Sudan University of Science & Technology

College of Graduate Studies

Department of Plastic Engineering

An Analytical Study of the Combined Process Of Bottles Production

دراسة تحليلية للعمليات المزدوجة لإنتاج القوارير

SUBMITTED IN PARTIAL FULFILMENT OF THE DEGREE OF M.SC IN PLASTIC ENGINEERING

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{ فَبَدَأَ بِأَوْعِيَتِهِمْ قَبْلَ وِعَاءِ أَخِيهِ ثُمَّ اسْتَخْرَجَهَا مِن وِعَاءِ أَخِيهِ ۚ كَذَٰلِكَ كِدْنَا لِيُوسُفَ ۖ مَا كَانَ لِيَأْخُذَ أَخَاهُ فِي دِينِ الْمَلِكِ إِلَّا أَن يَشَاءَ اللَّهُ ۚ نَرْفَعُ دَرَجَاتٍ مَّن نَّشَاءُ ۗ وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ} (76) سورة يوسف.

Dedication

To my mother which recently passed away.

To my father and my wife whom I respected and will always love.

Acknowledgments

I do appreciate all those who supported me and made me to finalize this research mainly **(Dr. Mohamed Deen Hussein)** and thank very much all others who devoted their efforts to assist us.

And I wish this research becomes very fruitful and beneficial to all.

المستخلص

هذه الدراسة تهدف الي دراسة الجمع بين عملية تشكيل البريفورم عن طريق الحقن ومن ثم التشكيل عن طريق النفخ في ماكينة واحدة، وتتميز هذه العملية بمزايا بالمقارنة مع تشكيل البريفورم فقط في ماكينة واحدة ومن ثم تشكيل العبوات عن طريق نفخ البريفورم في ماكينة منفصلة.

كمثال لإستخدام العملية المزدوجة عبوات الأدوية صغيرة الحجم تصبح أقل عرضة للتلوث وأكثر إقتصادا، وفي حالة العملية المنفصلة تصبح أكثر عرضة للتلوث وأكثر صعوبة ، لدينا ثلاث نقاط رئيسية ذات تأثير كبير في العملية المزدوجة وهي:

(البريفورم، القوارير و إنخفاض اللزوجة النوعية)

وقد وجد أن أكبر مشكلة تواجة عملية التشكيل هي إنخفاض اللزوجة النوعية وثانيا البريفورم وأخيراً القوارير.

Abstract

This research study process of combined process of injection of preform and immediately then blowing of these preform on the same machine.

Such a process has its advantages compared with the traditional sequence of preform injection in one machine and later the blowing of the preform to produce the bottle.

Process combined products like pharmaceutical bottles made in a small size are not susceptible to pollution and more economical, in the case of the separate process becomes more susceptible to pollution and more difficult.

We have three key points in process of Stretch Blow Molding machine Preform Molding, Container Blowing and Lowered Intrinsic viscosity (I.V.).

It found that Lowered Intrinsic viscosity (I.V.) was the most common one, Preform Molding is most second one to happen and the last one is Container Blowing.

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Table of contents

Chapter Four Result and Discussion

Chapter Five Conclusion and Recommendation

List of Figures

Chapter one

Introduction

1.1. Introduction:-

In injection stretch blow molding machines, the process involves injection of performs as well as blowing of bottles in the same machine. Performs are not cooled down completely after injection, instead residual heat inside the perform allows blowing without reheating. Obviously this makes it more complex than the two stage process. Where the first stage to produce perform by injection molding and on a different machine the perform is stretched and blown into bottles. There is some interaction present between injection and blowing which adds to the complexity.

Machines of this type are commonly used in cosmetic, personal care and medical drugs. They are hardly used in water or carbonated soft drinks. There are two types of injection stretch blow molding (ISBM) machines:

1.1.1 Four station machines:

Injection, conditioning, stretch blowing and ejection.

1.1.2 Three station machines:

Injection, stretch Blowing and ejection.

A machine with four station rotates 90° moving performs and bottles around each cycle, whereas a three stations machine rotates 120°.

In both types of machines there is a lip plate it is a circular plate divided into four or three sections depending on machine type each section contains the cavity that forms the screw of the bottle and it holds the perform or bottle throughout the cycle. The number of screw cavities in the section is equal to the number of cavities in the mold of injection. The lip plate moves performs / bottles through different stations. A servo motor controls the movement of the lip plate.

1.1.3. The advantages of ISBM system besides the ability to make both preforms and bottles in one machine are as follows:

- Flexibility to make bottles of different shapes with good wall distribution.

- Production of blemish-free bottles. Since preforms are not touched, bottles have no marks when they leave the machine. Important feature for pharmaceutical bottles.
- Zero contamination between preform and bottle stage. This may decrease sterilization measures in the filling plant.
- A neck support ring is not necessary, also interesting for cosmetic bottles.
- Thermal efficiency; preforms are cooled down only to blowing temperature of about 100°C, saving energy needed to cool them to about 60°C necessary for two-stage molding.
- Automatic neck orientation; some caps require the neck to start in a particular position with respect to an oblong bottle shape. This requires an expensive device in two-stage molding but is “free” in ISBM as the neck start can be chosen deliberately and the preforms are held in place between injection and blow without spinning.
- Vertical injection tooling leads to longer tool life because gravity does not try to pull tools off-center as is the case with horizontal injection machines.
- Many custom bottles have special neck finishes for which it is hard to find preforms on the open market. In this case, a single-stage solution may be the most cost-effective solution as it is often cost-prohibitive to build and run injection tooling for preforms of low volumes.
- The inside of the preform is always hotter than the outside. This is of great advantage as the inside always has to stretch more than the outside . The reason why this is happing in single stage is that the cooling area on the core side is always smaller than on the cavity side and often with less flow . This explains the ease of forming difficult container shapes.

1.1.4. There are also a number of disadvantages mentioned as follows:

- Cycle times are relatively slow even when comparing the same thickness and weight preform molded on a modern injection machine. Part of this has to do with the way the machine rotates requiring several tool movements that accumulate dead time.
- Long changeovers: Injection tooling is very cumbersome to remove as each injection core must be replaced individually. Machines are also difficult to access making it more time consuming to work on them.

- Each blow cavity requires one injection cavity. Because injection usually takes 2 to 3 times longer than blowing the blow section is idle for half to two thirds of the cycle time. In two-stage molding it is much easier to match the output of an injection machine with that of a blow machine.

1.2. Objectives of the Research:

The combined process of perform followed by the stretch blowing to produce bottles save energy needed to heat the perform and other preparatory steps before the stretch blow molding take place. In stretch blowing step the temperature profile is an important factor that determines the bottle wall thickness in the different parts of the bottle.

In this research a study was made for parameters that can affect the temperature profile in the perform and how to get the best temperature profile that suits the stretch blowing process.

Chapter two

Literature review

2. 1Process Steps

2.1.1 Injection:

All machines on the market use reciprocating screws. That is, the screw turns and pushes material to the front of it while retracting backward in the barrel. This is called recovery. During injection the screw moves forward pushing material into the hot runner while a check valve located at the
front of the screw prevents material from moving back.

The parameters that can be adjusted on the machine are discussed as follows:

- injection pressure
- injection speed
- transition point or switchover point
- hold pressure
- hold time
- cooling time
- cushion length

2.1.1.1 Injection Pressure and Speed

Processors can dial in injection pressure either from the screen or manually on a pressure relief valve. A maximum of 100 bar (1500 psi) is recommended for Polyethylene terephthalate (PET) to avoid shearing the material too much. This is hydraulic, not material pressure and the difference should be explained. The hydraulic injection piston has a 5–7 times bigger area than the screw area leading to pressure intensification. For example, a 200-mm injection piston has an effective area of 31.4 cm^2. The 80-mm screw is connected to have an area of 5.024 cm^2. Using 100 bar in the piston results in a force of 3140 kg acting now on the smaller screw area. This leads to the screw experiencing a pressure of 3140 bar/5.024 cm^2 or 625 bar. This is the pressure the material is subjected to and 700 bar (10,000 psi) is the recommended maximum for PET.

It is possible to increase this pressure slightly during start-up to get the process going but many machines run well below the maximum. A notable exception is very thin preforms (<2.3 mm), as these require fast injection and with it high pressure to prevent freezing off in the cold tool. Pressure is also not actually regulated by the pressure setting. Instead, this setting is just limiting the pressure to the dialled-in value, draining oil to tank when the actual pressure reaches the selected threshold. What actually creates the pressure is the speed of injection. The faster the speed the higher is the resulting pressure. Speed should be chosen so that the maximum pressure is not reached. Most machines show the actual pressure on the screen while on some it can be read on a dial gauge at the extruder.

Injection time is the time between start of injection and when the screw reaches the transition or switchover point. The actual injection time is not a time that can be dialled in. Instead, it is the result of the speed setting and how long it takes to move the material from start of injection to the transition point. This in turn depends on the chosen speed setting and melt viscosity. As discussed earlier, melt viscosity is a function of the material intrinsic viscosity (IV) and melt temperature. Fig. 8.5 gives a guideline what injection time should be for PET.

In order to get to these times there are usually three or more speed settings that the processor can use. These are mostly open-loop controls that can be set depending on the screw position. On the machine a proportional valve receives speed percentages as variations of milliamps and allows a proportional amount of oil flow into the injection device. Recommended is a slow start, a fast middle, and then a slowdown before the screw reaches the transition point.

2.1.1.2 Choosing the Transition Point:

As explained earlier the transition point should be chosen as that point when the injection cavity is completely filled with material. There are several ways to calculate it.

The first takes advantage of our knowledge of melt density versus solid density. For PET these values are 1.16 and 1.335 g/cm^3, respectively. We assume that the material is at the melt density during injection and at solid density after hold and cooling, even though this may not be that correct as explained later. Because melt density is about 87% of solid density our initial shot calculation should allow 87% of the stroke to happen in injection and 13% of it during hold. The 13% hold phase stroke allows the material to grow in density, that is, shrink to the solid density. The reason this is not as accurate is that the material, especially the melt front, cools down during injection and increases in density as a result. This is especially true for thin preforms that cool down quickly. The 13% density difference may be as low as 8% or even 6% thereby changing the necessary settings.

Another way of finding the transition point is to observe hydraulic injection pressure. During injection the cavity is empty (except for air) and there is little resistance to the flow of plastic into it. Once the cavity is filled with material injection pressure will increase immediately as the material now blocks further injection. An experienced processor can thus determine at which point the cavity is filled.

A third way is to calculate the screw stroke with the screw diameter, the melt viscosity and the shot weight as parameters.

2.1.1.3 Hold Pressure and Time:

During hold time the material shrinks to solid density as explained and the main purpose is to allow some material to enter the cavity to compensate for this shrinkage. Most machines have three hold pressure and time settings. The first is responsible for the neck area of the preform, the second for the body, and the third for the gate. A general guideline would be to set the three timers to equal time and the pressures to 60, 50, and 40%, respectively of the actual injection pressure.

2.1.1.4 Cooling Time:

After the hold timers have timed out cooling time starts and the screw moves back relieving pressure in the hot runner and cavities. Cooling time should be chosen to allow the preform to shrink away from the cavity for easier preform removal and to control gate crystalline. [1]

As seen in figure 1, part cooling time accounts for approximately two thirds of the cycle. Cooling time is a function of polymer material properties, part thickness and molding temperatures. [2]

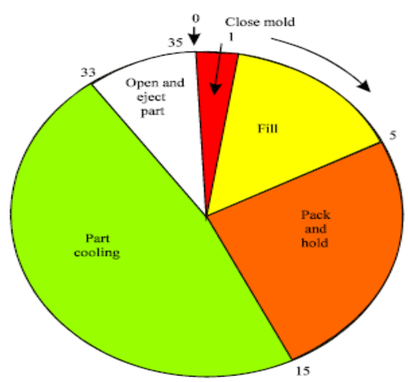

Figure 2.1 Typical injection molding cycle clock

2.1.1.5 Cushion Control:

The screw should not bottom out at the end of the barrel with each stroke; instead there should be what is called a cushion, that is, some material is left to cushion the screw stroke. Typically 5–10 mm is chosen but in single-stage processing a larger cushion may be selected to give the material more time to homogenize.

2.1.2 Interaction between Injection and Blow:

It should be obvious at this point that the injection process has an impact on the blow process. Different hold and cooling times change preform temperatures and this in turn will change the way the bottle blows, especially in areas that are close to the upper and lower limit of PET’s ability to stretch.

But that is not all. As previously mentioned, one disadvantage of ISBM is that processors are not in complete control of the temperature profile of the preform. Because the melt in the neck area had a longer time to cool down compared with the melt in the gate area it is also cooler and we may find a temperature profile. Actual temperatures and differences depend on process conditions and are therefore not shown here.

This heat profile will result in a relatively thin bottle base with more material toward the neck because PET will stretch first in the hotter areas. To counteract this behavior preforms are designed with thinner gate areas and/or more cooling and thicker areas toward the neck. While this may sound counterintuitive, a thicker wall in the preform neck area leads to a thinner area in the bottle neck. This is because the thicker preform area retains more heat and will then stretch more resulting in an overall thinning.

For the processor there is another way of changing this temperature profile. It relies on the observation that faster injections will lead to less difference between cooler and warmer areas because the material injected first has less of a time difference spent in the cold mold than with longer injections. Overall, the temperature will be higher but the temperature gradient from hot to cold is less. This will then result in thicker bottle bases. Of course the opposite is also true, to increase material thickness in the bottle base a slower injection may be selected.

2.1.3 Conditioning:

Four-station machines have the ability to condition preforms after injection and before blow. There are two devices on these machines:

- heater bands that move around the outside of the preforms and heat them without touching them and temperature-controlled conditioning cores that move inside the preforms and touch them.

Depending on the length of the preform there can be up to three heater bands that are thermally insulated from each other and that can be adjusted with separate temperature controllers. Heat transfer is limited as the air around the preforms does insulate them to a large degree but they have some effect and are mostly used to heat the preform portion below the neck in order to get material away from the shoulder of the bottle (Fig.2.2).

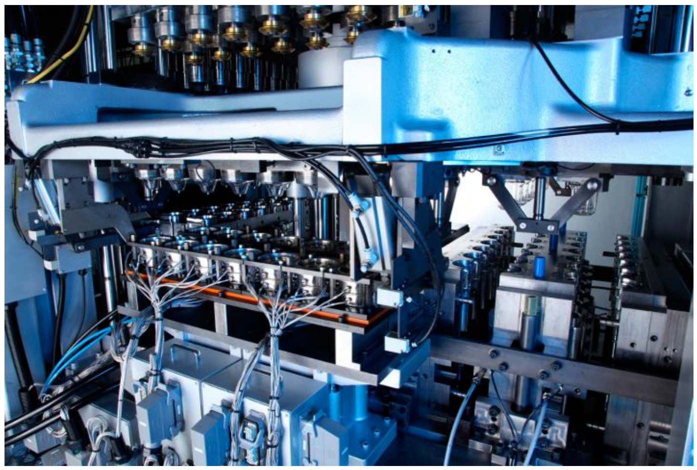

Figure 2.2 Conditioning station machine

The conditioning cores on the other hand are very effective and are the main reason oblong shapes with very good wall distribution can be manufactured.
The function of the conditioning core is to cool down areas that are expected to blow thin compared to areas that will be thick. A typical example is an oval bottle. The short sides of the container would be thick if the preform was heated evenly. Cooling the areas of the preform that will form the far sides of the container down has the effect that these cooler preform parts pull the warmer areas apart thinning them out in the process. The cores are usually run with temperature-controlled water. Thermolators keep the temperature between 55 and 75°C. Conditioning cores are made from aluminum and can be shaped easily into a variety of shapes for oval, rectangular, or other oblong containers. They can also be used to cool down a hot bottom area leaving the top part of the preform untouched. Used in this way there are another way of overcoming the often disadvantageous heat profile that hot runners impart on preforms. While it is not optimal from a process point of view to heat the outside and cool the inside of the preform, the inside temperature of the preform is substantially higher than the outside. [1]

2.1.4 Container Blowing:

Blow molds move horizontally and are similar to molds used in the two stage process. Since they are idle for around half the time, some companies just cool the back plates they are mounted on, thus saving the drilling of water lines in the molds. This works because PET is only at about 100°C at the time of blowing and the large aluminum body of the molds acts like a giant heat sink and dissipates the preform heat. As cycle time is not an issue they can be closed for a few additional seconds as they warm up over time. It is actually beneficial for the process if the molds warm up to about 60°C, the material flows easier and blown containers are already stress-relieved to some extent.

Stretch rods enter the preforms from the top controlled by pneumatic cylinders. Most machines use long hoses to carry blow air to the cavities, air that has to be exhausted every cycle. This makes the machines large air consumers and contributes to operational costs. On most machines there are only three timers for all cavities that control stretch rod delay, prelaw delay, and blow delay. All three are triggered from the mold close signal (Fig 2.3).

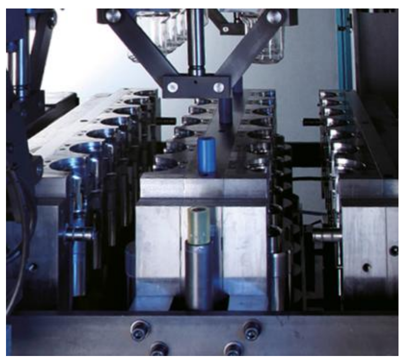

Figure 2.3 Blow molds.

Timers offer a lot of flexibility as they are easy to change from the screen and the operator has full control over the sequence of events. For example, he/she can bring in prelaw air before the stretch moves. One disadvantage with this approach is that stretch rods will not always be in the same position when prelaw or blow air enter the preform. This is because preforms offer varied resistance against the stretch rod action depending on their temperature, which varies in a typical day/night temperature cycle. While these variations are small often the process window on multi cavity tools is not very wide and even small changes can throw the process off in at least some of the cavities. Another problem is that the operator does not know when the stretch rod is fully extended. The stretch rod must be fully extended before high-pressure air is introduced. Otherwise, the gates will go off center. The only way of knowing when that point in time happens is to reduce the delay blow air to the point when all gates are off, then add some time to it.

A better albeit slightly more cumbersome way is to time the start of prelaw and blow air from switches that are mounted somewhere along the vertical axis the stretch rods have to follow. This assures both that the stretch rod is always in the same position when prelaw air comes on and that it is fully extended before blow air enters the cavity. It is therefore the preferable method. Some machines use both switches and timers whereby the switches trigger the timers and this set up offers even more flexibility.[1]

2.1.5 Hot Runners:

Hot runners are mounted between the extruder and the injection cavities. Their function is to distribute the single melt stream into the appropriate number of streams depending on the cavitations of the tool. Each cavity should get the exact same amount of material and at the same speed and pressure.

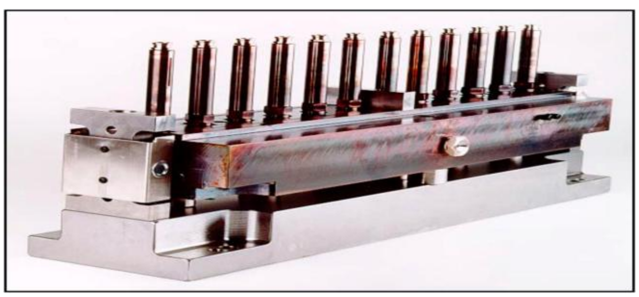

Figure 2.4 All hot runners in single-stage.

This is best achieved by “naturally” balancing the flow channels. This means that the path from the extruder to each cavity has the same length and number of turns. This is relatively easy for cavitations whose numbers are a power of 2, that is, 2, 4, 8, 16, and 32. However, even with this condition in place, there are imbalances in any hot runner system that stem from the uneven heating up of the melt stream commonly referred to as viscous heating (Fig 2.4).

2.1.6 Gate Mechanism:

There are two ways to separate the hot melt coming through the hot runner from the cooled preform: thermal and mechanical. Thermally gated hot runners are most prevalent in one-stage while it is the other way around in two-stage injection molding. In a thermally gated hot runner the break point between the hot and cold melts is controlled by temperature alone. As seen in Fig.2.5 the temperature difference between the cold cavity and the hot melt is substantial at around 255°C. A suitable insulation made from stainless steel or other material with insulating properties separates the two sections. When the machine ejects the preforms the melt breaks at the point where the cold gate vestige connects with the hotter material inside the nozzle. This material is already partly cooled down and so has a higher than melt viscosity. This prevents it from seeping into the cavity or lead to "stringing," a common defect where small strands of PET from the melt stream are pulled out with the preform during ejection. An air gap may also assist in the separation process.

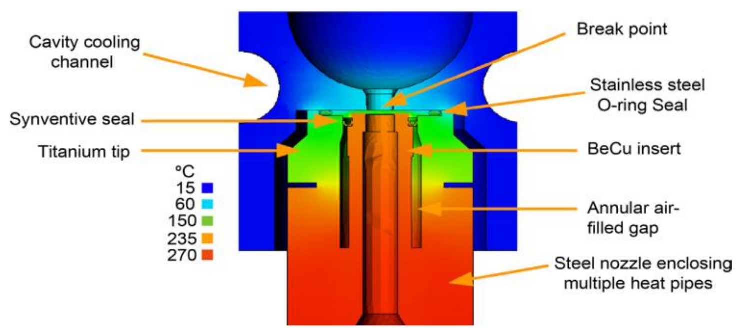

Figure 2.5 Thermally gated hot runner nozzle

Valve-gated hot runners use a mechanical seal between the hot and cold areas by means of a pin called the valve stem. Usually around 3 mm (1/8 in.) to 5 mm (0.2 in.) in diameter, this pin moves back allowing melt flow into the cavity, stays back during hold time, then moves forward controlled by a timer that energizes with the end of hold time. Gate vestiges made with valve-gated hot runners are on average shorter than with thermally gated ones and the cut-off is more precise. Properly operated they also tend to give less problems with stringing and gate crystallinity. Disadvantage of valve gates is the higher maintenance requirement for the pins and the air cylinders driving them (Figs2.6 and 2.7). [1]

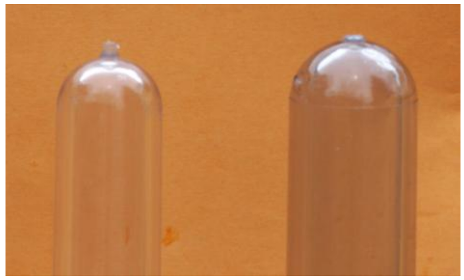

Figure 2.6 Typical difference in length of gate

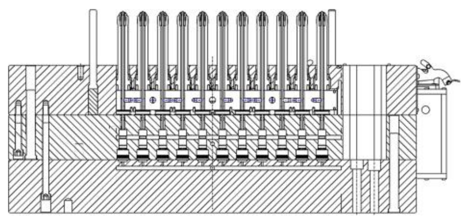

Figure 2.7 Valve-gated hot runners.

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2.2 Integrated Two-Stage Stretch Blow Molding:

This process is sometimes referred to as "one-and-a-half stretch blow molding." It is similar to one-stage molding in that both preforms and bottles are made in the same machine. It is also similar to two-stage molding as preforms are completely removed from the injection tooling, placed on mandrels, heat-conditioned in some way, and then blown. The impetus for this development was the above-mentioned fact that the blow stations in onstage machines are underused. The concept of ITSBM machines then is to reduce the number of blow cavities in some ratio to the number of injection cavities. The blow part of the machine cycles is two or three times for every injection cycle and has only half or a third blow cavities, respectively as compared with the injection cavities. For custom molders with small-volume jobs this can result in significant savings as less blow cavities have to be purchased. It also speeds up the machine because fewer parts have to move at the same time. It adds complexity though as a robot of some sort is needed to take preforms out of the injection tool, turn them 180 degrees, and then place them on mandrels. Machines as large as 80 injection and 40 blow cavities and outputs of up to 36,000 bottles/h have been built but more common are machines with 6 injection/2 blow or 16 injection/8 blow cavities (Fig13). Heat conditioning preforms on mandrels can be done in several ways and infrared ovens like the ones used in two-stage stretch blow molding are often used. Another method is to blow hot air against cooler parts of the spinning preform. This is especially useful to heat up material just underneath the transfer ring. This part of the preform tends to be cooler than the area around the gate as it had longer time to cool during injection. This is much more effective than the heater bands that are used for the same function in standard single-stage machines.

ITSBM machines share most of the same advantages and disadvantages as one-stage machines but do not have automatic neck orientation as they do not keep the preforms in place. They also add another complication that may sometimes cause problems: the two parts of the machine (injection and blow) need to be synchronized in some way, which may limit options for the processor. Given a certain injection time, blow timing has to be limited to a value that allows both parts to stay in synchronized and vice versa. In most cases this is not an issue with machines that feature 2:1 ratios but may be more challenging when a 3:1 ratio is employed. Whenever the total time of the blow time cycles (2 or 3) exceed the injection cycle, the injection part of the machine has to add the missing time somewhere. This may be by adding cooling or mold open time. However, this changes the preform temperature and so affects the blow process. It is important that the machine warns the operator of this condition so that he/she can adjust the process accordingly.

Figure 2.8 Thirty two preforms.

2.3 At the end of this chapter, I would like to mention that the two processes (single stage and two-stage) have their distinct advantages and disadvantages and brand owners are well advised to know those in order to make the right choice for their products.

2.3.1.1 The advantages of single stage are repeated as follows:

- blemish-free bottles
- transfer ring not necessary
- control over preform production
- good conditioning possibilities for oblong bottles on some machines
- thread start can be chosen to coincide with bottle shape
- compact and flexible

This makes this process a shoe-in for all no beverage containers.

2.3.1.2 However, there are also some disadvantages:

- long cycle times
- long changeover times
- uneven wall distribution
- quality problems with thermo gated hot runners, valve-gated ones are available and are recommended
- machines should be run 24 h/day to avoid higher scrap percentage
- longer learning curve for operators as two processes and PET drying must be mastered
- inefficient blow station as the injection station always has precedent over the cycle time

The latter issue has led to the subcategory of integrated two-stage machines that has been described previously. Thermo-gated hot runners are inferior compared to valve-gated ones but most machines still run with the former.

2.3.2 Now let us look at the advantages of the two-stage process:

- scalable from 1,000 to 81,000 bottles/h
- fast cycle times
- fast changeover
- flexibility; preforms can be made elsewhere and stored
- very good wall distribution for round bottles
- on average lower gram weights are possible for round bottles
- Process can be stopped at any time.

The main disadvantage is preform damage that occurs when preform tumble onto conveyor belts and storage containers and then again when they are dumped into the hoppers of blow molding machines. Many of the little nicks and scratches can be stretched out when high stretch ratios are used but this is not always the case especially when a preform is chosen from a vendor and does not exactly fit the bottle to be blown. Wrap-around labels or sleeves are a good way to hide these marks and have added to their popularity. [1]

Chapter three

Methodology and Raw Material

3.1. Methodology:

3.1.1. Four-Station Machines:

Preforms and bottles are oriented vertically and in rows, typically one row only but there are also machines with two rows of up to 16 cavities making 32 cavities the current maximum number. They are spaced not with respect to the preform dimension but to the maximum bottle dimension as the pitch between the cavities does not change within the machine. A 90-mm wide or round bottle requires spacing of about 100 mm in both preform and blow tooling to allow some metal between the blow cavities. A particular machine can produce a 300-mL bottle in 16 cavities or a 15-L bottle in single cavity with various bottle sizes and respective cavitation in between (Fig.3.1).

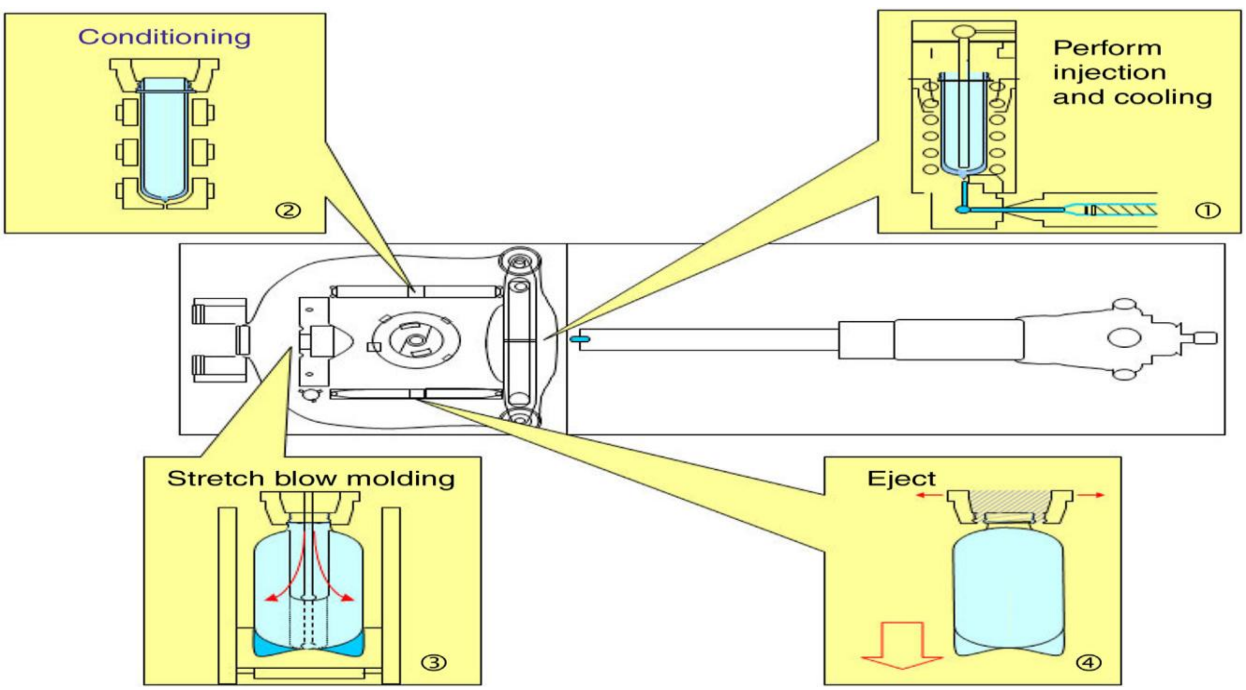

Figure 3.1 Four-station ISBM process

In order to engage the injection tooling vertically, the following movements are required, cavities and neck inserts move up leaving the cavities in place. This is a superior solution as the problem is not an issue (Fig.3.2).

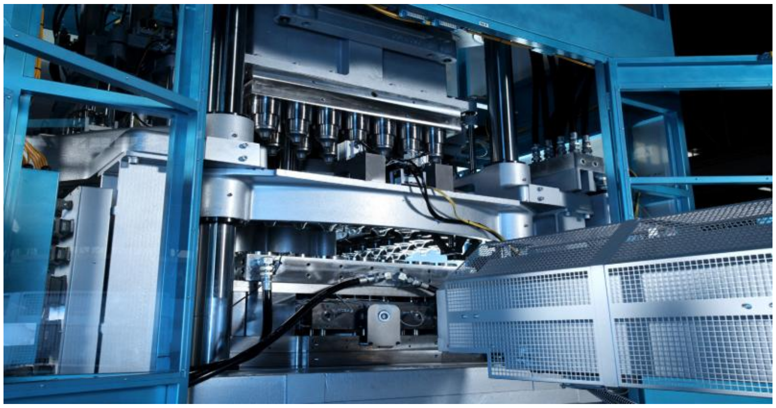

Figure 3.2 Injection tools.

A machine with four stations rotates 90 degrees moving performs and bottles around every cycle, whereas a three-station machine rotates 120 degrees. Orientation of each station is vertical allowing a very compact footprint.

3.2. Analysis of the process, the steps of bottles making are:

3.2.1. Drying unit:

The raw material is pumped from its container where hot air at 150°c is used to dry it for a period of four hours.

3.2.2. Coloring unit:

The dried PET is transferred through a hoist to small mixer located on the top of the hopper of the extruder. The color is at room temperature white the PET granules at 150°c. The quantity of color is controlled by a motor connected to spiral to convey the color granules. The speed and the time are set on a separate control system.

3.2.3. Injection Station:

It consists of screw driven by hydraulic motor and a cylinder which operates the screw as a plunger at injection step. On the extruder there are four heaters which raise the temperature of the material to (265~280) °c. The hydraulic motor rotates the screw to convey and melt the material. The mixing of the screw leads to homogeneous melt in the front of the screw when the right quantity of melt is prepared the hydraulic motor steps and the cylinder pushes the screw forward injection the melt through the hot runners inside the cavities of the mold.

The hydraulic pressure of the cylinder is 11 MPa. The injection mold contains seven heaters located around the hot runners of the mold. The heaters temperature is set at (263~278) °c.

Each cavity has a core. Together it has the shape of the preform. The cooling water temperature that flows through the mold is at 18°c and pressure of 4 bar. The cooling time is 4 second.

During the injection to produce the preform the other three stations are operating:

3.2.4. Conditioning Station:

This station consists of 12 heaters; each preform is heated by 3 heaters. The first is at the preform neck where the temperature is set at 150°c. The second at the middle of the preform the temperature is set at 120°c and the third at the bottom of the preform and the temperature is set at 140°c. In each cycle four preforms are conditioned.

3. 2.5. Stretching and Blowing Station:

The first step the stretch rod descends inside the preform stretching it to the Bose of the bottle mold. After 0.02 second the primary blowing is carried with air at pressure of 10 bar at time 0.2 second the secondary blowing is done using air at a pressure 24 bar and continues for 3 seconds. The pressure inside the bottle is relieved and the mold is opened.

3.2.6. Ejection Station:

Product bottles are them ejected by this unit through a gate.

3.3 Polyethylene Terephthalate (PET):

PET was patented in 1941 by John Rex Whinfield, James Tennant Dickson and their employer the Calico Printers' Association of Manchester, England. E. I. DuPont de Nemours in Delaware, USA, first used the trademark Mylar in June 1951 and received registration of it in 1952. [3]

It is still the best-known name used for polyester film. The current owner of the trademark is DuPont Teijin Films US, a partnership with a Japanese company. [3]

In the Soviet Union, PET was first manufactured in the laboratories of the Institute of High-Molecular Compounds of the USSR Academy of Sciences in 1949, and its name "Lavsan"is an acronym thereof (лаборатории Института высокомолекулярных соединений Академии наук СССР).[3]

The PET bottle was patented in 1973 by Nathaniel Wyeth. [3]

3.3.1 Physical properties:

PET in its natural state is a colorless, semi-crystalline resin. Based on how it is processed, PET can be semi-rigid to rigid, and it is very lightweight. It makes a good gas and fair moisture barrier, as well as a good barrier to alcohol (requires additional "barrier" treatment) and solvents. It is strong and impact-resistant. PET becomes white when exposed to chloroform and also certain other chemicals such as toluene.

About 60% crystallization is the upper limit for commercial products, with the exception of polyester fibers. Clear products can be produced by rapidly cooling molten polymer below Tg glass transition temperature to form an amorphous solid. Like glass, amorphous PET forms when its molecules are not given enough time to arrange themselves in an orderly, crystalline fashion as the melt is cooled. At room temperature the molecules are frozen in place, but, if enough heat energy is put back into them by heating above Tg, they begin to move again, allowing crystals to nucleate and grow. This procedure is known as solid-state crystallization.

When allowed to cool slowly, the molten polymer forms a more crystalline material. This material has spherulites containing many small crystallites when crystallized from an amorphous solid, rather than forming one large single crystal. Light tends to scatter as it crosses the boundaries between crystallites and the amorphous regions between them. This scattering means that crystalline PET is opaque and white in most cases. Fiber drawing is among the few industrial processes that produce a nearly single-crystal product. [4]

3.3.2 Intrinsic Viscosity:

One of the most important characteristics of PET is referred to as intrinsic viscosity (IV).

The intrinsic viscosity of the material, found by extrapolating to zero concentration of relative viscosity to concentration which is measured in deciliters per gram (dℓ/g). Intrinsic viscosity is dependent upon the length of its polymer chains but has no units due to being extrapolated to zero concentration. The longer the polymer chains the more entanglements between chains and therefore the higher the viscosity. The average chain length of a particular batch of resin can be controlled during polycondensation. [5]

The intrinsic viscosity range of PET:

Fiber grade:

0.40–0.70 Textile

0.72–0.98 Technical, tire cord

Film grade:

0.60–0.70 BoPET (biaxially oriented PET film)

0.70–1.00 Sheet grade for thermoforming

Bottle grade:

0.70–0.78 Water bottles (flat)

0.78–0.85 Carbonated soft drink grade

Monofilament, engineering plastic

1.00–2.00 . [6]

3.3.3 Development of the PET bottle:

PET poly (ethylene terephthalate) was developed in the 1940's and since then it has played an important role in the food and beverage packaging industry. [7]

Due to its popularity the use of PET in carbonated soft drinks bottles has been studied extensively. [8]

Initially, PET bottles consisted of two pieces; the blown bottle section, and a separate 'cap' section fitted over the over the hemispherical bottle base. The polyethylene cap section made the bottle self-standing.
In recent times, PET bottles have been made in one piece with a self-standing petaloid-shaped base. [9]
The desirable properties of PET (clear, lightweight, high strength, stiffness, favorable creep characteristics, low flavor absorption, high chemical resistance, barrier properties and low price) make it the material of choice for carbonated soft drinks containers, fibers and films. [7]
Due to low cost, better aesthetic appearance, and better handling, PET is being preferred over polycarbonate (PC) polymers. [10] PET has been also known for many years as a textile fiber forming material. But lately, it has started to be used in extrusion foam processing for textile fibers because of its elastic nature. [11] PET is also used as a recyclable polymer, and the markets for recycled PET (R-PET) are growing by the year.

3.3.4 Crystallization behavior of PET:

'Crystalline' means that the polymer chains are parallel and closely packed, and 'amorphous' means that the polymer chains are disordered. [14]
Most polymers exist as complex structures made up of crystalline and amorphous regions. Crystallinity is usually induced by heating above the glass transition temperature (Tg) and is often accompanied by molecular orientation. [12] It is impossible to reach 100% crystallinity with the lowest free energy because polymers do not have a uniform molecular weight.

Instead, the polymers can only react to produce partly crystalline structures, usually called "semi crystalline". [13]
The degree of polymer crystallinity depends on both intrinsic and extrinsic factors. Narrow molecular weight, linear polymer chain structure, and high molecular weight are very important pre-conditions in terms of obtaining high crystallinity. [15]

Crystallinity is also affected by extrinsic factors, like stretch ratio, mode of extension and crystallization temperature in the preparation of polymer films [9]. Below the glass transition temperature, polymer chains are rigid; after reaching the glass transition temperature, the chains become more flexible and are able to unfold under stress. If the temperature is above Tg and stretching is carried out, the randomly coiled and entangled chains begin to disentangle, unfold, and straighten and some of them even slide over their nearest neighbor chains. [16]

PET is a crystallizable polymer because of its regularity in chemical and geometric structures. It is either in the semi-crystalline state or in the amorphous state. The levels of crystallinity and morphology significantly affect the properties of the polymers. [17]

Even with limitations in its barrier properties and mechanical strength, crystalline PET is still widely used. Polymers with high crystallinity have a higher glass transition temperature Tg (Tg is 67 °C for amorphous PET and 81 °C for crystalline PET) and have higher modulus, toughness, stiffness, tensile strength, hardness and more resistance to solvents, but less impact strength. [17,18]

Crystallinity in PET is usually induced by thermal crystallization and/or by stress or strain induced crystallization. Thermally induced crystallization occurs when the polymer is heated above Tg and not quenched rapidly enough. In this condition the polymer turns opaque due to the spherulitic structure generated by thermal crystallization aggregates of un-oriented polymers. [19]

In stress-induced crystallization, stretching or orientation is applied to heated polymer and the polymer chains are rearranged in a parallel fashion and become closely packed. [20]

The crystallization process is composed of nucleation and spherulitic crystallization, and may occur at temperatures above Tg and below the melting point Tm. [21]

Quenching the melt quickly results in a completely amorphous PET. [18]

Crystalline polymers have a heterogeneous structure due to the interspersed amorphous regions while amorphous polymers in all their forms (melts, rubbers, glasses, etc.) have a homogeneous structure. Polymers are characterized by a glass transition temperature Tg and a melting temperature Tm. [22]

The glass transition behavior of semi-crystalline polymers are greatly affected by the factors affecting degree of crystalline such as molecular weight, amount of crystalline phase and morphology. [17, 21, 23]

The glass transition temperature of semi-crystalline polymer is higher and broader than that of the amorphous polymer. [17]

3.3.5 Drying:

PET is hygroscopic, meaning that it naturally absorbs water from its surroundings. However, when this 'damp' PET is then heated, the water hydrolyzes the PET, decreasing its resilience. This means that before the resin can be processed in a molding machine, as much moisture as possible must be removed from the resin. This is achieved through the use o f a desiccant or dryers before the PET is fed into the processing equipment.

Inside the dryer, hot dry air is pumped into the bottom o f the hopper containing the resin so that it flows up through the pellets, removing moisture on its way.

The hot wet air leaves the top o f the hopper and is first run through an after cooler, because it is easier to remove moisture from cold air than hot air. The resulting cool wet air is then passed through a desiccant bed. Finally the cool dry air leaving the desiccant bed is re-heated in a process heater and sent back through the same processes in a closed loop. Typically residual moisture levels in the resin must be less than 5 parts per million (parts o f water per million parts o f resin, by weight) before processing. Dryer residence time should not be shorter than about four hours. This is because drying the material in less than 4 hours would require a temperature above 160 °C, at which level hydrolysis would begin inside the pellets before they could be dried out. PET can also be dried in compressed air resin dryers. Compressed air dryers do not reuse drying air. Dry, heated compressed air is circulated through the PET pellets as in the desiccant dryer, and then released to the atmosphere.

3.4 Permissible heavy metals content:

a. Aluminum Maximum…...1 ppm.
b. Antimony Maximum…….1 ppm.
c. Barium Maximum……….1 ppm.
d. Cobalt Maximum………..1 ppm.
e. Germanium Maximum…..1 ppm.
f. Manganese Maximum…...1 ppm.
g. Titanium Maximum……...1 ppm.
h. Zinc Maximum…………...1 ppm. [24]

Chapter Four

Result and Discussion

The problems in **Preform Molding, Container Blowing and Lowered I.V.** will be discussed.

4.1. Preform Molding has three areas to consider **Neck Area, Preform Body and Gate Area.**

- In case of **Neck Area** the problems are **Flash on Support Ring**, **Short Shot (Not All Cavities), and White Spots.**

4.1.1.1 Flash on Support Ring which is a large disk of material has leaked from the mold at the joint between the lip cavities and the injection cavity. It may sometimes be accompanied by other flashing either at the thread or the top surface of the neck. And caused by:

a. **Shot Size Too Large** is solved by reducing the shot size, for machines fitted with sensors, adjust the screw charge confirmation sensor forward a little using the hand screw. For machines fitted with electronic injection control systems, decrease the value of the shot size parameter on the injection control screen. For machines fitted with sensors, check that the locking screws are tightened after adjusting the sensor position. It is possible that vibration is causing the sensor to move.

b. Holding Pressure Too High this problem is solved by reducing holding pressure, on machines fitted with five-step electronic injection control, steps 4 and 5 operate as holding pressure. Simply reduce the setting of each point in steps of about 0.5Mpa, and then check the preform quality. On machines without electronic injection control, hydraulic valve found on the operator side of the injection unit is used to control the holding pressure. During the holding pressure time, turn the handle anti-clockwise while looking at the injection cylinder pressure gauge. After adjusting hydraulic valves, always tighten the locknut to prevent the setting from changing.

c. **Frozen Gate On Another Cavity** Some machines and hot runner systems do not have any means of adjusting the hot runner nozzles. In this case, it may be necessary to adjust the Hot Runner block and barrel settings to achieve the desired effect. Where fitted, adjust each Hot Runner nozzle zone upward in steps of around 5ºC. If there is a problem maintaining the correct temperature, use a clip-on ammeter to test all heaters are working correctly and check the calibration of the instruments.

4.1.1.2 Short Shot (Not All Cavities) which is the top of the preform neck is missing due to under filling of the cavity. This may appear on one cavity only or may be on all cavities. When it is a severe case on one cavity only, this may cause flashing on other cavities. And caused by:

a. **Shot Size Too Small** is solved by machines fitted with sensors; adjust the screw charge confirmation sensor back a little using the hand screw. For machines fitted with electronic injection control systems, increase the value of the **shot size** (S/S) parameter on the injection control screen.
b. **Holding Pressure Too Low** is solved by on machines fitted with five-step electronic injection control; steps 4 and 5 operate as holding pressure. Simply increase the setting of each point in steps of about 0.5Mpa, then check the preform quality. On machines without electronic injection control, hydraulic valve found on the operator side of the injection unit is used to control the holding pressure. During the holding pressure time, turn the handle clockwise while looking at the injection cylinder pressure gauge.
c. **Cushion Too Small** is solved by For machines fitted with sensors (most ASB Series), adjust the screw charge confirmation sensor and V/P point sensor back a little using the hand screws. For machines fitted with electronic injection control Systems, increase the value of the shot size and V/P parameters on the injection control screen.

4.1.1.3 White Spots on Neck which is Small fuzzy white spots of crystallized PET appears in the neck. They are normally seen on the lip cavity parting line and at 90º to the parting line. They are most common in containers that have necks with sudden changes in thickness (traditional glass design liquor neck is common example). And caused by:

a. **Filling Speed Too Fast For Neck Design** is solved by machines fitted with electronic injection control, reduce the velocity percentage value on the injection screen of the electronic injection control system. Minimum usable value is typically around 15~17% but beware of making a short shot at very low settings. For machines without electronic injection control, reduce the setting of the valve found on the operator side of the injection unit. Beware of making a short shot at very low settings.

b. **Blocked Venting In Lip Cavities** is solved by Stop the machine and manually operate the valves required to eject preforms, this will differ according to the machine model. Use a brass rod or spacer block between the lip plates to protect your fingers in case of accidental closing. Use paper or cotton cloth with a degreasing solution to wipe between the face of the lip cavities and plates. Take care, the corners of lip cavities can be very sharp. Close the lip plates and apply fresh lubrication to all sliding parts of the mold before re-starting the machine.

c. **PET Not Dried Correctly** is solved by check the:
   - **Airflow** - Most common problem is a blocked process filter, but also check blowers are operating correctly and the delivery hoses have not been squashed.
   - **Temperature** - Confirm process air temperature is correct on the display panel. The regeneration air temperature is not so easy to check since most regeneration controllers are hidden away in the electrical panel.
   - **Time** - If you know the capacity of the hopper in liters, you can calculate the PET quantity using a figure of 0.84kg/L as the bulk density. Compare this figure (kilograms of PET) against the current consumption of PET by the machine in kg/hr. If you are not sure, the safest method is to switch off the hopper loader and check the time necessary for the material to be consumed.
   - **Dewpoint** - Use a commercially available dewpoint meter to sample the air coming from the desiccant chamber. Typical vales may be anything between -20ºC and -50ºC. Check the manual for correct specification. In machines with more than one desiccant chamber, be sure to check all of them.

➢ In case of **Preform Body** the problems are **Bubbles, Sink Marks (Outside) and Uneven Wall Thickness.**

4.1.2.1 Bubbles, which are Bubbles of gas appear in the body and / or neck of the preform.

It is relatively common to see a few bubbles in the first few cycles of operation, however if the problem persists for more than 10 cycles, then it is likely that a real problem exists. And caused by:

a. **Too Much Suck Back (Where equipped)**, is solved by Reduce Suck Back.
b. **Injection Barrel Nozzle Alignment**, is solved by Loosening the fixing bolts holding the injection unit Carefully and evenly adjust jacking bolts on each side of the injection unit to set the vertical alignment. Check the horizontal alignment by viewing the injection unit from above, there is enough clearance around the fixing bolts to allow the injection unit to move a little each way.
c. **Insufficient Screw Back Pressure**, All machines have a pressure relief valve on the operator side of the injection unit. To increase the back pressure, theis valve should be screwed in slightly. The screw back pressure will be observable on the injection unit pressure gage during screw charging.

4.1.2.2 Sink Marks (Outside) which is The preform has an uneven appearance. The outside of the preform wall has sink marks in it. Do not confuse this fault with internal sink marks. It is common to see this fault on the first one or two shots after a start-up from cold because decomposed material will have come from the hot runner. And caused by:

a. **Holding Pressure Too Low** as mention before.

d. **Holding Time Too Short** is solved by, increase the injection time in the timer display, or increase injection velocity.
e. **Chilled Water Temp. Too High**, Most chillers have a simple digital controller for temperature, this problem solved by try lowering it in steps of around 2ºC until the problem is eliminated. If the chiller is supplying more than one molding machine, check that the process of the other machine(s) has not been upset.

4.1.2.3 Uneven Wall Thickness which is Preform thickness varies. For a preform thickness of 3.0mm, the normal variation should be less than 0.1mm (2.95mm ~

3.05mm). For thinner preforms, the variation is **more** critical, for thicker preforms the variation is **less** critical. Measurements should be taken at the tip of the preform (just before the gate radius) to maximize the observable error, and at 6~8 points around the preform. And caused by:

a. **Injection Core Bent** is solved by Remove the chilled water from the injection cores, then loosen the Injection Core Fixing Plate 'A'. Open the Upper Mold fully then rotate the appropriate injection core, it should be possible to do this by hand but if the mold has been assembled on the machine for a long time with inadequate servicing, then it may have become tight. Carry out a standard re-alignment procedure and re-tighten the fixing plate, and then re-start the machine.
b. **Worn Or Damaged Lip Cavity** Once you have the lip plate on the bench, split the halves by removing the return rod assemblies and remove all fixing screws from the cavity to be replaced. Thoroughly clean the seating area of the lip plate. Install a new lip cavity set in the same orientation as the others, i.e. Thread start and cavity identification mark should be in the same direction. Do not tighten the fixing screws yet. Lay each lip plate on a surface table with the mating face poining downwards. Tap the plate and cavity down firmly with a plastic hammer and tighten the fixing screws a little. Repeat the tapping and tightening until screws are fully tight.
c. **Ensure Correct Injection Mold Alignment** is solved by all machines; correct alignment relies on first having perfectly clean and smooth mating faces. Before fitting the mold, thoroughly clean the platens then use a flat oil stone to remove any damage, corrosion etc from the faces. Slide the mold into position carefully, taking great care to ensure that no dust or other contamination gets between the faces.

- In case of **Gate Area** the problems are **Broken Gate, Frozen Gate, And String.**

4.1.3.1Broken Gate which is Part or the whole of the gate of the preform has broken. The broken part remains in the cavity gate causing a blockage so that the next cycle has one preform missing. And caused by:

a. **Holding Pressure Too Low** as mention before.

b. **Damage in Gate Area**, is solved by most likely that the injection cavity block will require removal from the machine, removal procedure will vary according to the model. If the damage is not too severe, it may be possible to use fine abrasive materials to polish out the damage. Typically, it will be necessary to replace the individual injection cavity with a spare and have the damaged one professionally repaired. Removal will probably require a hydraulic press due to corrosion and scale deposits in the water cooling channels.
c. **Bad Cooling in Cavity Base**, The cooling water for this area comes from the cooling tower, not the chiller. This water is generally of a lower quality than the chilled water because it is not a closed loop. Remove the pipes from the plate and blow air through the cooling channels. If there appears to be some restriction, remove the plate from the machine for proper cleaning.

4.1.3.2 String which is fine fiber is extending from the gate of the preform around 30 to 150 mm in length. It is likely that the fiber will become wrapped around the preform leading to ugly lines around the finished bottle. And caused by:

a. **Holding Pressure Too Low** as mention before.
b. **Lower Mold Opening Too Slow**, Check your machine instruction manual for the timer named "Lower Mold Open Fast Start" (its number may vary slightly between certain machine models). Try reducing the value slightly (if it is reduced too much, the lower mold may open with a slight bang and this should be avoided wherever possible).
c. **Hot Runner Nozzle Too Hot**, Some machines and hot runner systems do not have any means of adjusting the HR nozzles. In this case, it may be necessary to adjust the HR block and barrel settings to achieve the desired effect. Where fitted, adjust each HR nozzle zone downward in steps of around 5ºC. If there is a problem maintaining the correct temperature, use a clip-on ammeter to test all heaters are working correctly and check the calibration of the instruments.

4.2. Container Blowing has three areas to consider **Shoulder Area, Container Body and General Quality.**

- In case of **Shoulder Area** the problems **are Constriction, Grainy Appearance and Neck Rings.**

4.2.1.1**Constriction**, which is a fold has appeared in the shoulder region of the bottle that has created a constriction. This may appear just under the neck or may be nearly into the body of the bottle. These are typically caused by bad blow settings, or because the body of the preform has inflated too easily relative to the shoulder. And caused by:

a. **Primary Blow Too Late,** is solved by:

1. Increase the setting of the Secondary Blow Delay timer to the same or more than the Blow timer. This will prevent the Secondary Blow from taking place.
2. Reduce the Primary Blow Delay time to 0.0 seconds.
3. Start the machine, allow the preform temperature to stabilize, then turn on the blow mold. Take a sample then increase the Primary Blow Delay setting, this should be about 0.05~0.1 seconds per step. Collect a sample container at each step, mark it and place it on a table. At some point, the container quality will go bad; typically this will be a constriction mark around the shoulder area. There is no point in going any further once this happens and it is possible that a stretch rod tip may be broken if you continue.
4. Stop the machine and study the sample bottles produced, it is likely that the quality will have gone through a range as shown by the red curved line, somewhere around the middle setting, the best formed bottle will be seen. This is the optimum setting for the Primary Blow Delay timer.
5. After the Primary Blow Delay has been optimized, you should then optimize the Secondary Blow Delay setting.

Referring to the chart figure 4.1

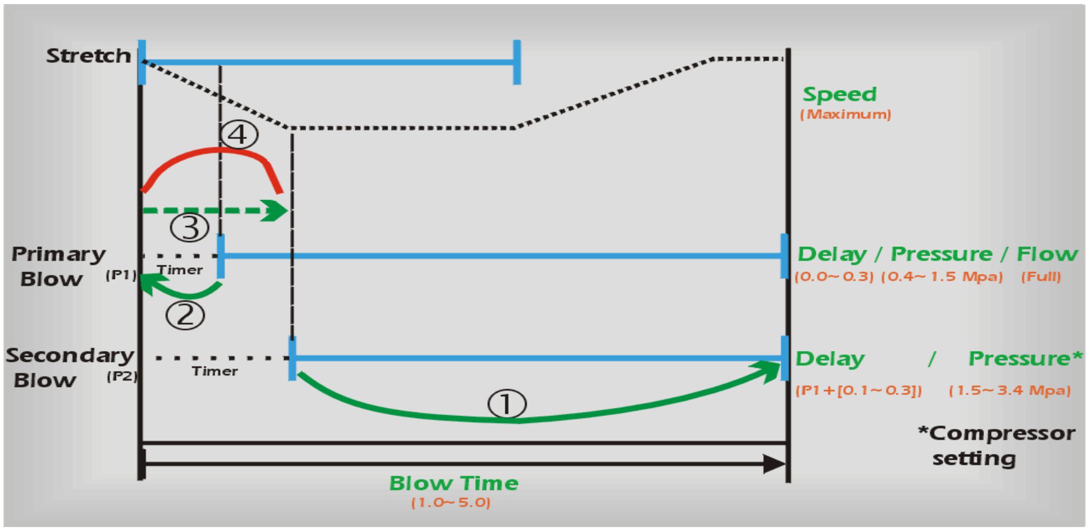

Figure 4.1 Primary and Secondary Blow [1]

b. **Primary Blow not operating,** is solved by: Increase the setting of the Secondary Blow Delay timer to the same or more than the Blow timer. Check the blown container, if Primary Blow is working correctly it should be 70~90% blown. If the preform comes out unblown, then some part of the Primary Blow system (valve, relay etc.) is not operating correctly.

c. Preform Generally Too Hot, is solved by Adjust the Temperature or Heating Time in the Conditioning Station**.**

4.2.1.2 Grainy Appearance, which is the shoulder area of the container appears to have criss-crossing grainy lines. This mark is typically associated with a constriction in a very mild form. And caused by:

a. **Primary Blow Too Late** as mention before.
b. **Wall Thickness Too Much,** There are two major methods of doing this:

In the first method, injection velocity is used to control the temperature balance of the preform. Since most of the retained heat from the injection process is used in the blowing of the container, this method can have dramatic effects on the finished container.

- Filling the injection cavity faster will have the effect of making the shoulder portion of the preform relatively cooler resulting in a container having a thicker shoulder area and a thinner heel.
- Filling the injection cavity more slowly will allow less cooling time for the shoulder area of the preform (relative to the base) leading to thinner shoulders and a thicker heel.

This method is more critical where the preform is relatively long. Shorter preforms show less response. The second method uses temperature adjustment at the conditioning station. The method of adjusting preform temperature depends on the type of conditioning system fitted.

4.2.1.3 **Neck Ring**, which is a band of thick material just below the neck. This material has not been stretched out correctly and is typically a result bad blow delay settings or a preform with a body section that is too hot. And caused by:

a. **Heating Piece Operation Not Correct,** is solved by:

1. Visually confirm the correct fitting of the Heating Piece.
2. Slowly adjust the voltage regulator from 0 volts up to maximum. If the heater is connected and working, the voltage indicator will increase smoothly. If the movement suddenly steps from low to high voltage, then the heater may be broken or disconnected.
3. The timer is named "Core Down" and is typically timer number 11. Use the voltage regulator instrument to control the temperature. Judge the correct voltage setting by observing the condition of the bottle.

b. **Preform Body Too Hot at Blowing,** is solved by:

1. Reduce the injection time setting in the timer display unit.
2. Most chillers have a simple digital controller for temperature; try lowering it in steps of around 2ºC until the problem is eliminated.

c. **Secondary Blow Too Early,** is solved by :

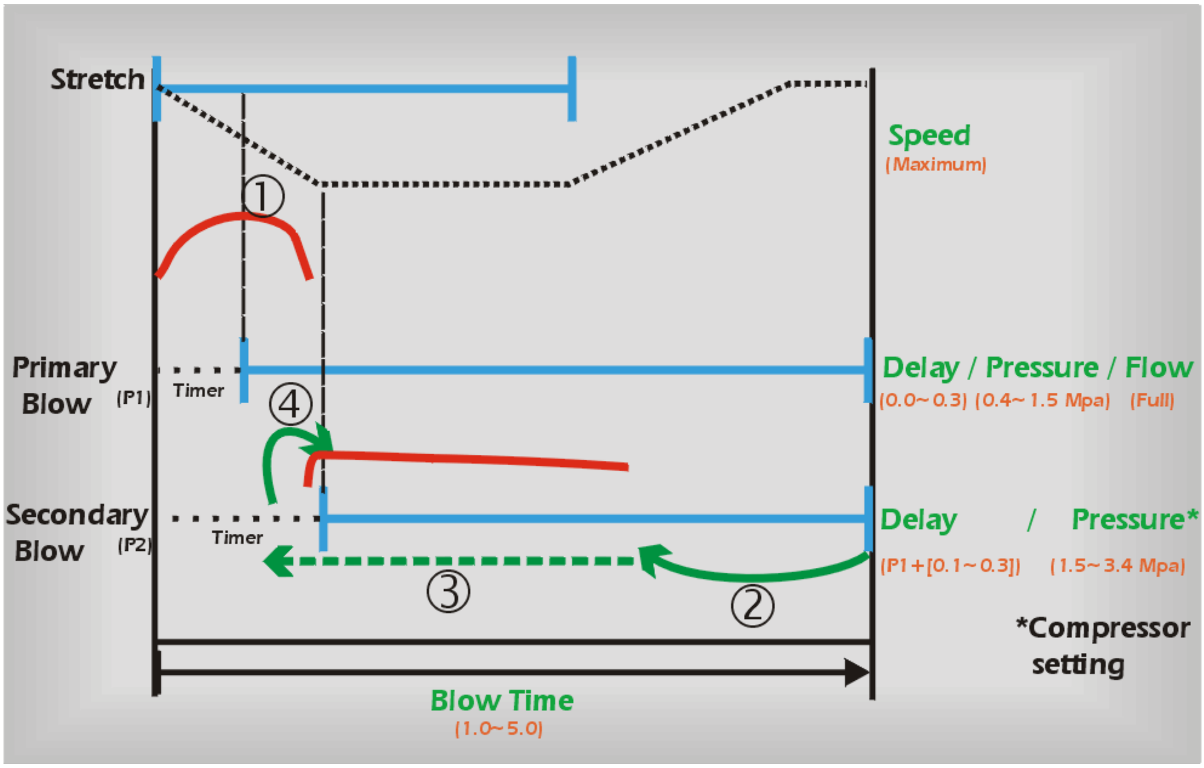

Figure 4.2 Primary and Secondary Blow [1]

1. After the Primary Blow Delay time has been set to give the best blown bottle using Primary Air only, the machine should be re-started.
2. Reduce the Secondary Blow Delay setting from its long setting to a setting of about 0.5~0.8 seconds.
3. While blowing bottles, decrease the Secondary Blow Delay setting in steps. For an ASB Series machine, this should be about 0.1 second per step. Collect a sample container at each step, mark it and place it on a table. At first, there will appear to be no or very little difference in the containers but on close inspection you should be able to see improvements in the definition of ribs, logos and corners. At some point, the container quality will go bad, typically this will be an off center gate or a neck ring. There is no point in going any further once this happens

and it is possible that a preform will split leaving fragments of PET in the mold if you continue.

4. Once the quality has turned bad, slightly increase the Secondary Blow Delay setting a little until the container quality comes good again. This is the optimum setting for the Secondary Blow Delay timer.

- In case of **Container Body** the problems are **Haziness, Small Lumps Inside and Uneven Wall Thickness (Circumferential).**

4.2.2.1Haziness, when held to the light, the container is not perfectly clear, a grey / white cloudiness is visible. This is a mild form of crystallization that becomes visible in the blown container, even though the preform may appear to be clear. And caused by:

a. **PET Resin Not Dried Correctly,** Airflow - Most common problem is a blocked process filter, but also check blowers are operating correctly and the delivery hoses have not been squashed.
b. **Preform Temperature Too High**; Reduce the injection time setting in the timer display unit.

4.2.2.2 Small Lumps Inside, The material has internal lumps looking similar to drops of water. And caused by:

a. **Water In The Blow Air**, is solved by:

   1. The compressor system should have an air drying system installed, ensure that it is maintained in good condition.
   2. Each day, especially in humid weather conditions partially open the drain valve installed on the air tank inside the molding machine. If your machine does not have an air tank, use another point for partial draining.

b. **Contaminants In The Blow Air,** Most compressor systems are fitted with particle filters down to 1 micron. However, if the pipe work from the compressor is dirty due to corrosion (from moisture in the air), then it is still possible for contamination to reach the molding machine.

4.2.2.3 Uneven Wall Thickness (Circumferential), Preform thickness varies. For a preform thickness of 3.0mm, the normal variation should be less than 0.1mm (2.95mm ~ 3.05mm). For thinner preforms, the variation is more critical, for thicker preforms the variation is less critical.. And caused by:

a. **Injection Core Bent**, as mention before.
b. **Mold Not Aligned Correctly**, for all machines, correct alignment relies on first having perfectly clean and smooth mating faces. Before fitting the mold, thoroughly clean the platens then use a flat oil stone to remove any damage, corrosion etc from the faces. Slide the mold into position carefully, taking great care to ensure that no dust or other contamination gets between the faces. Machine molds use dowel pins to locate the correct position of the cavity / hot runner assembly. Therefore, no special alignment should be necessary between these two parts. However, this assembly must be aligned around the Lip Cavities which form the central point of an mold. In addition, the injection core assembly rely on the taper locking of the mold to pull the mold into alignment during the first closing of the mold.
c. **Injection Velocity Too High**, For machines fitted with electronic injection control, reduce the velocity percentage value on the injection screen of the electronic injection control system. Minimum usable value is typically around 15~17% but beware of making a short shot at very low settings. For machines without electronic injection control, reduce the setting of the valve found on the side of the injection unit. Beware of making a short shot at very low settings.

- In case of **General Quality** the problems **are Low Top Load Strength, Low Capacity and Stress Cracking.**

4.2.3.1 Low Top Load Strength, when a top load is applied to the container, an unacceptably low result is obtained before initial collapse of the container.

Note, this fault only applies to those conditions where the top load test results have been correct but have now deteriorated, and not to containers that have intrinsically low test results. Good top load resistance is achieved by a combination of correct processing, but more importantly, by good design and correct weight. And caused by:

a. **Preform Too Hot When Blown,** is solved by:
    1. Reduce the timer setting for injection.
    2. Most chillers have a simple digital controller for temperature; try raising it in steps of around 2ºC until the problem is eliminated.
    3. Increase the injection time setting in the timer display unit.
    4. Adjust The Temperature Or Heating Time In The Conditioning Station.

b. **PET Resin Not Dried Correctly,** as mention before.

c. **Bad Quality PET Resin,** Assuming that you have checked everything else first, the easiest way to check is to exchange the bag of material for another one of the same maker and grade but having a different batch number. If this is not available, use the closest equivalent material that you can find. Before changing over the material, make sure that samples from the suspect batch are kept and make sure that no processing changes are made in the machine, It is important to clearly understand the performance of each material so precise records should be taken of reject levels for several hours or days before and after the change. Cool the material in the hopper to around 100ºC before emptying it. Exposing very hot material to ambient air can allow hydrolysis to occur. Refill the material with the fresh material, wait four hours then start the machine.

4.2.3.2 Low Capacity, the "Fill Point" Capacity, or the "Over Flow" Capacity is lower than the specification. And caused by:

a. **Secondary Air Pressure Too Low**, is solved by Increase Secondary Blow Pressure.

b. **Blow Time Too Short,** is solved by Increase the setting of the blow duration timer, typically this is timer 0.20. When doing this, be aware that the change in blowing time may have adverse effects on the cycle of the machine. I.E. If the blow mold is opening later in the cycle, then it may also influence the movement of the injection molds opening.

c. **Preform Too Cold When Blown,** is solved by:
    1. Reduce the injection time setting in the timer display unit.
    2. Most chillers have a simple digital controller for temperature; try raising it in steps of around 2ºC until the problem is eliminated.

3. Increase the injection time setting in the timer display unit.

4.2.3.3 Stress Cracking, Stress cracking will often lead to failures in burst pressure testing, and normally occurs in the amorphous (unscratched) parts of the preform at the neck or in the base, adjacent to the gate. The fault may occur in any container, especially those used for chemicals.. It can be observed as a "crazing" effect, where minute, multiple cracks may cause a silver appearance in the material when light is refracted through it. And caused by:

a. **Preform Stretched When Too Cold,** is solved by:
   1. Reduce the timer setting for injection.
   2. Most chillers have a simple digital controller for temperature; try lowering it in steps of around 2ºC until the problem is eliminated.
b. **PET Resin Not Dried Correctly,** as mention before.
c. **Stretch Rod Stopper Incorrectly Adjusted**, The procedure will vary slightly according to the specification of the machine
   1. Turn off the operation air and manually operate the valve for blow core down and stretch rod down.
   2. Drain the remaining operation air from the system.
   3. Turn the blow mold select switch to the OFF position and operate the blow mold close switch (this will bring the bottom mold up but the blow mold will stay open)
   4. Check the gap between the stretch rod tip and the bottom mold.

   The gap should typically be around 1.0 to 1.5 mm or just enough to lightly pinch the material in the gate area

4.3. Lowered I.V has two consider **Preform and Container.**

Although Lowered I.V. is one of the most common molding problems, it can also be one of the most difficult to diagnose. This is mainly due to the fact that the symptoms will vary according to the bottle being made and the severity of the Lowered I.V.

- In case **of Preform** the problems are **Flash On Thread**, **Flash On Top Of Neck** and **Haziness (Clouds & Swirls)**.

4.3.1.1 Flash on Thread, A thin film of flashed resin that has ocurred between the parting line of the lip cavities, running along the axis of the preform. It may sometimes be accompanied by other flashing either at the top surface of the neck or at the support ring. And caused by:

a. **Holding Pressure Too high,** as mention before.
b. **Shot Size Too Large**, for machines fitted with sensors, adjust the screw charge confirmation sensor forward a little using the hand screw. For machines fitted with electronic injection control systems, decrease the value of the shot size parameter on the injection control screen.
c. **Contamination between Lip Plates**, Stop the machine and manually operate the valves required to eject preforms, this will differ according to the machine model. Use a brass rod or spacer block between the lip plates to protect your fingers in case of accidental closing. Use paper or cotton cloth with a degreasing solution to wipe between the face of the lip cavities and plates. Take care, the corners of lip cavities can be very sharp. Close the lip plates and apply fresh lubrication to all sliding parts of the mold before re-starting the machine.

4.3.1.2 Flash On Top Of Neck, A thin film of material has escaped from the mold at the joint between the Injection Core and the Lip Cavity. This may appear as a disk or a vertical extension of the neck depending on the design of the mold parts in this area. This fault may be accompanied by flash on the thread or at the support ring. And caused by:

a. **Holding Pressure Too high,** as mention before.
b. **Shot Size Too Large,** as mention before.
c. **Upper Mold Not Closing Fully,** is solved by Close the Upper Mold, you will note that the platen touches the stopper. Put the switch to neutral and close the lower mold. When the Lower Mold is fully closed it will push up on the Rotary Table and will lift the Upper Mold Slightly. Check the gap that is created between the stopper and the Upper Platen. The gap should be between 0.1~0.2mm.

4.3.1.3 Haziness (Clouds & Swirls), the preform has a white, hazy appearance that is made up of streaks, swirls and clouds in some parts or the entire body. This may be very slight or may be so strong that the body is nearly opaque. Typically, the neck and the tip of the preform will be clear but in extreme cases, the swirls will appear here also. This fault will probably be accompanied by string in the gate. Take care not to confuse this fault with consistent haziness. It is normal to see this fault on the first one or two shots after a start-up from cold because decomposed material will have entered the cavity from the hot runner. Do not recycle preforms since they will have a lowered I.V.

- In case of **Container** the problems are **Crater, Gate off Center and Stretch Rod Makes a Hole.**

4.3.2.1 Crater, a large fold has appeared in the base of the bottle, this type may be a larger diameter than full crater. It is caused mainly by incorrect preform temperature but improper settings in timers and air flow may also have some effect. And caused by:

1. **Primary Blow Timing Incorrect**, as mention before.
2. **Primary Air Pressure Incorrect**, is solved by:

    1. Referring to Optimize Primary Blow Time, increase the time delay of Secondary Air to the same as the blow time. This will prevent the secondary air from starting so that the Primary Air inflation can be more easily observed.
    2. Reduce the Primary Air Pressure to around 0.3~0.4 MPa (3~4 Kg/cm^2), then start the machine.
    3. Wait for the preform temperature to stabilize, then turn on the blow mold.
    4. Collect a sample bottle, make a note of the pressure used, then increase the pressure by 0.1 Mpa (1kg/cm^2) and repeat the sample collection.
    5. Continue this until the pressure has reached around 2.5 Mpa (2.5 kg/cm^2) or the inflation of the preform becomes uncontrolled.

3. **Preform Body Temp. Too High,** is solved by:

    In the first method, injection velocity is used to control the temperature balance of the preform. Since most of the retained heat from the injection process is used in the blowing of the container, this method can have dramatic effects on the finished container.

1. Filling the injection cavity faster will have the effect of making the shoulder portion of the preform relatively cooler resulting in a container having a thicker shoulder area and a thinner heel.
2. Filling the injection cavity more slowly will allow less cooling time for the shoulder area of the preform (relative to the base) leading to thinner shoulders and a thicker heel.

This method is more critical where the preform is relatively long. Shorter preforms show less response. The second method uses temperature adjustment at the conditioning station. The method of adjusting preform temperature depends on the type of conditioning system fitted.

4.3.2.2 Gate off Center, The gate of the preform is not in the center of the bottle base. There are many possible causes of this fault. And caused by:

a. **Stretch Rod Speed Too Slow,** is solved by try increasing the flow controller up to its maximum setting. If this does not cure the problem, try fitting a quick release valve.
b. **Primary Air Flow Too High,** most machines are fitted with one flow controller per cavity. In a large machine with a multi cavity mold, it may be found necessary to reduce the flow to the center cavities only since the Primary Blow Air flows into the center of the manifold. Take samples off the machine blown only at primary pressure and adjust the flows to achieve equal blow up on all cavities.
c. **Broken Or Missing Stretch Rod Tip,** is solved by Stop the machine and visually check the condition and design of all stretch rod tips. All molds use a spring pin to retain the tip so removal of any broken parts is relatively easy, however, very old molds may have a screw-in type.
   To remove the broken end of a screw in type, heat up a piece of square-section steel and melt it into the broken end. It should be then possible to remove the broken piece by unscrewing.

4.3.2.3 Stretch Rod Makes A Hole, During blowing, the stretch rod punches a hole through the base of the preform. And caused by:

a. **Stretch Force Too High,** Although neither are a standard fitted part, there are two ways to achieve this.
    1. Replace the stretch rod cylinder with one of a smaller diameter. This will lessen the force being exerted on the preforms for a given air pressure.
    2. Install a pressure regulator on the feed line to the stretch cylinder. Use this to reduce the stretch force being applied. Do not go below about 0.4 MPa (4 kg/cm^2) otherwise the cylinder will not return to to up position correctly.

b. **Primary Air Flow Too Low,** Take samples off the machine blown only at primary pressure and adjust the flows to achieve equal blow up on all cavities.

Chapter five

Conclusion and Recommendation

Chapter five

5.1 Conclusion:

It has been found that the production problems in the preform are the lowered intrinsic viscosity (I.V.) and the flash on the thread, for Flash on Thread it was the most one happened and the solution was reducing holding pressure.

The second problem in the sink marks (outside). The solution to this is to increase holding pressure. There should be compromise to solve both problems.

The Container Blowing problems, are Uneven Wall Thickness (Circumferential), its solution was to reduce the velocity percentage value on the injection screen of the electronic injection control system.

5.2. Recommendation:

There is increased demand for PET bottle in pharmaceutical and cosmetics and soft drinks factories, this leads to the need for well trained operators to operate the machines. Training in this field is recommended.

The use of plastic containers made from the most widespread PET has caused a huge amount of damaged packages. We recommend a study to take advantage of them in recycling and manufacturing again to produce plastic bottles.

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Appendix

IPCC

PET BG-800 (Bottle grade)

(POLYETHYLENE TEREPHTHALATE)

1) Product Description:

Polyethylene Terephthalate bottle grade chips (highly viscous) is a condensation polymer produced by a continuous meltphase polymerization process followed by a solid state polymerization process ,with an I.V of 0.75-0.85 .The products has an excellent transparency and gloss ,an outstanding gas barrier against oxygene and carbon dioxide,and outstanding toughness and impact strength**.**

2) Applications:

-CSD
-Carbonated Water
-Edible Oil
-Alcoholic Beverage
-Pharmaceuticals
-Wide Mouth Jars
-APET sheet
-Strapping

3)Typical Data

Parameter	**Unit**	**Typical Value**	**Test method**
Intrinsic Viscosity(IV)	dl/gr	0.80±0.02	Ubbelhode
DEG Content	%wt	Max1.5	GC
Color(CIE Lab)	L	>90	Spectroscopy
	b	<2	
Carboxyl End Group	meq/gr	Max 32	ZIMMER WN-B010-7090E
Melting Point	ºC	248±2	ZIMMER WN-B010-7089E
Acetaldehyde (AA)	ppm	<1	ZIMMER WN-B010-9013E
Water Content	%wt	<0.3	ZIMMER WN-B010-7089E

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Sales Specifications

Product: Polyethylene Terephthalate (PET) Polymers - Copolymer

RAMAPET N1

Sl. No	Property	Unit	Specifications	Test Equipmet
1	Intrinsic Viscosity	dl/g	0.80 ± 0.02	IR-001 (Ubbelohde Viscometer)
2	Acetaldehyde	ppm	1 Max.	IR-002 (Gas Chromatograph)
3	Melting point	°C	247 ± 2	IR-003 (Differential Scanning Calorimeter)
4	Color b		-1.5 ± 1.5	IR-004 (CIE Lab)
5	Crystallinity	%	50 Min.	IR-005 (Density Gradient Column)
6	Moisture content (when packed)	wt %	0.2 Max.	IR-006 (Gravimetric Method)
7	Chips / gm	pieces	60 ± 5	IR-007 (Weighment Method)

Description

RAMAPET N1 is a General purpose food grade PET copolymer resin that is suitable for a wide variety of containers. The resin offers good strength characteristics like dimensional stability and mechanical properties. Suitable for Carbonated water, Alcoholic beverages, Pharmaceuticals, Oils, Agrochemicals, wide mouth containers and for APET sheet / Film extrusion application. It is also suitable for heat set blow molding that are used for warm fill applications

RAMAPET N1 resin is considered safe for food packaging applications based upon compliance with FDA regulation 21 CFR Section 177.1630, EC Directive 2002/72/EC & EC Directive 2004/19/EC amendment, EC Directive 94/62/EC and the CONEG Regulation (Heavy metals).

Warranty

Indorama warrants that its products will comply with the specifications and related regulatory compliance detailed in its publications. No other warranty, either expressed or implied regarding the suitability of the product for any particular purpose is made. The buyers are expected to make their own determination about the safety, health, environmental protection and suitability of use for their intended purpose. No warranty is made of the merchantability or fitness of any product and nothing herein waives any of the seller's conditions of sale.