooling group. At values below 17 °C, sweating occurs in the mold and products with defects on the surface are formed. The total cost has been determined as approximately 13.673 ₺. Monthly expenses are specified in Table 5. This study will be helpful in future studies in determining the average expenses of these studies and determining the appropriate parameters for the product in the studies that will make production with the plastic injection molding method.

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