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REDESIGNING OF CLAMP LOCK MECHANISM FOR A STRETCH BLOW MOLDING MACHINE

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ABSTRACT

Stretch blow molding process is the main method for the mass production of PET containers. In the stretch blow molding process, the motion of the mold is provided by the machine's clamp. Since the speed control of the pistons of clamp is difficult and its precision is poor, it can not be get the product quickly during the production stage. In this study, the top plate of the clamp is designed to fit the servo motor to provide the motion of the clamp. Then solid model analysis was performed and manufacturing of top plate was accomplished. The clamp plate was placed and the servo motor was mounted on the clamp. After the servo shaft had been assembled to the system, the roll bearing and the cam were assembled to the system for the motion of the base of the mold. Finally, the sensors were assembled to indicate the opening and closing points of the clamp. After this constructive change, while the production rate of the double-mold was 900 bottles per hour at the beginning, it was observed that 1042 bottles were produced by an increase of 15.8%. The problem of obstruction was solved, moreover, the air and electricity was saved.

INTRODUCTION

The idea of reheating a thermoplastic material and then stretching it to enhance its properties was first employed in extruded sheet in the 1930s [1]. The blow molding process is a molding process in which air pressure is used to inflate soft plastic into a mold cavity. There are several different types of blow molding such as, injection blow molding, extrusion blow molding and stretch blow molding (SBM). In the blow molding process, the material typically experiences a high speed, large strain biaxial deformation [2]. As far as bottles are concerned and beside specific properties required for the liquid that will fill the bottle, the transformer has to guaranty the transparency, the lightness, the thickness distribution and the mechanical performances of the container. Polyethylene terephthalate (PET) bottle is one of the most appropriate materials for this application [3]. Among the techniques devoted to the manufacture of PET bottles, such as injection stretch blow molding, the two stage stretch blow molding (SBM) process is probably the most popular. In a first step a preform is injection molded. After the first operation the preforms are fed into the blow molding machine and then heated in an infrared oven above the glass transition temperature (~80^{0}C), followed by being simultaneously longitudinally stretched with a cylindrical rod and blown-up with high pressure air inside to create bottles of desired shapes. The last stage is solidification [4].

In Fig. 1, a schematic diagram of main three stages of stretch blow molding which is highly suitable for low volumes and short runs is represented.

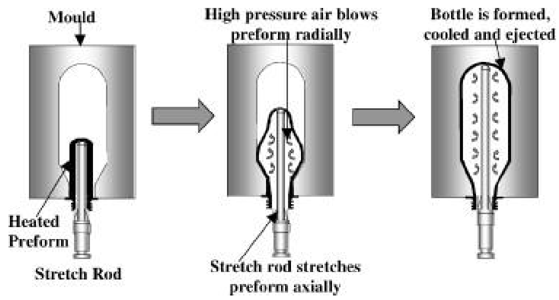

Fig. 1. Stretch blow molding of PET bottles [5]

For SBM, a common approach is to perform biaxial stretching experiments [6]. Relatively few papers have been dedicated to stretch blow molding. A number of them have been concerned by structure development. Some researchers were developed prototype stretch blow machine [7] but the information given by such devices was insufficient for some reasons. Both experimental study and numerical modelling have been employed to optimize the preform design and process parameters. Adams et al [8] found to be able to produce accurate simulations in terms of both free-blowing deformation and bottle thickness distribution. Yan et al [2] aimed to develop a new material characterization method providing new data for the deformation behavior of PET relevant to the SBM process. Ajawa and Pavel [9] were investigated blending of reactive extruded recycled (RER-PET) with virgin PET in order to

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find optimum composition for producing bottles using injection stretch blow molding process. Deloye et al [3] studied the influence of molecular architecture of PET on its ability to be processed by stretch blow molding. In another study Deloye et al [10] aimed to explain the tight correlation between the chemical structure and the behavior of the polymer. For this purpose, well controlled PET resins were characterized both from the point of view of their intrinsic properties and from the point of view of their process abilities.

Numerical optimization methods for SBM have received more and more attention in the last two decades. Researchers attempted to optimize all the elements within the stretch blow molding process to reduce the cost. Attar et al [11] attempted time reduction and part quality improvement for manufacturing in blow molding. Lee and Soh [12] presented a FE method to determine the optimal thickness profile of a preform, given the required wall thickness distribution for the blow molded part. Thibault et al [13] proposed an automatic optimization of the preform geometry (initial shape and thickness) and operating conditions. Bordival et al [14] presented a numerical modeling of the full SBM process. Bagherzadeh et al [15] studied the numerical modeling of the stretch low molding of PET bottles and compared the numerical results with the experiments by means of the thickness distribution.

DESCRIPTION OF THE PROBLEM

In this study, a new design of the closure mechanism of molds of 2-liter bottles of liquid oil was carried out. Preforms that produced in the injection molding machine is transferred into the receptacle of the stretch blow molding machine. The preforms, queued with the help of a belt, are placed on the conveyors. Thanks to the conveyors, the preforms, both going forward and turning around in circular motion (for homogeneous heating), move through the furnace and heat up. Once hot, the preforms, after coming out of the oven, go into the blowing mold. Entering into of blowing mold, preforms take the bottle form with the help of the 36 to 40 bar air pressure and also stretching rod. Mold is mounted to the machine's clamp and opens and closes as the clamp moves. The movement of the clamp in the present machine is provided by pistons. The mold, consisting of three pieces, is shown in Fig. 2. After the preform goes into the mold on the conveyor, the mold cavities move by clamp movement. Simultaneously the mold base descends down by piston movement. The two mold cavities approach to mold base and the mold closes.

Fig. 2. A sample multi cavity mold type used in the experiments

While the process continues, some difficulties occur related to the pistons which provide clamp movement. we can sort them as follows:

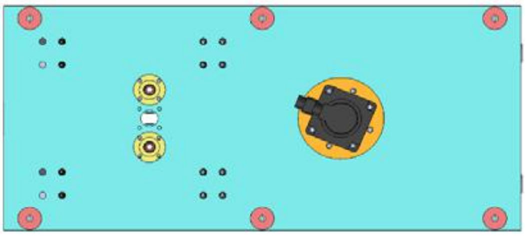
- Because it is difficult to control the speed of the pistons, in the production stage fast enough production is not possible. maximum 900 bottles per hour can be produced.
- The number of defective products when the air pressure is not balanced in the system is high.
- Blockages occur in the pneumatic sleeves of the pistons.
- Constructive difficulties are experienced when assembling the mold.
- Due to the noise of the pistons, a quality working environment is not provided.

DESIGN, SOLID MODELLING, MANUFACTURING AND ASSEMBLY

The top plate of the clamp driven by pistons in its current form is presented in Fig. 3. Servo motor is planned to replace pistons which provide clamp movement. The servo motor which will be selected should be able to hold the weight of the differential spider and perform this movement faster than the pistons. The movement of the clamp will be provided by a servo shaft going through the differential spider. Also designing a rail system that will facilitate the movement of the clamp is planned. Instead of the piston which provides the movement of the mold base, a system of roll bearings and cams will be installed. Finally installing the sensors to follow the movement of the servo motor is planned. As a matter of priority, after the pistons are removed, instead of the upper part of the clamp, a plate was modelled upon which the servo motor can be installed. As there is no heavy load on the upper plate, a plate which is the same size and width as the original one was planned. The place on the plate where the servo motor is to be installed has been determined and after modelling, it was manufactured. Solid modelling of the plate and its manufactured condition are shown in Fig.4.a and Fig.4.b respectively.

Fig. 3. Initial mechanism of the top plate of the clamp driven by pistons

In the next step, the pistons and the upper plate in the machine had been removed. After the differential spider was removed, screw shaft of the servo motor which shown in the Fig. 5 was assembled to the system. A roll bearing was put in place on the bottom plate for the assembling of the servo motor's screw shaft. Then the differential spider was mounted in its place. This shaft will transfer the motor's movement to the differential spider and provide the up and down movement of the differential spider. With this movement, the mold will open and close. To make sure that no unnecessary load is placed on the servo motor and it moves freely, a rail system was assembled to the clamp.



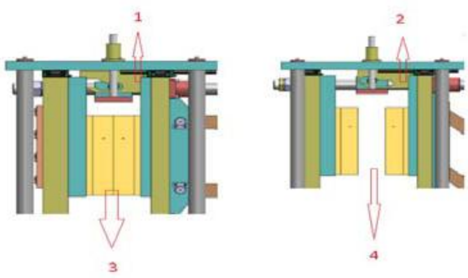
a) Solid model;

b) Manufactured plate

Fig. 4. New form of the top plate of the clamp

Fig. 5. Servo motor screw shaft

A cam and roll bearing system, whose movement is depicted in the Fig. 6.a and whose picture is shown in the Fig. 6.b, is also assembled on the clamp. This system is moving up and down the base of the mold. When the mold closes, the roller goes down with this motion and when the mold opens it goes up.



a)

(1) Cam roller mechanism in closed position, (2) Cam roller mechanism in open position, (3) Mold in the closed position, (4) Mold in the open position

b)

Fig.6. a) Schematic representation of the cam and roll bearing system which moves the base of the mold upside down
b) Picture of the cam and roll bearing system

After the cam and roll bearing system has been added, the top plate has been mounted. After the servo shaft and servo motor were assembled, actuator sensors were added to the starting and ending points of the motor's movement. These sensors, blocking the extra movement of the servo motor, in a sense protect the machine. After that, according to the planned changes, the solid modelling of the clamp was drawn and shown in Fig.7. In the figure it is also explained that the working principles of the new system.

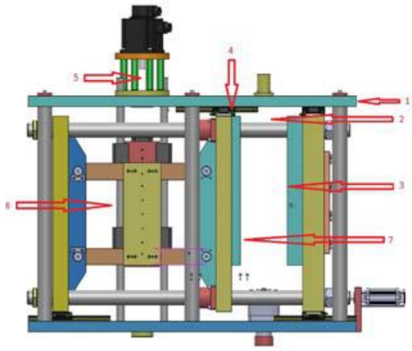
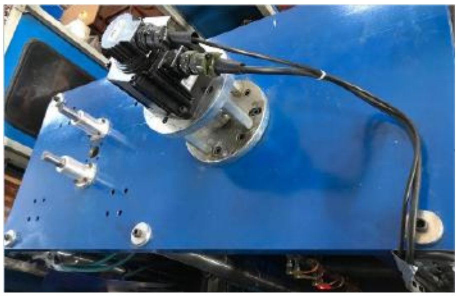
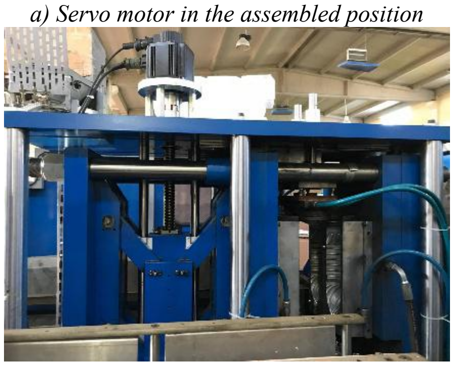


Fig. 7. Schematic representation of the working principles of the clamp mechanism after the new design
(1) The upper plate produced in accordance with the servo motor, (2) The cam and roll bearing system which moves the base of the mold upside-down, (3) The stable mold part, (4) The guides which move on the rails and facilitate the movement of the clamp, (5) The area where the servo shaft is installed, (6) The mechanism which opens and closes the mold as the servo shaft moves the differential spider, (7) The plate where the moving part of the mold will be assembled

The servo motor assembled on the upper plate is shown in the Fig. 8.a and the complete system is shown in the Fig. 8.b. as a picture.



a) Servo motor in the assembled position



b) Clamp system (Open position)

Fig.8. Picture of the new system

RESULTS AND DISCUSSION

The bottle production times, as a comparison between the system with pistons and the system with the newly-designed servo motor are shown in Table 1.

Including the time necessary to move the preforms to the mold, the elapsed time between two production step for the piston system is 8 seconds. Therefore, the molds open and close 450 times in an hour and 900 bottles are produced in a two cavities mold. In the present study, the servo motor used is of 3000 r.p.m. capacity.

Table 1. Initial and next production time results

	Piston (sec)	Servo motor (sec)
Opening time	0.8	0.18
Feed and blowing time	6.4	6.4
Closing time	0.8	0.18

Depending on the shaft pitch, the shut-off operation takes theoretically 0.18 seconds. So, theoretically, the process will be completed in 6.76 seconds and the mold will close and open 532 times per hour. Saving time in this manner, 18% increase in the number of bottles produced per hour is predicted. However, as the clamp's closing movement cannot be completed before the servo motor reaches its full rotation, the total time elapsed is 6.9 seconds and 1042 bottles per hour were produced. Thus, 15.77% increase in the number of bottles produced was obtained.

Another advantage of servo motor adopted in the system is that as the clamp movement is completely fixed, the produced bottles can be blown with higher quality and without error. As the original closing system was totally dismantled, the blockage problem of the sleeves is eliminated.

On the other hand, the production rate can be speeded up even more. But higher production rates require better pre-heating of the preforms. Also, air valves should be replaced with stronger ones.

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