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PRODUCTIVITY IMPROVEMENT OF PET BOTTLES MANUFACTURING UNIT

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Abstract - *This project comprises of a case study of a pneumatic PET bottle manufacturing machine, which studies to determine the main factors affecting the machine's production rate, and study their influence to improve the production rate to reach the optimum. The purpose of this study is to investigate different aspects, including the speed of the running machine, the pressure applied to fill the bottle, and the machines utilization. Data is collected for current machine, which is set up at AR PET and POLYMER Company, and then solutions for each aspect will be implemented. It is found that above mentioned factors has significant effect on improving the production rate. Machines should be utilized effectively and run at the optimum speed, to improve the productivity and avoid extra maintenance cost. Moreover, effort to convert manually operated pneumatic machine into automatically operating pneumatic PET bottle manufacturing machine is being studied*

***Key Words*: PET bottle manufacturing machine working, alternatives for current operation.**

1. INTRODUCTION

PET (Polyethylene terephthalate) belongs to one of the largest and most diverse of the polymer families. Polyethylene terephthalate (PET), from which most single-use bottles (and some other containers) are made, has a high strength-to-weight ratio, which makes it a good choice for beverage containers because they can hold a lot yet are light. PET resin consumption exceeds 500,000 tons in the past years and may exceed 600,000 tons in the coming years. Growth prospects of PET plastic recycling are enormous. PET bottles are popular with consumers and retailers because they provide a convenient, highly functional, lightweight, strong, cheap and hygienic way to contain beverages. As the demand of PET bottles is increasing, the rate of production also needs to be increased. Now-a-days PET bottles are used for many commercial as well as household purposes. They can be used for storage purpose, transport purpose, etc. Manufacturing of these PET bottles are done by various molding methods. Some of the methods are listed below:

1. Extrusion blow molding

2. Continuous extrusion molding

3. Injection blow molding

4. Stretch blow molding

5. Intermittent extrusion molding

Stretch blow molding is the most common method used for manufacturing of PET bottles. For Stretch Blow Molding, the polymer is first heated above the glass transition temperature (75 degree Celsius to 130 degree Celsius). Then polymer is inflated at a particular pressure and stretched with a hollow core-rod. This process resembles that of rubber balloon inflation. As the sir starts filling in the perform, it inflates and the hollow core-rod helps the perform to elongate inspecific direction. Following are some of the advantages of stretch blow molding process: 1. Large production. 2. Highly accuratethickness. 3. Small thickness walls can be easilydone. Due to various advantages of stretch blow molding and easy operation with low cost, this process is also being used in the manufacturing unit that is being studied. As demand in productivity and Packaging process is increasing, automation techniques are used in a wide range. Similarly, in this project the system used for manufacturing is an automatic pneumatic conveyor machine. But various other operations are done manually. So alternatives and attempts for making the entire system free from labor dependencies being studied.

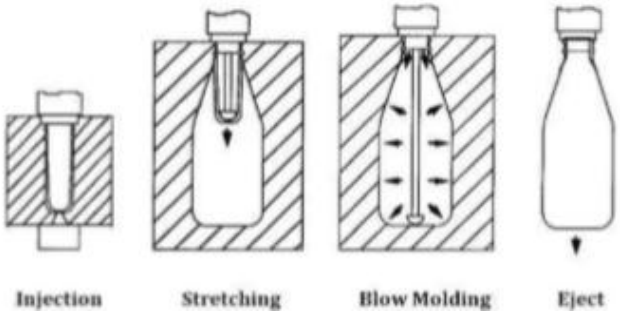

Figure 1: Stretch blow molding process

The transmission of perform is done with the help of conveyor system. Some of the important reasons for use of automatic conveyor systems are as follows:

1. Conveyance of container from one station to other at variable speed.

2. Accurate positioning of container at given station

3. Automatic filling.

4. Synchronous conveyance and filler operation.

Various transmission methods can be used such as belt transmission, chain transmission and, gear transmission.

In this project, we are dealing with the production problems that are occurring at THE AR PET AND POLYMER COMPANY. The AR PET and POLYMER Company make use of pneumatic PET bottle manufacturing machine. Originally, the entire machine is manually operated. That means, lifting the heated perform from the heater and placing the preform in the die mouldis done manually. The error occurring is that, due to some mechanical error, after every 10th bottle next bottle is faulty. This is affecting the rate of production. Moreover, due to delay in placing the preform in the die, there is delay in time with is affecting the production and quality of product. To reduce this error which is caused by manually placing the preform, research and development is being done to transform the manually operated pneumatic manufacturing machine into an automatic pneumatic manufacturing machine.

2. PROBLEM STATEMENT

1. Improve the productivity rate by implementing automation technique.

2. Reducing the defects occurring in manufacturing, thereby, reducing the cost occurring due to the defects.

3. METHOD APPROACH

Various alternatives for making the system semi automatic or fully automatic is being done. With the use of various software like FEM, Catia V5, etc the design analysis of perform as well as other parts is beingstudied.

3.1. Model

3.1.1. Configuration of PET bottle

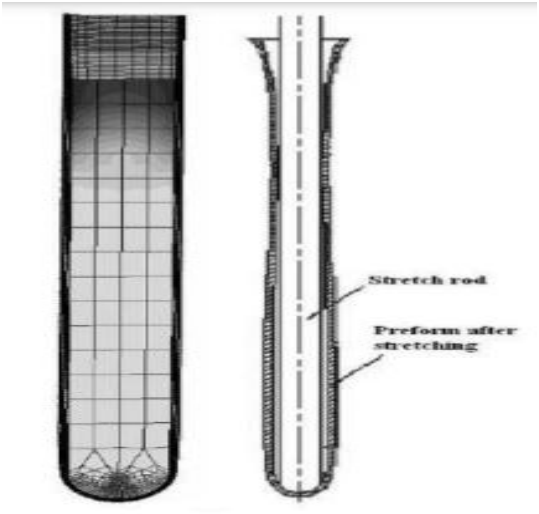

Figure 2 : Structure of perform

Assumed dimensions of perform are as follows:

i. Length of perform = 100 mm

ii. Top lip diameter = 30 mm

iii. Thickness of top lip outer and inner diameter = 3 mm

iv. Neck diameter = 26 mm

v. Thickness of neck outer and inner diameter = 5 mm

vi. Bottom portion diameter = 19 mm

vii. Thickness of bottom inner and outer diameter = 3.5 mm

viii. Thickness between outer perform portion and inner perform surface from bottom = 3 mm

All further design considerations are based on above dimensions of perform.

4. ACTUAL WORKING OF PET BOTTLE MANUFACTURINGUNIT

The actual manufacturing unit, set up at AR PET AND POLYMER COMPANY, consists of following components:

- Chiller
- Air pre-heater
- PET bottle die unit
- Compressor
- Pneumatic actuator
- Pressure regulator valve
- Inbuilt PLC input panel

4.1. Working of actual system

First the preforms are passed through the chiller. The chiller machine removes the heat from the preform. Then the preform is collected in a container. This container is then shifted manually to the pre-heater. Then one-by-one the preforms are placed in pre-heater, the preform is heated up to a predefined temperature where the preform becomes elastic enough to get blown when air pressure is released in it. Then these heater preforms are placed manually in the die.

After placing the preform in the die, by using stretch blow molding process the perform is blown. And fully blown bottles are collected and distributed further to the customers.

4.2. Modification in the existing system

As mentioned above the main problems arising are mainly due to manual errors and leakage in valves.

Manual errors causes delay in time which results in low production of PET bottles. As the entire unit is operated by workers, the workers may experience fatigue, and as a result of negligence errors may occur.

So to overcome manual errors occurring and to minimize labor work, automation of the system was one of the alternative. Now-a-days automation of systems is increasing day by day. Due to automation the errors occurring can be minimized totally. With the help of elevator conveyor systems, rotary pre-heater, belt drives, etc the manually operated system can be converted into semi-automatic operated system.

5. COMPONENTS USED FOR AUTOMATION OPERATION

- Elevator type conveyor system (buckettype)
- Funnel shaped inclined transmission line with pipelining
- Rotatingflappers
- Rotarypre-heater
- Steppermotor
- Two sided beltdrive

5.1. Bucket type elevator conveyor system

Bucket type elevator is same as normal elevator but as bucket shaped element attached to it. This bucket shape is used to lift the preform from the container up to required height and place. It works on same principle as that of lifting of water with the help of bucket wheel from river.

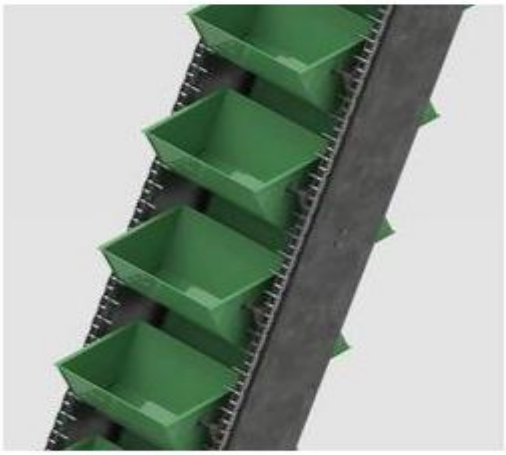

Figure 3: Bucket type elevator system

5.2. Funnel shaped inclined transmission line with pile lining

After the perform is lifted with the help of elevator they are collected in the funnel shaped transmission line. This consist of a funnel shaped opening at the top and with decreasing length it will hold the perform the neck portion. Due to the inclination the perform will slide up to required destination. To avoid deformation or any harm to the perform, the mouth at with the neck of perform is being held is lined with circular metal pipes. These pipes will avoid the friction and due to smooth surface the perform will slide easily.

Figure 4: Funnel shaped transmission system

Figure 5: Pipe lining

5.3. Rotatingflappers

Rotating flappers are placed at some distance from the elevator and at top of the funnel shaped transmission system. These flappers rotate continuously in one direction. The flappers can be designed into various shapes as per the requirement. The flapper used for this project id trapezoidal shaped. One end with larger length is mounted on shaft and the other end with shorter length is used for positioning the preform in correct position in the funnel shaped transmission. As the flappers are rotating it may cause damage to the preform. To avoid any damage the shorter edge of flapper are made of cushioning material. A rectangular slot with slightly bigger diameter than that of perform is made so that the preform will pass in correct

position i.e. with neck held in the funnel shape and the lower portion of perform hanging down.

Figure 6: Rotating flappers with edge cushioning

5.4. Rotary pre-heater

After travelling from inclined funnel shaped transmission system, the performs are held in a rotary type pre-heater. The rotary type pre-heater consists of a circular body and has notching which is equal to the diameter of neck of preform. The preform gets placed in the notch and starts rotating as the pre-heater rotates. As the surface of rotary pre-heater and preform neck causes resistance, rotating bearing are used for smooth rotation of preform throughout the circumference of the pre-heater. The preform is heated from both the sides for equal distribution of heat. The mechanism of pre-heater is same as that of a domestic heating coil which is used for heating water.

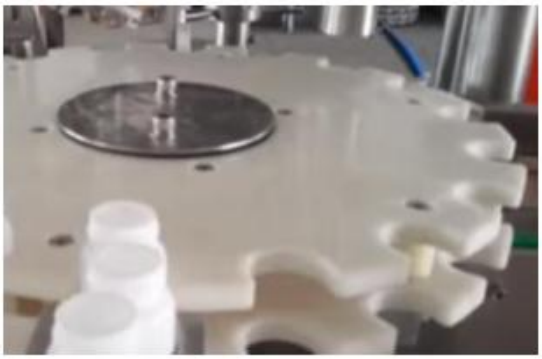

Figure 7: structure of rotary pre-heater

Figure 8: rotary pre-heater with bearing

5.5. Steppermotor

Stepper motor is a device which is used to give input to the rotary pre-heater. Stepper motors are DC motors that move in discrete steps. They have multiple coils that are organized sequence, the motor will rotate, one step at a time. By giving proper step angle the perform heated at required temperature.

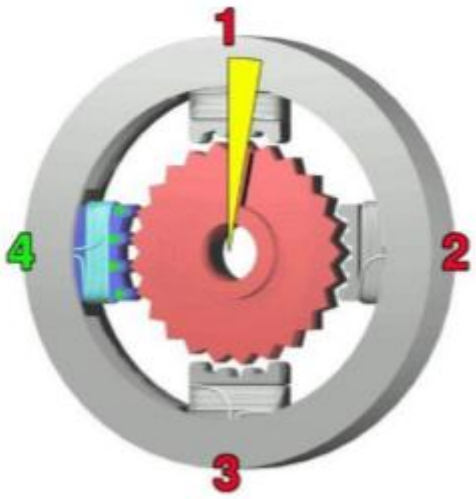

Figure 9: Stepper motor

5.6. Two sided belt drive

After the preform is pre-heated, the preform is transferred to the two sided belt drive. As the name suggests there are belt drive on both sides of perform. This will hold the perform firmly. With the forward movement of belt drive the preform will also move forward and will be dropped in the die. One the preform is place in the die, with the help of stretch low molding process the preform is blown.

6. CALCULATIONS:

6.1. Design Procedure of Conveyor Belt

Considerations used for designing of conveyor belt: Inclination of belt (α)=20 degree

Density(ϱ)=1500kg/m^3

Belt Width=1000mm

Belt Speed(v)=1.75m/s

Flowability factor of material(K)=2.5×10^-4

Driving pulley speed(N)=1440rpm

Length of belt=500m

Capacity of conveyor (M)

M = ϱK(0.9B-0.05)^2×v

=1500×(2.5×10^-4)(0.9×1-0.05)^2×1.75 =0.4741kg/sec

=0.4741×3600

=1706.76kg/hr

Reduction Ratio(G)

G=N/n

Where, N=driving pulley speed=1440rpm

n=driven pulley speed

Diameter of pulley,

d=k1.k2.Z

Assume, k1=2 k2=80 Zp=4

Diameter of driven pulley,

d=2×80×4

d=640mm

d=0.640m

Driven pulley speed: v= (π×d×n)/60

1.75 = (3.14×640×10^-3×n)/60

n=52.2rpm

G=1440/52.2492

G=27.5802

6.2. Electrical requirement:

380-415 VAC / 3 phase / 50 Hz

OR

200-240 VAC / 3 phase / 60 Hz

6.3. Total power load:

1. Machine with heater – 17 kW

2. Compressor, dries, chiller – 23 kW

6.4. Funnel shaped transmission system (un-scrambler):

- Length from horizontal axis = 200-250 mm
- Width from edge-to-edge = 400 mm
- Perpendicular length of inclined section of un-scrambler = 150 mm
- Length of perpendicular part above inclined section = 50 mm
- Angle of funnel shape inclined section = 40 degree – 45 degree
- The transmission system line should hold at least 40-45 preforms
- By adding diameter of 40 preforms = 40* 30 = 1200mm length (minimum)

For smooth transfer of performs without deformation or damage at the section where bottle is being held circular pipes are fitted to avoid resistance to flow of performs. These pipes are places on both sides of two ends of funnel shaped transmission system.

Assume, Diameter of circular pipe = 15 mm

Distance between two pipes = 28 mm (30>28>26) Where, 30 mm = diameter of neck of perform 26 mm = diameter of remaining body of perform below neck portion.

6.5. Flappers:

Single shaft contain 4 flappers along the circumference of the shaft. Each flapper has inclined shape at both sides and horizontal base at top and bottom end. The upper flat surface has a rectangular notch for passage of performs. The lower flat base is mounted on the shaft. To avoid any damage to perform or avoid deformation of perform the part of notch is made to cushioned with cushioning material. The remaining portion is made with aluminum. Length of flapper = ¾ ×200 = 150mm

The flappers are mounted on top of funnel shaped transmission system. Minimum clearance between the

tunnel shaped transmission system and flapper should be 1-2 mm.

Length of flapper from lower base = 390 mm.

Angle of inclined portion from horizontal = 40 degree – 45 degree.

Perpendicular length of inclined section of flapper = 150 mm.

7. RESULT

In the present work, research for proper dimensions of various components like speed, length, diameter, input parameters as well as material is being done. With proper input parameters the modified system will convert the manually operated system into semi-automatically operated system.

Further research on minimizing leakages and pressure drop causing error in production of Pet bottles is being done.

8. CONCLUSION

When all the problems will be solved the production rate of PET bottles will increase. The system will be successfully modified into semi-automatic system. This automation of system will result in minimizing manual errors and also increase quality of the product. Also labor work will be minimized.

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