THESIS

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Hungarian University of Agriculture and Life Science
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Mechanical Engineering BSc

PURGING COMPOUNDS FOR EXTRUSION

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INSTITUTE OF TECHNOLOGY MECHANICAL ENGINEERING (BSC)
Machine Production Technologies

THESIS

worksheet for

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(BSc) student

Entitled:

Purging Compounds for Extrusion

Task description:

Reducing waste and machine downtime with the use of purging compounds and liquids. Purging compounds for extrusion, and injection molding.
Department: Institute of Technology

Consultant:.

Supervisor: *Dobos József Associate Professor,* MATE, Institute of Technology

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Approved		**Received**
(head of department)	(host course leader)	Dilma Gomes (student)

As an independent consultant of the author of this thesis I hereby declare that the student took part in the planned consultations.

Gödöllő, day month 2023.

(Consultant)

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1. Introduction

Purging compounds are machine cleaning agents that help reduce machine downtime and increase the machine's productivity without much work or loss of time.

This paper will highlight the purging compounds, and the different types, including the advantages and benefits of using purging compounds for extrusion and injection molding. Therefore, this paper will also emphasize the extrusion and injection molding processes, the different types, the applications, advantages, and disadvantages.

Engineers frequently use the extrusion process in mechanical engineering to create objects with fixed cross-sectional areas. The raw material is forced into a die during the creation of the object to give it the desired shape. Since only shear and compressive stress are encountered during the extrusion process, the main benefit of this method is that brittle materials can be easily transformed into the desired product. Extrusion can be used to create hot or even cold materials, and it can be argued that it is a semi-continuous or even continuous process. (Noaman Adenwala 2023)

Extrusion is a type of metal forming process in which dies are used to modify the shape of the metal piece using an external compressive force. Different complex shapes are created using this method. Extrusion can be divided in general into two types: hot extrusion and cold extrusion. (Noaman Adenwala 2023)

Extrusion molding’s high output and long runs can lead to elevated scrap rates during prolonged changeovers with protracted gaps in between production runs. Fortunately, there are adaptable purging compounds for extruders that are engineered for performance and designed to overcome the difficulties extrusion molders encounter. (**http1**)

A purging compound is a resin-based product used to clean thermoplastic molding machines of different types, such as injection molders, blow molders, and extruders. (**http2**)

The majority of thermoplastic producers use a purging compound to clean the screws, nozzles, mold, hot runners, and die of injection molding and extrusion machines. As an alternative to purging with virgin resin, purging compounds were created to reduce machine downtimes and scrap rates during material or color changes. Emulsifiers, abrasives, and foam agents are among the components in purging compounds, which accelerate the removal of contamination from the barrel. Purging compounds were created for this purpose. Instead of

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using resins and regrinds that are intended to be molded into parts rather than pushing impurities out of the system, purging compounds are faster and more effective. Purging compounds can be mechanical, chemical or liquid. (Andres Rodriguez, 2020a)

A Purging Compound:

- Reduce Scrap - Eliminate leftover resin and color residues from previous production to reduce waste production. The factory's productivity and efficiency increase as a result.

- Reduce downtime - Reduces the amount of time spent changing resins.

- Remove Contamination - During production changeovers, their chemical components assist in removing gels, color streaks, and carbon residues. This decreases the factory rejection rates and prevents obtrusive production related machine stops.

- Avoid Screw Pulls - Eventually, it will be necessary to remove the screw to perform a manual cleaning if the machine is not properly cleaned.

- Decontaminate the hot runners of any contamination - Due to obstinate color residues inside the hot runners, some injection molding changeovers might take longer. Purging materials that can be used through the mold safely are now available. In this situation, liquid purging compounds are specifically helpful.

- Decreases the rate of rejections – It can be avoided to have the product rejected by the quality team or have difficult orders returned by the customer by thoroughly cleaning the machine after changing the material or color or after a lengthy shutdown.

- Produce good results without costing a significant amount of money - By minimizing downtime and scrap during color and material changes, purging compounds help to reduce costs. All factors, including material, machine, labor, scrap, customer satisfaction, lost production, and purging compound cost, must be taken into account when evaluating this solution. (Andres Rodriguez 2020a)

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2. Literature Review

2.1 Extrusion Process

Extrusion can be shortly defined as a compressed metal forming process. A piston or plunger is used in this process to apply a compressive force to the workpiece. A billet or ingot (a metal workpiece of standard size) is offered initially. In an extrusion press (which works similar to a piston-cylinder device in which the metal is placed in a cylinder and pushed by the piston), this billet is heated in hot extrusion or remains at room temperature. A die is attached to the cylinder's upper portion. ((Saif M 2022)

A plunge installed in the press immediately applies a compressive force to this component, forcing the billet to the die. The die is the required cross-section's small opening. Thanks to the strong compressive force the worked metal can flow through the die and take on the desired shape. The extruded part is then pull out of the press and heated to improve its mechanical properties. (Saif M 2022)

By enclosing the metal in a closed chamber with one hole made through a die, the extrusion method subjects the metal to plastic flow. The material is typically treated so that it can withstand plastic deformation at a rate that is fast enough and can be extracted from the die-hole. During the process, the metal passes through the die's opening and emerges as a long piece with a cross-section identical to the die opening. The provided metal piece has a longitudinal grain flow. (Saif M 2022)

Extrusion is most commonly used to produce solid and hollow sections of nonferrous metals and alloys such as aluminium, aluminium-magnesium alloys, magnesium and its alloys, brass, copper, and bronze. And extrusion is also used to create some steel products. Cast iron ingots or bullets are the shapes of the stock or material, that will be extruded. Either hot or cold extrusion is possible. (Saif M 2022)

2.1.1 Extrusion Working Principal

In the extrusion process, a plunger or piston provides the necessary force to produce the compressive force. The extrusion process operates on the following principles:

The manufacturer develops an ingot or billet at the beginning of the process that is a standard size; In the case of a hot extrusion process, the billet is then heated to a higher temperature

and stored at room temperature before being pushed through a press; The plunger mounted in the press pushes the billet in the direction of the die to apply the compressive force; To develop the material into the desired shape, the die must first be manufactured at the required shape. The material can take on the desired shape with the help of high compressive force; The material is finally removed from the press, to improve the mechanical properties, the material must then go through the finishing process. (Noaman Adenwala 2023)

2.1.2 Types of Extrusion

The following extrusion processes can be categorized:

Hot Extrusion: The most widely used technique for creating objects with a fixed cross-sectional profile is hot extrusion. By performing the extrusion process at a higher temperature, the materials are kept from processing hardening and the process of forcing the material through the die is simplified. Mainly, horizontal hydraulic presses with a tonnage range of 250 to 12,000 tons are used to perform large-scale hot extrusion. In this case, lubrication is necessary due to the pressure range of 30 to 700 Mpa. (Saif M 2022)

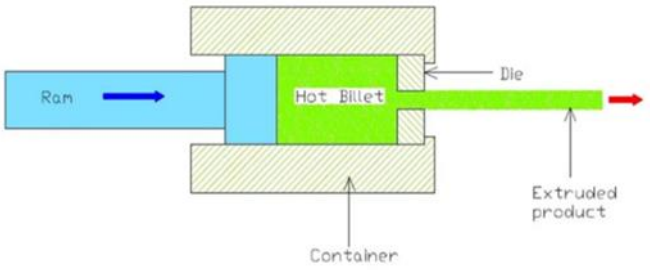

Figure 2.1.1 Hot Extrusion Process. (Noaman Adenwala 2023)

For extrusions at higher temperatures, glass powder can be used as lubrication; for extrusions at lower temperatures, oil or graphite can be used. Hot extrusion has some limitations due to the cost of the extrusion machines and the upkeep of those machines, even though hot extruded material is highly preferred. (Saif M 2022)

Hot extrusion can be divided into two distinct types, forward or direct extrusion and backward or indirect extrusion. (Saif M 2022)

Forward or Direct Extrusion: The material that needs to be extruded in this process is in the shape of a block. It is heated to the necessary temperature before being moved into a chamber. A die with an opening in the shape of the cross-section of the extruded products is mounted in

the front part of the chamber. A follower pad and a ram are used to apply pressure from behind the material block. The heated material is forced to pass through the die opening as a long strip with the required cross-section because the chamber is completely closed on all sides. Although the procedure appears straightforward, the friction between the material and the chamber walls needs to be reduced by using the proper lubrication. (Saif M 2022)

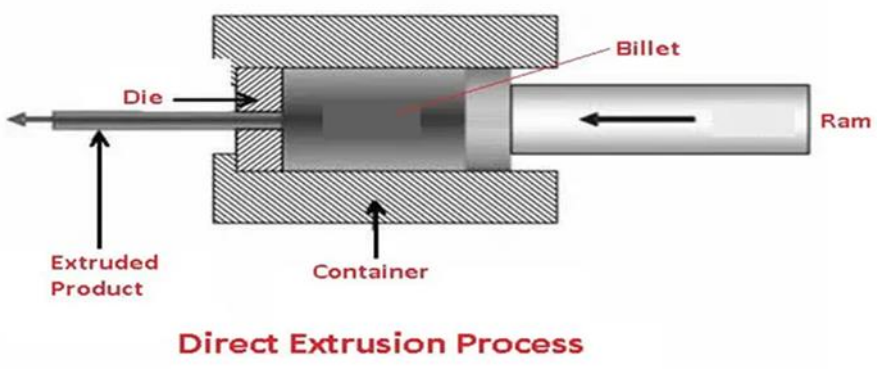

Figure 2.1.2 Forward or Direct Extrusion process. (Saif M 2022)

It is challenging to find a suitable lubricant because steel must be heated to a high temperature before extrusion. By lubricating with molten glass, the issue is identified. A mixture of oil and graphite is used as a lubricant when a lower temperature is applied. (Saif M 2022)

Backward or Indirect Extrusion: The chamber is filled with the heated metal block. Except for the front, where a ram with a die presses on the material, it is surrounded by the container walls. The material must flow forward through the opening in the die when the ram presses backward. The ram is made hollow to allow the extruded metal bar to pass over it without being obstructed. Since the material flow in this process is in the opposite direction from the movement of the ram, it is known as a backward extrusion process. The material flow and ram movement in the forward extrusion process are both in the same direction. (Saif M 2022)

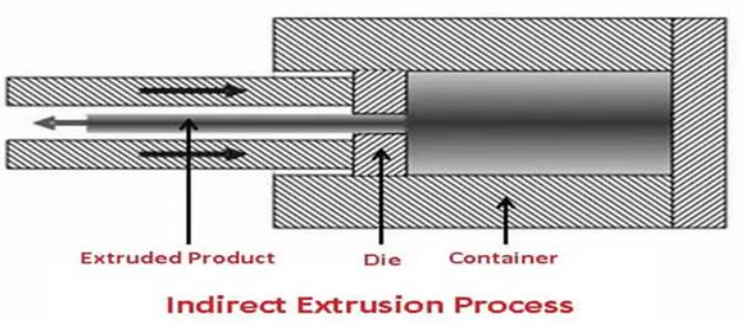

Figure 2.1.3 Backward or Indirect Extrusion process. (Saif M 2022)

Cold Extrusion: The process of cold extrusion is carried out at room temperature or at temperatures that are fairly high with the help of extruders and extrusion machines. These specific devices/machines were created using cutting-edge extrusion technology. (Saif M 2022)

The process of shaping cold metal by striking a slog is known as cold extrusion. The metal is pushed upward around the punch during this strike, which is made with a punch (in a closed cavity). Extrusion pressing, cold forging, cold pressing, and impact extrusion are additional names for this procedure. (Saif M 2022)

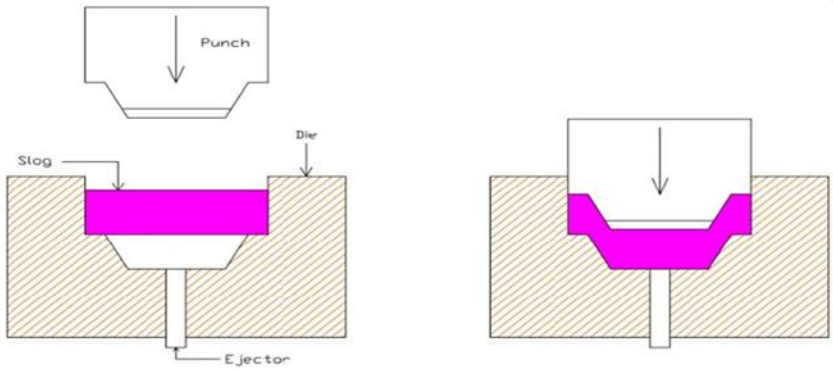

Figure 2.1.4 Cold Extrusion Process. (Noaman Adenwala 2023)

Hooker Extrusion: This is a widely used extrusion method for producing seamless, thin-walled copper or aluminium tubes. To shape the workpiece into a cup, a punch is first used to press the billet or blank into the container forcefully. Next, a longer-length punch is used to exert force into the cup once more, resulting in a long cylinder-shaped product with the usual reduction in thickness. (Noaman Adenwala 2023)

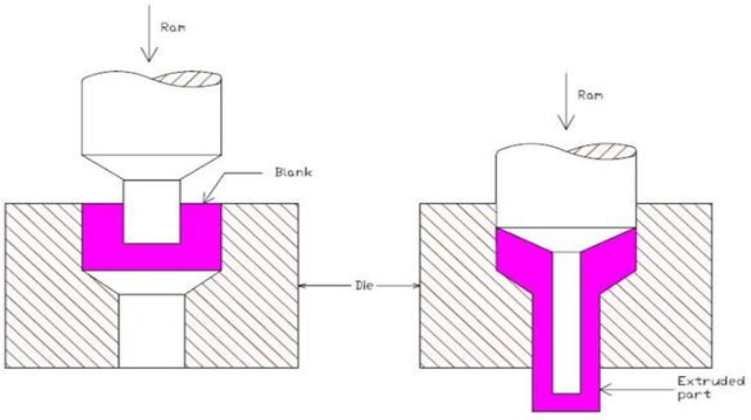

Figure 2.1.5 Hooker Extrusion. (Noaman Adenwala 2023)

Hydrostatic Extrusion: The billet is pressurized using fluid in this type of extrusion. A billet is first loaded into the container, which is then filled with fluid, typically castor oil. All but one side of the container, which contains a ram and piston, is then closed. Normally, hydrostatic extrusion operates at room temperature. The billet is kept in a conical shape to facilitate easy passage through the die and maintain a smooth process. Therefore, when the machine is turned on, the ram applies strong pressure to the fluid, which is then transferred to the billet. The high-pressure fluid causes plastic deformation in the billet, which then exits the die on the other side and takes on the shape of the die. The main benefit of this process is that very small friction force is generated because the container wall and the billet are not in contact. (Noaman Adenwala 2023)

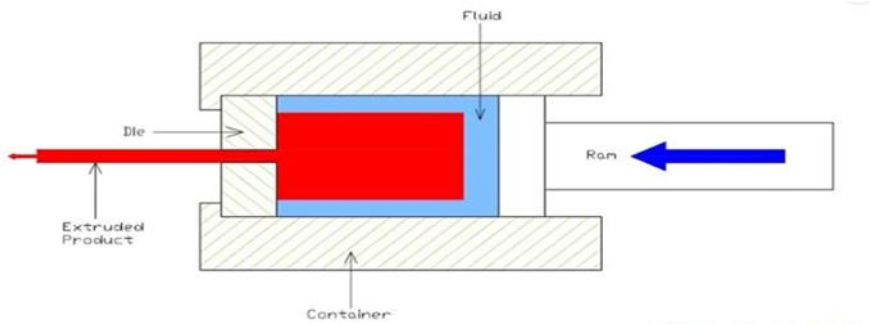

Figure 2.1.6 Hydrostatic Extrusion. (Noaman Adenwala 2023)

Impact Extrusion: During the impact extrusion process, a punch is struck against the workpiece in this process at a very high rate of speed to create an impact load. It can be of any kind, including both forward and backward. Backward impact extrusion is a common impact extrusion method that is used when products such as cups, toothpaste covers, or any hollow section are requested. (Noaman Adenwala 2023)

Cold Extrusion Forging: Cold extrusion forging is a backward extrusion process and it follows the same procedures as impact extrusion. The punch or ram moves slightly more slowly in this process than it does in impact extrusion. (Noaman Adenwala 2023)

The length of the extruded product is relatively short but the thickness is greater because the force applied to the blank is gradually increased. (Noaman Adenwala 2023)

2.1.3 Applications of the Extrusion Process

The production industry can use the extrusion process, which is primarily used to create hollow pipes. In addition, manufacturers take into account the extrusion process when

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producing products such as instant foods and snacks. When processing food, the extrusion process is used to heat the product and turn it into a liquid state. Today, the extrusion process which involves mixing, shearing, separation, cooling, heating, and other steps is also used in the kitchen. Producers also take into account the extrusion process for removing moisture from the products and for encasing materials. (Noaman Adenwala 2023)

Though, a cold extrusion process is used to create ready-to-eat materials. For instance, the cold extrusion process is used to create products for example pasta. Low moisture content is a feature of these products, which extends their shelf life and makes them easier to provide for customers. (Noaman Adenwala 2023)

Furthermore, the extrusion process is used to create pharmaceutical products. The extrusion process is used to create polymeric filters and other nanoporous products. Both hot and cold extrusion processes are used in the manufacture of pharmaceuticals. The hot extrusion process is used to improve the solubility and bioavailability of the products. Manufacturers consider a significant amount of pressure, heat, and agitation in this process. (Noaman Adenwala 2023)

In addition, the aluminium extrusion process is utilized in structural work. This procedure involves windows, doors, etc. Brittle materials are also used in the extrusion process in the automotive industry to create the desired type of material. (Noaman Adenwala 2023)

Finally, the extrusion method is frequently used to create plastic materials. (Noaman Adenwala 2023)

2.1.4 Advantages and Disadvantages of Extrusion

Extrusion has several advantages, including the following: The extrusion process has a very wide range and complexity of parts that it can create; Extrusion has been reduced by a very sizable amount; Automation of the extrusion process is simple; Die-making is comparatively straightforward; One pass is all that is required for extrusion to be finished. Rolling is an exception to this; Extrusion is a simple process that can easily produce large diameter, hollow products, thin-walled tubes, etc; Extruded products are known for their excellent dimensional and geometrical accuracy and good surface finish. (Saif M 2022)

Some disadvantages of extrusion: The setup’s high initial cost; There are changes to the product’s size; One type of cross-section at a time is all that can be used to achieve product limitations; It can take sometimes several time to complete this process; The operator must be

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sure that the plunger is properly fixed in the press because a significant amount of compressive force is needed during the extrusion process. (Saif M 2022 & Noaman Adenwala 2023).

2.1.5 Comparing the Different Types of Extrusion

Extrusion can be defined as a manufacturing technique that involves pushing raw metal through a die that has already been pre-shaped to produce items with a particular shape and profile. The metal's shape adapts to the die's shape as it passes through the die. However, there are different extrusion processes, such as cold, hot, friction, and micro. (**http3**)

Cold Extrusion: Metal is pushed through the die while at or near room temperature when using cold extrusion. Generally, the metal used in cold extrusion comes in slugs that are poured into the feeder of the die, where pressure fuses them to form a solid object with a new shape. Here follows of the usual metals used during the cold extrusion process: Aluminium, Copper, Lead, Niobium, Steel, and Tin. (**http3**)

Hot Extrusion: Hot extrusion entails heating metal to high temperatures and then pushing it through the die while it is still molten. Temperatures can vary from 340°C for magnesium to 700°C for steel, depending on the type of metal. When performing hot extrusion, manufacturers must make sure to use the proper temperature. The base metal may have trouble passing through the die if it isn't heated to its recrystallization temperature. However, hot extrusion is a precise and efficient method of reshaping metal when heated to the proper temperature. Here follows of the usual metals used during the hot extrusion process: Aluminium, Copper, Magnesium, Nickel, and Steel. (**http3**)

Friction Extrusion: This contemporary extrusion method, developed by The Welding Institute in the 1990s, involves the automatic rotation of the metal slugs or billets based on the position of the die. The metal-on-metal friction around the die entry generates heat as the die rotates. Metal can more easily pass through the die thanks to this heat. Manufacturers are increasingly using the effective and efficient friction extrusion process. (**http3**)

Micro Extrusion: Small, micro-sized objects can be produced using the relatively new extrusion process known as micro extrusion. In particular, the die supports base metal with a cross-sectional diameter of just 1 millimeter. It is a contemporary method that was created in the 1990s, similar to friction extrusion. Micro Extrusion has not attained the same level of

popularity as its friction counterpart because making such small dies that can withstand such pressure requires several technical skills. As micro extrusion technology develops, this might change. (**http3**)

2.1.6 Plastic Extrusion

Because of their adaptability, durability, and easier manufacturing requirements, plastics are utilized everywhere. One of the most popular methods for high-volume production is plastic extrusion and injection molding. Extrusion is typically used for continuous profiles that incorporate pipes, tubes, door profiles, and other large objects. (**http17**)

Over a century ago, plastic extrusion was first used industrially, and it has since developed significantly. It continues to be the method of choice for many plastic manufacturing projects today because it is straightforward, effective, and produces precise results. (**http17**)

With the support of heat and pressure, plastic extrusion is a process in which small pieces of plastic are fed through different extruder components to form a continuous profile.(**http17**)

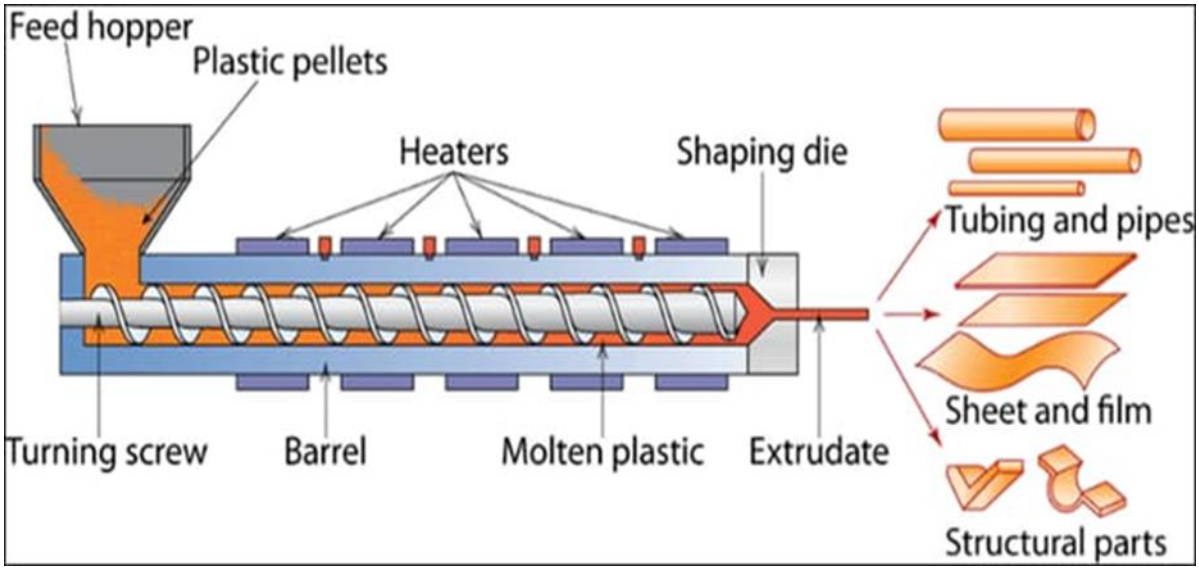

Figure 2.1.7 The Typical Plastic Extruder. (http17)

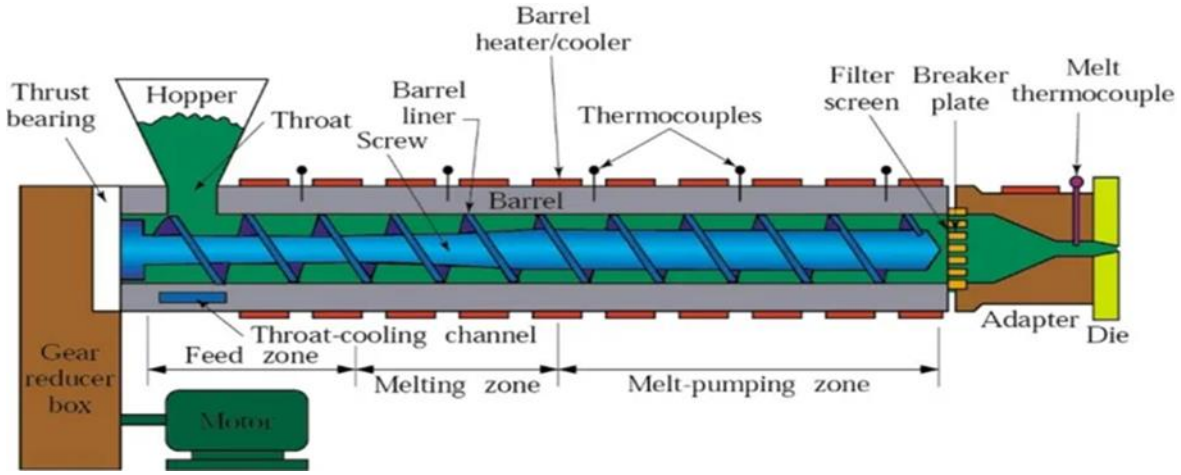

Figure 2.1.8 Plastic Extruder. (Saurabh Ranjan 2017)

The following are the components of the typical extruder:

- Hopper: The plastic extruder's initial phase is represented by this. Hopper keeps the plastic prepared for the following step of the process by storing it in granulate form.

- Feed throat: The feed throat sends plastic flowing from the hopper in the direction of the barrel.

- Breaker Plate: This part serves as a filter for the barrel and helps in pressure maintenance.

- Barrel: This heated component causes the plastic to become softer and approach the melting point. Additionally, the material is pushed into the feed pipe by the rotating screw in the barrel.

- Feed pipe: Transports the molten plastic coming from the barrel.

- Die: The material is forced through this rigid metal component to achieve the desired profile.

- Cooling system: The extrusion profile solidifies during the final stage of rapid cooling.(**http17**)

Plastic extrusion is a continuous high-volume manufacturing process in which raw plastic is melted and formed into a continuous profile. The extruder barrel is filled with plastic material (pellets, granules, flakes, or powders) from a hopper. The material is gradually melted. Turning screws and heaters arranged along the barrel generate mechanical energy. The molten

polymer is then forced into a die, which shapes it into a hardening shape during cooling. (Saurabh Ranjan 2017)

2.1.7 Screw Design

Since the screw is the only moving part in the plastic extruder, it directly affects the heating rate, feed rate, and other essential extrusion factors. Careful consideration of the size and design of the screw is required. Screw diameter and length are calculated using the melting rate, resin size, raw plastic type, and amount of pressure required to maintain uniformity. A twin-screw design may be used in applications where materials are blended inside the barrel of the extruder to ensure adequate mixing. (**http18**)

A thermoplastic screw has five potential zones. Different names for these zones may be used because the industry's terminology is not standardized. Different polymer types will have different screw designs, some of which may not include all potential zones. (Saurabh Ranjan 2017)

These three zones are found on most screws:

The feed zone: Also known as the solids conveying zone, is where the resin is fed into the extruder. Typically, the channel depth is uniform throughout the zone.

Melting zone: The majority of the polymer is melted in the melting zone, also known as the transition zone or the compression zone, the channel depth decreases in this zone.

Metering zone: also known as the melt conveying zone, the metering zone melts the last particles and mixes them to a uniform temperature and composition. Such as the feed zone, the channel depth is constant throughout this zone. (Saurabh Ranjan 2017)

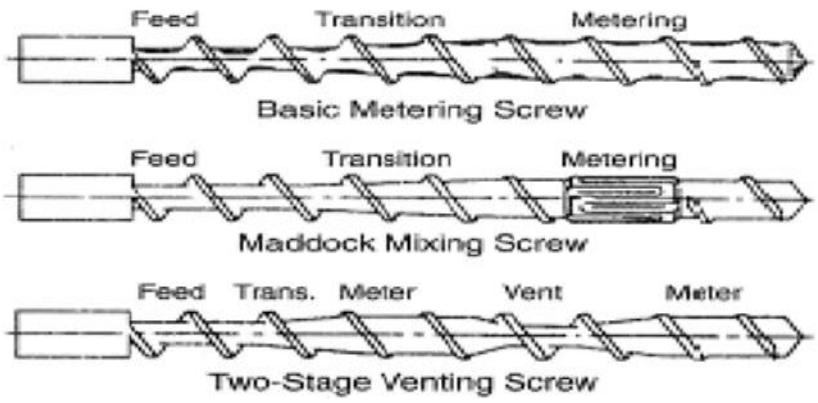

Figure 2.1.9 Different Screw Design. (Saurabh Ranjan 2017)

2.1.8 Different Types of Plastic Extrusion Processes

The shape of the die determines the type of extrusion process to work with. The different types of processes permit to effectively handle the complexities and intricacies of working with different shapes, while the basic process of plastic extrusion remains the same. (**http17**)

Tubing Extrusion: Long tubes, pipes, and other similar items can be processed using this method. Processing hollow machinery generally becomes more challenging. However, this extrusion procedure stays the same up until the die. At that point, the process makes use of positive internal pressure to get around the more demanding power needs associated with dealing with hollow parts. (**http17**)

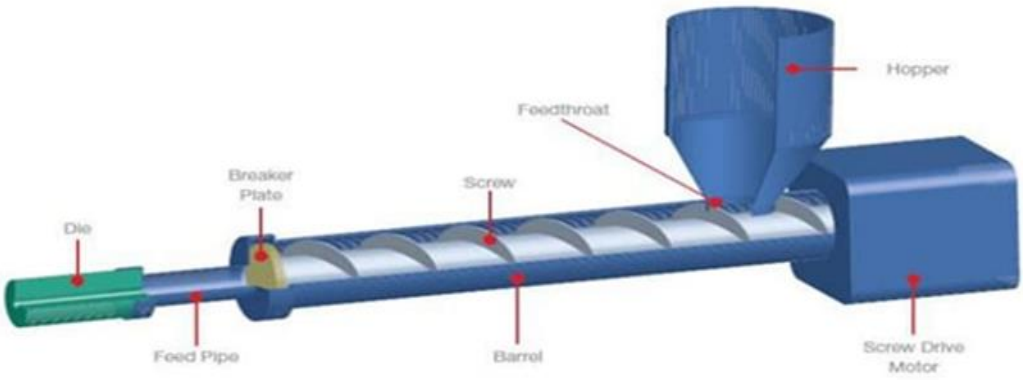

Figure 2.1.10 Tubing Extrusion Machine. (http17)

Blow Film Extrusion: Since it produces many commonplace items such as shopping bags and other packaging materials, the blow film extrusion process is quite common. The procedure is identical to every other extrusion type (including the aluminium extrusion process). The material goes through cooling in the die stage before leaving it, which is the primary difference. (**http17)**

The material still does not completely solidify at that point. Because of this, it later goes through an additional blowing-based expansion process. Thinner plastic films are the only ones that can be processed. An additional process is used for thicker sheets. (**http17**)

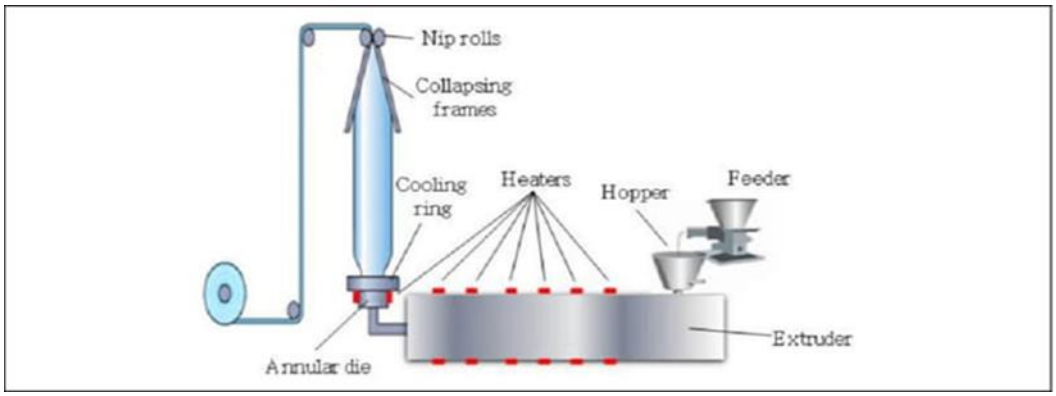

Figure 2.1.11 Blow Film Extrusion Machine. (http17)

Sheet Film Extrusion: This method and the previously mentioned blow film extrusion are very similar. For workpieces, though, that are too thick to blow, it is used. In that case, the material is pulled and rolled to achieve the desired shape. (**http17**)

The cooling that occurs during rolling enables the plastic to permanently solidify. In general, this procedure makes it simple to produce thicker plastic packaging such as ice cream boxes, juice cartons, wine boxes, and other containers. (**http17**)

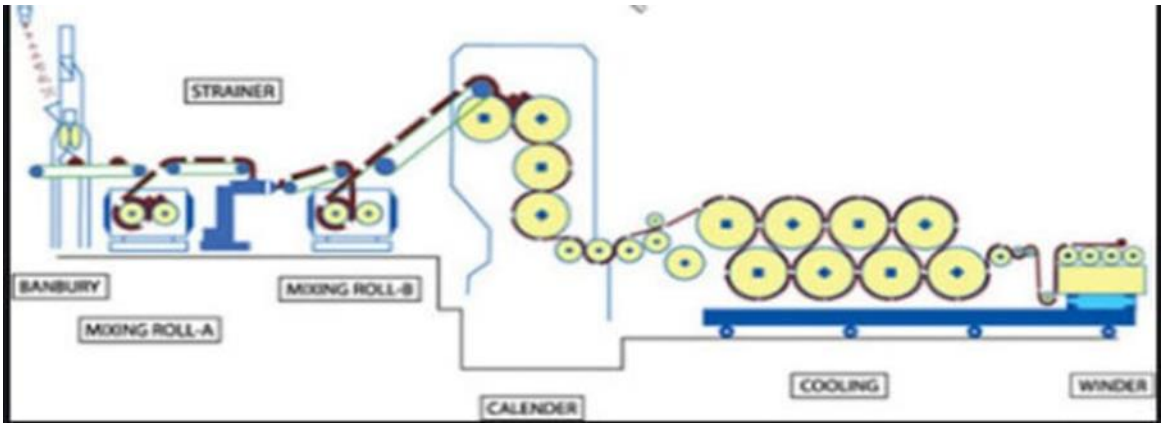

Figure 2.1.12 Sheet Film Extrusion. (http17)

Over Jacket Extrusion: This type of extrusion is used for insulation wires and other similar applications in which a material is coated with plastic. Adhesion is required between the plastic and the material, depending on the application. By pressure tooling, it applies sufficient pressure to the material to provide long-lasting adhesion. (**http17)**

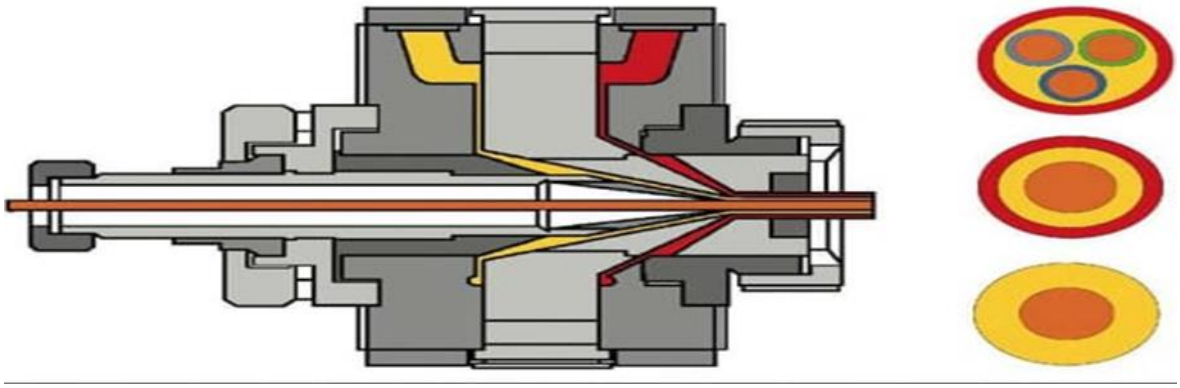

Figure 2.1.13 Over Jacket Extrusion. (http17)

2.1.9 The Main Applications Of Plastic Extrusion

The extrusion processes overall applications are too widespread given that it is one of the main methods for producing plastic parts. However, the areas where plastic extrusion technologies are most evidently used are listed below. (**http17**)

Pipes and Tubes: One of the most popular plastic extrusion products are pipes and tubes. The requirements for the die are the most simple, a cylindrical profile is required. Although there are other alternatives, PVC pipes common in the industry. (**http17**)

Figure 2.1.14 Pipes and Tubes one of the Plastic Extrusion products. (http17)

Wire Insulation: Plastics are excellent at insulating electricity by nature. Additionally, plastics are the ideal material for insulating live wires and jacketing due to their natural flexibility and thermal stability. Extrusion is typically used in the majority of jacketing and insulation projects because it is the most simple and produces the longest-lasting results.(**http17**)

Windows: Another typical application of extruded plastics are window frames. PVC is frequently used for that purpose because it is durable and naturally resistant to the sun's UV rays. (**http17**)

Doors: Due to their continuous profile and constant cross-section, door frames are a common extrusion application, such as windows. Again, due to its stability and superior mechanical properties, PVC is quite popular for door frames and other household fittings. (**http17**)

Blinds and Shades: This is yet another prime illustration of how common extrusion is. Many blinds and shades have several identical slots that work together to provide functionality. The faux-wooden image or look that is frequently seen in common blinds can be achieved through the extrusion of Polystyrene, a popular plastic material. (**http17**)

Cleaning Equipment: Plastic is used for the handles of cleaning tools such as squeegees and wipers. Even some products have a rubber-like plastic that provides better cleaning, and extrusion is required to produce them in bulk. (**http17**)

2.1.10 Comparing the Plastic and the Aluminium Extrusion

Extrusion is not just for plastics. The method is also applicable to metal parts with continuous profiles. Because of its strength, density, recyclable nature, and other mechanical properties, aluminium is typically one of the metals that undergoes the extrusion process. (**http17**)

Aluminium extrusion is a popular manufacturing process used today to produce a wide range of products, including bars, tracks, pipes, heatsinks, and many others. In general, aluminium must meet the specifications of the material, and the type of profile or cross-section.(**http17**)

The temperature is another significant distinction between the plastic extrusion process and aluminium extrusion. Aluminium extrusion can be both hot and cold, unlike plastics. Although it requires more power, cold extrusion typically produces materials with high strength. On the other hand, hot extrusion occurs between 350° and 500°C, which is easier to process but an expense of the mechanical properties. (**http17**)

2.2 Purging Compounds

The barrel, screw, nozzle, and mold or die must be free of any residue or contaminants when the resin is introduced into a machine to create a plastic component to produce quality parts. For instance, before a molder can start producing white parts after finishing a run of black parts, the black plastic resin must be completely removed from the machine. Additionally, before satisfactory parts can be produced, the previous material and any contamination (such as black specks) must also be purged out if the processor needs to change tooling and/or material. (**http2**)

A purging compound is a resin-based product used in the thermoplastics industry to effectively clean thermoplastic processing equipment of leftover resin and other impurities that accumulate on interior processing surfaces. The majority of purging compounds have a resin base, which enables them to be loaded and processed during the purging process like resin. (**http4**)

Purging compounds that are effective are made to operate on a range of machines, in a wide range of temperatures, and with a range of materials. Purging compounds are made to effectively remove contaminants and leftover resin with the least amount of material and time needed. Purging compounds can now be used to clean the expensive and time-consuming thermoplastic processing equipment that is used in modern plastics manufacturing. Purging compounds are a time and cost-efficient solution as they are used to maximize the uptime of the machinery while minimizing wasted resin and defective plastic parts. (**http4**)

2.2.1 Mechanical Purging Compound

Mechanical Purging Compounds rely on the machine's strength to complete the task. Injection molding and other high-pressure applications are where they perform best. This is because they rely on pressure and agitation to remove any contamination or previously used resin from the machine. Mechanical Purging Compounds, as opposed to regrind or virgin resins, are intended for cleaning. They have high detergency and no metal affinity. This ensures that the machine will start operating fast and cleanly. (**http5**)

An entirely new idea for cleaning and purging extruders and molding machines. High speed and efficiency, decreased time and material use, and high cleaning power all contribute to lower operating costs, better product quality, and smoother operation throughout the entire process, from resin changeover to impurities reduction. (**http5)**

Figure 2.2.1 Mechanical Purging Compound. (http5)

2.2.2 Chemical Purging Compound

Chemical Purging Compounds are mixed compounds that are adapted to the processing temperatures, resins, melt flow rates, and demands. Chemical Purging Compounds clean using a heat-activated chemical reaction that works best in low-flow and low-pressure environments, in contrast to Mechanical Purging Compounds. (**http6**)

For extrusion or blow molding, chemical grades are typically advised because they expand to efficiently clean large dies or other areas where contamination can occur.

Chemical purging Compounds are powerful cleansers that are used to clean difficult parts to reach in the equipment. They do need a brief soak period. (**http6**)

Figure 2.2.2 Chemical Purging Compound. (http6)

2.2.3 Liquid Purging Compound

When it comes to removing carbon residues and color stains, as well as decreasing machine downtime and significantly improving processing efficiency, purging compounds has proven to be incredibly helpful. The product segmentation market for liquid purges is expanding, increasing the demand for solutions to remove scrap and stains at reasonable costs. Turbulent flow is caused by liquid purging compounds disrupting the flow lines and additives and emulsifiers in the formula increases the volume inside the barrel. (Andres Rodriguez 2020b)

Consequently, stream velocity increases along with volume as the current contamination and purging compound combine to form a melted mass that is easier to remove from the barrel.

Unlike when using mechanical purging compounds, where there is a linear flow, contamination is slowly pushed out and moves through the layers until it is clean. With the help of additives found in liquid purging compounds, the material inside the barrel becomes

less viscous and more fluid. Increasing flow in areas where color contamination is typically more difficult to remove. (Andres Rodriguez 2020b)

Inside the barrel, some liquid purging compounds, such as Easypurge, contain chemical foaming agents that react at high temperatures inside the barrel, disrupting the linear flow following the same principle. (Andres Rodriguez 2020b)

Raising the pressure maximizes the effect of the other additives when breaking the flow lines. The purging compound can emulsify carbon residues and color pigment due to a reaction, which is similar to boiling. Putting the carbon residues and color pigment in a state of suspension so that they will be effortlessly pushed out by shots of virgin resin. (Andres Rodriguez 2020b)

Figure 2.2.3 Pet perform being clean with liquid purging compound. (Andres Rodriguez 2020b)

Figure 2.2.4 How liquid purging compounds chemical agents react inside the barrel. (Andres Rodriguez 2020b)

2.2.4 Comparing Mechanical and Liquid Purging Compound

With mechanical purging compounds, it is necessary to confirm the material's operating temperature to match it with the purging compound's working temperature in pellet form, depending on the material to change. Otherwise, the mixture will not behave normally or could lead to issues inside the machine.

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On the other hand, liquid purging compounds perform better at higher temperature ranges. For instance, Easypurge is simple and practical to use in factories that use different temperature range materials during production because it works for all thermoplastics that operate between 135°C and 350°C. (Andres Rodriguez 2020b)

Granulometry, which refers to the particle size of its components, is another aspect to consider when comparing liquid purging compounds with physical purging compounds.

Mechanical purges rely on high-density resins and abrasive materials that increase viscosity, creating a dragging force that pushes contamination out of the barrel, in contrast to liquid purges that clean by causing chemical reactions inside the barrel. (Andres Rodriguez 2020b)

The majority of mechanical purging compounds, as advised by their manufacturers, should not be used to clean the hot runners due to their granulometric composition.

The particle size of liquid purges is intended to be much smaller than the diameter of the hot runners, which is a technical benefit since the purging compounds remove contamination deposits from the hot runners. Before applying a purging compound through hot runners, the fabricant's approval is requested. (Andres Rodriguez 2020b)

Typically, one to two barrel capacities of the compound are needed for the mechanical purge cleaning process, and at least 1 barrel of virgin resin must be used to remove the cleaning agent. Two cycles are the suggested standard procedure for the Easypurge purging compound. (Andres Rodriguez 2020b)

Overall, liquid purging compounds are one of the top product categories in the purging compounds industry. While reducing scrap, production costs, and material waste, and improving downtime. (Andres Rodriguez 2020b)

Turbulent flow is caused by liquid purge components disrupting the flow channels and additives and emulsifiers in the formula increasing the volume inside the barrel. As a result, stream velocity increases along with volume as the current contamination and purging compound combine to form a melted mass that is easier to remove from the barrel. Unlike when using mechanical purging compounds. Where there is a linear flow, which will slowly push contamination out of the layers until it is finally clean. (Andres Rodriguez 2020b)

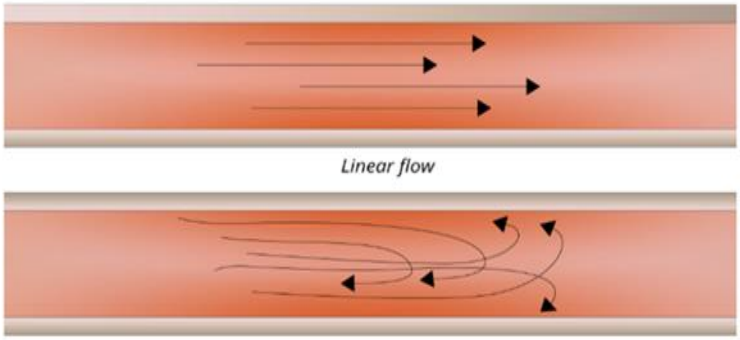

Figure 2.2.5 Material Flow graphical representation. (Andres Rodriguez 2020b)

2.2.5 Purging Compounds for Profile Extrusion

Profile extrusion is the process of creating continuous shapes of plastic through extrusion. This process does not include forming sheet or film products.

The plastic products produced by profile extrusion can be solid (such as vinyl siding) or hollow (such as drinking straws). (**http28**)

Figure 2.2.6 Plastic Profile Extrusion Product. (http7)

Contamination problems in the continuous process of profile extrusion can result in significant amounts of scrap and demand time-consuming teardowns. The wide range of resins and additives in the profile raises the possibility of issues. (**http7**)

Profile Extrusion processors do not need to experience contamination and lengthy changeovers. It is typically advised to use Mechanical Purging Compounds for profile extrusion applications. Chemical or purge concentrates are typically not required because

profile extrusion is a relatively straightforward process and cleaning is mainly concentrated on the screw and barrel. (**http7**)

Many extruders only use purging compounds under the direst circumstances. However, using this method of purging process decreases productivity and efficiency. (**http7**)

Preventive purging procedures not only prevent machine downtime at the facility. Additionally, it reduces shutdowns, customer rejections, and scrap rates. Regularly applying a purging agent avoids contamination from the beginning. (**http7)**

Usually, contamination can be avoided with 1-2 barrels of the purging compound. Through effective capacity use and the avoidance of unscheduled downtime, preventative purging reduces time and costs. (**http7**)

Three principal benefits to implementing a preventive maintenance program and purging process:

- Reduces unnecessary purging time and material waste at the end of production runs;

- Avoid the accumulation of color and carbon contamination;

- Reduces the frequency of screw pushes and the time for manual cleaning of the screw.(**http7**)

The majority of plants are concentrated on solving the immediate issue rather than how expensive the cleaning is, because, screw pushes are frequently only carried out after a problem is identified. (**http7**)

Without a purge, it takes much work to remove a screw from a machine, and cleaning requires hours of laborious, manual scrubbing. The layers of resins or contaminants that have gathered close to the screw must be removed. (**http7**)

For Profile Extrusion, purging compounds: Eliminate all carbon and color streaking; Reduce the time needed for material and color changes; Promote rapid and simpler screw pushes; Easily purge super-engineering resins; Significantly reduce the rates of scrap and defects; Properly clean the screw and barrel. Purging compounds, keep the machine sealed while it is off to facilitate simpler starts. (**http7**)

2.2.6 Purging Compounds for Injection Molding

Injection molding is used to create a range of widely used products, such as bottle tops, remote control casings, syringes, and more. It is also commonly used in the production of larger items such as car body panels. Injection molding is primarily used when thousands or millions of identical parts must be produced from a single mold. (**http19**)

Figure 2.2.7 Bottle tops, injection molding product. (http8)

During the injection molding process some defects may occur, such as flow lines, burn marks, warping, vacuum voids or air pockets, sink marks, weld lines, jetting, discoloration, delamination, short shot, and flash. (Ali Abbas Khan 2023)

Typically, mechanical purging compounds are advised for molders.

For Injection Molding, purging compounds: Remove carbon contamination and black specks; Properly clean the screw and barrel; Thoroughly clean the nozzle tips and valve gates; Proficient in hot runner color changes and cleaning; Reduce significantly the scrap and defect rates; Make it simpler to remove screws. Purging compounds keep the machine sealed while it is off to facilitate simpler starts. (**http8**)

2.2.7 Purging Compounds for Extrusion Blow Molding

One of the most popular plastic forming techniques, blow molding is used to create bottles, big drums, tanks, toys, and several automotive applications. The only process that has been slow to adopt purging is blow molding. (**http9**)

Figure 2.2.8 Bottles, blow molding product. (http9)

Purge suppliers did not have grades that performed well enough to support the implementation of a purge program for many years. Many blow molders experience changeover times between 8 and 24 hours as a result of the unwillingness to purge. Thankfully, purging compounds have advanced significantly in recent years. (**http9**)

Chemical Purging Compounds are typically advised for blow molders because they perform well in low-flow areas and it is suitable for cleaning flow lines or accumulators (principally if they are poorly made). (**http9**)

For both extrusion blow molding, purging compounds: Thoroughly clean the accumulator's heads; May run through heads without disassembling the machine; Will run through the entire system; Significantly reduce the time needed for material and color changes; Can hold the parison; Eliminate carbon stains and black specks; Make it simpler to remove screws; Effective with multilayer lines; Reduces the rates of scrap and defects; Keep the machine sealed while it is off to facilitate simpler starts.(**http9)**

2.2.8 Advantages of the Purging Process for Production

The purging compounds are important products because they guarantee an improvement in production quality by removing plastic waste, impurities (such as oil), colors and pigments from the machinery. The purging procedure for production has the following main advantages: It is an economic process; Reduces wear on machine components; Improves waste management; Reduces production costs; Improves productivity and efficiency, and thus competitiveness; Reduces production scrap due to color and material changes, as well as

carbon accumulation; Reduces machine downtime and manpower when changing colors or material. (**http10**)

Incomplete cleaning of the equipment can result in mechanical property losses, the appearance of stains on molded parts due to the breakdown of old resins, a reduction in machine life, an increase in production stops, maintenance needs, and material waste.(**http10)**

Therefore, to improve results and prevent a serious buildup of impurities, materials, and pigments in the thread, cylinder, hot chambers, and extrusion dies, the purge process should ideally take place frequently, or at the very least with each shutdown of the equipment, to accelerate the production. Knowing when the purging process is required will help to achieve good production results. (**http10**)

The purging process is required during every color change, when color spots appear, when occurring the exchange of raw materials, when the machine is shutdown, during preventive maintenance, furthermore in case of dark spots or contamination.(**http10**)

2.2.9 Tips to Increase the Effectiveness of Purging

The need for screw pulls can also be avoided by using the right purging compound. Additionally, purging compounds can significantly reduce the time and effort needed for the procedure when screw pulls are necessary. (Dave Denzel 2022)

To select the right purging compound, an evaluation of the process is required, which should start with the equipment and/or tooling and any limitations they may have. (Dave Denzel 2022)

Each purging compound type serves a purpose:

- Mechanical Purge: Scrubs with a particulate, such as glass or mineral.

- Chemical Purge: uses chemical reactions.

- Hybrid Purge: combines chemical and mechanical purging components. (Dave Denzel 2022)

Even though mechanical purging compounds can be efficient, some of their particles may lodge or obstruct process components such as the extruder screens or small hot-runner tips. Although a mechanical purging compound is frequently a fantastic option for cleaning the screw and barrel, a chemical-type purge, or even one that foams or expands, may prove more

effective in cleaning the dead areas that are frequently found in some screws and tooling.(Dave Denzel 2022)

The key steps that will guarantee an optimized evolution of the purging process are:

- Make sure the barrel is completely charged;

- Once the purge begins to exit the machine, injection molding screw speed must be run between 70 and 120 rpm. Throughout the procedure, the mixing nozzle and the check ring must be cleaned in brief bursts;

- When extruding, the screw must begin to be rotated slowly and gradually increase or decrease the speed as the process continues;

- The screw is stopped during the purge process and the purge is settled into the dead areas;

- The purge process must be at the temperature of the current removing material for both injection molding and extrusion;

- When introducing the next production material, the process must be repeated for maximum effectiveness. (Dave Denzel 2022)

By changing the screw speed and velocity of the material flow a highly fluctuating environment of pressure and agitation is promoted that allows a purging compound's best performance. This is executed until the purge is visibly free from contamination. (Dave Denzel 2022)

To prevent contamination build-up, which could result in more challenging purging situations requiring more time and effort, a periodic purging routine or preventive-maintenance purge program should be established, because:

- Enhances the use of the machine;

- Minimizes scrap;

- Reduces screw pulls by at least 50% on average;

- Usually result in a 65% reduction in production downtime;

- Generally result in a 45% reduction in the amount of natural or virgin resin requested for purging;

- Tends to result in a 35% average increase in production efficiencies. (Dave Denzel 2022)

It is not advised to leave material in the machine barrel during shutdowns because the use of regular resins causes oxidation over time, which results in carbon contamination. Since a commercial purging compound is more thermally stable and able to withstand extreme heat variations, purging with one is advised for cleaning out equipment before shutdowns. (Dave Denzel 2022)

By sealing the barrel, it can be cleaned while it is prevented from further oxidative deterioration.

The following are important purging guidelines for shutdowns:

- Ensure that all auxiliary equipment is turned off;

- The hopper and feed throat must be clean;

- By starving the screw, the barrel must be free from resin;

- The appropriate commercial purging compound must be initiated at a 100% percentage;

- The entire barrel must be charged after inserting the commercial purging compound into the feed throat or hopper;

- The purging must be continuous until a contamination-free and clean purge is reached;

- Any color or degraded polymer in the barrel and on the screw is destroyed during the process by a thermal mixing reaction that takes place inside the commercial purging compound;

- Even though soaking is not necessary, it might be necessary for difficult purging applications. In some cases, a more effective purge can be achieved by gently reducing the temperatures and the commercial purging compound settling in the barrel;

- After the barrel is thoroughly clean, the entire barrel must be charged with the purging compound, the machine screw rotation is stopped, and all the heaters are turned off on the machine;

- While the system is cooling down, rotating screws is not allowed. (Dave Denzel 2022)

2.2.10 Benefits of Using Purging Compounds

The upside of using purging compounds for extruders and machine cleaning is that it works fast and produces superior results than any alternative. Workers in the plastic processing industry are constantly looking for ways to reduce costs and accelerate production. Purging compounds can also assist with this. (**http27**)

Here are the following benefits of using purging compounds:

- Delivers incredibly thorough and effective results by cleaning the screw and barrel;

- Regular resin is simply unable to effectively clean or remove stubborn deposits, but purging compounds can. Purging compounds removes effectively colors and carbon buildup;

- Enables faster changeover compared to other conventional techniques, which typically involve large amounts of regrinds and resin. Allows rapid switching of materials and colors;

- The laborious and time-consuming manual overhaul of the machine is not necessary. Purging compounds avoids the necessity for screw pulls. (**http27**)

3. Materials and Methods

3.1 Materials

3.1.1 Ultra Purge Purging Compounds

Ultra Purge purging products are extremely effective purging compounds created to work with the materials, equipment, and operating parameters of plastics processors producing a range of final products. Multiple processes are supported by Ultra Purge purging compounds, including Blow Molding; Extrusion; Hot Runners; Injection Molding; PET Preform Production. (**http11**)

For pipes and profiles, while Ultra Purge 1220 has an improved black speck removal feature, Ultra Purge 3615 offers a no-residue feature. (**http13**)

In extrusion blow molding and blown film applications, the Ultra Purge 3615 purging compound not only enables rapid color changes and the removal of carbonized deposits but also ensures fast and simple screw pulling and proper machine shutdown. (**http12**)

Many companies in the plastics processing industry shutdown their plants for several days during the holiday season. This is also sensible in light of the increased energy costs. However, stopping and restarting machines is fraught with risks. The main issue here is extruder contamination caused by oxidation and thermal degradation of the polymer left inside the cylinder. The better the injection molding machine or extruder screw, cylinder, nozzle and die are cleaned, the easier it is to start production after the shutdown period.(**http12**)

It is crucial to stop machines by using the proper procedure at the beginning of the holidays. Discoloration and black spots may develop if the right procedures and the use of a specially formulated purging compound are not followed, leading to lengthy start-ups and the creation of excessive and avoidable scrap. (**http12**)

Carbonized deposits may escape and contaminate the finished product even hours after production. In this instance, the entire batch that was produced up to that point must be discarded for quality assurance reasons. Such a situation can be avoided by thoroughly cleaning the extruder and injection molding machine while it is shut down. (**http12)**

Manufacturers looking for the fastest, easiest, and residue-free start-up procedure now have the option of using a purging solution. A particularly suitable product for machine shutdown is the Ultra Purge 3615. (**http12**)

During color changes, the product can also be used to clean the screw, cylinder, and head of blow molding equipment without an accumulator. Because of the product's unique properties, a simple rotation of the screw effectively causes the system to empty itself of the Ultra Purge 3615 purging compound, leaving the cylinder residue-free, and eliminating the possibility of polymer oxidation or degradation. Because the purging compound does not adhere to metal, pulling the screw is also much easier if this operation is required. Ultra Purge 3615 can even completely stop contamination from forming when used as a routine maintenance product. Beyond the shutdown scenario, Ultra Purge 3615 supports rapid material and color changes. (**http12**)

The product is successfully used in compounding, where there are frequently precise process specifications requiring regular screw pulling, in addition to machine shutdown and the purging of extrusion blow molding and blown film extruders during color changes.(**http12**)

Ultra Purge 3615: is a ready-to-use purging compound designed for extrusion lines. It is made up of high-quality thermoplastic polymers and highly effective cleaning additives.(**http13)**

Benefits of Ultra Purge 3615: Fast cleaning effect; High efficiency; No odor; Simple to use.(**http13**)

Typical Properties: Appearance - Blend of beige and translucent white granules; Chemical action; Compatible with polyolefins. (**http13**)

Applications of Ultra Purge 3615: Cleaning the screw, barrel, and head of blow molding lines with and without an accumulator's head; Black speck removal and color and material changes. Ultra Purge 3615, when used as a preventive maintenance product, helps to prevent the development of black specks. (**http13**)

Because it is easy to remove from the screw, the product can facilitate screw pull. Ultra Purge 3615 can be used at temperatures as high as 300°C. (**http13**)

Both shutdown and restart procedures can use Ultra Purge 1220 purging compound. By removing old polymer from the system with Ultra Purge 1220, the risk of carbonization which can result in black specks even hours after production has begun is reduced. It is advised to purge the machine both at shutdown and at restart based on the best practices.(**http14**)

Ultra Purge 1220: is a ready-to-use purging compound that incorporates Ultra-X technology and is suitable for use in injection molding machines and extrusion lines. It is made up of high-quality thermoplastic polymers and highly effective cleaning additives. (**http25**)

3.1.2 Benefits of Ultra Purge 1220

The main benefits of Ultra Purge 1220 are: Simple to use; High efficiency ; Rapid cleaning effect ; Wide range of applications. (**http25**)

Easy to use: Ultra Purge 1220 is a ready-to-use purging compound that does not require mixing, making it convenient for users. (**http25**)

High efficiency: Ultra Purge 1220 is highly efficient in cleaning conductive resins, making it an ideal solution for material changeovers. (**http25**)

Rapid cleaning effect: The purging compound ensures rapid cleaning of the machine, minimizing downtime and maximizing productivity. (**http25**)

Operator and equipment safe: The purging compound does not contain any abrasives, making it safe for both operators and equipment. (**http25)**

Wide application range: Ultra Purge 1220 is suitable for use in injection molding, sheet extrusion, and blow molding machines, providing a wide range of applications. (**http25**)

3.1.3 Typical Properties of Ultra Purge 1220

The appearance of Ultra Purge1220 is a blend of greyish-brown and translucent white granules mixed with the grayish-brown tablet. The hybrid action of the Ultra Purge 1120 improves the removal of black specks from screws and hot runners. (**http13**)

It is recommended for Polymers and blends such as: Crystalline polymers, PA (Polyamide), POM (Polyoxymethylene), Polyolefins, Styrenics (PS (Polystyrene), SAN (Styrene acrylonitrile resin), HIPS (High Impact PolyStyrene), TPE (Thermoplastic elastomers), TPU (Thermoplastic polyurethane) PV C (Polyvinyl chloride) (hard), PVC (soft). (**http13)**

The applications of Ultra Purge 1220 are: Cleaning the screw, barrel, and nozzle on injection molding machines and extrusion lines. Additionally appropriate for hot-runner cleaning on injection molding machines. Ultra Purge 1220 can be used for the cleaning of screws, barrel, and head of blow molding lines with and without an accumulator. The product is suitable for color and material change as well as for the removal of black specks. (**http13**)

Ultra Purge 1220 can be used at processing temperatures ranging from 160°C to 350°C.(**http13)**

3.1.4 Usage Instructions for Ultra Purge 1220

The recommended procedure for efficient use is to use the product based on the severity of contamination. To ensure complete removal of the product from the system, the machine must be thoroughly flushed after purging. (**http25**)

The Ultra Purge 1220 is suitable for injection molding, sheet extrusion, and blow molding. However, it is advised to use the product with caution and to wear appropriate personal protective equipment. (**http25**)

For Injection Moulding: 1 full barrel for color changes and black specks removal with Injection molding machines, and ½ full barrel for shut-downs with Injection molding machines. (**http25**)

For Extrusion: 1 – ½ full barrel for color changes and black specks removal with Extruders machines is recommended, and 1 full barrel for shut down with extruders. (**http25**)

For Blow Moulding: 1 full barrel for color changes and black specks removal with Blow Molding machines, and ½ full barrel for shut down with blow molding. (**http25**)

Figure 3.1.1 Ultra Purge 1220. (http15)

3.1.5 PurgeMax Purging Compound

PurgeMax is an easy-to-use and high-quality grade purging compound formulated for fast color change and contamination effectively at lower overall costs for purging injection molding, extrusion and blow molding machines. PurgeMax is compatible with the most commonly used resin and has processing temperatures ranging from 150°C to 400°C.(**http16**)

The screw and barrel are critical components in thermoplastic processors. They should be cleaned regularly, especially during color or material changes, to reduce black specks and contaminations and to ensure product quality, as well as to reduce wastage and prolong the life of these components when money matters, but dismantling these assemblies for cleaning can be time-consuming and tedious. (**http16**)

In light of the industry's ever-increasing challenges, selecting the right purging compound is critical because it plays a critical role in balancing the overall costs and revenues resulting from machine downtime, product quality, purging materials cost, human resources required, efficiency rate, and wastage. (**http16**)

3.1.6 Benefits of PurgeMax Purging Compound

Cost Effective - PurgeMax, unlike most screw and barrel cleaning products, is unquestionably a product that anyone can afford. (**http26)**

Reduce Machine Downtime - Time is perhaps the most valuable currency in running production. PurgeMax will reduce downtime. (**http26**)

Reduce Waste - High amount of waste means high or extra expenses. (**http26**)

Increase Productivity – To remain in business long term, it is important to be ahead of the competitors. (**http26**)

Improve Rejection Rate – Improve customer satisfaction and increase profit at the same time. (**http26)**

Spared From Screw Dismantling - No messy and time-consuming part of screw and barrel cleaning. (**http26**)

Easy to use with toss packet - In comparison to purging compounds that must be heavily weighted, PurgeMax is a perfect design for easily tossing packets into purging barrels.(**http16**)

Non-abrasive, odourless, and non-toxic ingredients - The best of Purgemax all come with non-abrasive ingredients, non-toxic, and odourless that eliminate contamination and are harmless to screw and barrel. (**http16**)

3.1.7 Typical Properties of PurgeMax

Non-abrasive ingredients and a flexible temperature range allow for rapid cleaning of changing color solutions. (**http26**)

Compatible with most engineering plastics resin, such as ABS (Acrylonitrile Butadiene Styrene), PPS (Polyphenylene sulphide), TPE (Thermoplastic elastomers), TPU (Thermoplastic polyurethane), PC (Polycarbonates), PBT (Polybutylene Terephthalate), PEI (Polyetherimide), PET (polyethylene terephthalate), FR (Flame Retardant) Compound, Fluoropolymer, Filled Reinforced Resins. (**http26**)

The ultimate screw and barrel maintenance solution with high production output. Harmless to screw and barrel; Effective in hot runner systems; Suitable for Injection Molding, Blow Molding, and Extrusion process. (**http26)**

A small amount of smoke may appear during purging. Although not very common, it is a normal condition. (**http26**)

3.1.8 Usage Instructions for PurgeMax

PurgeMax does not need to be mixed with purging resin during the standard purging process. Soaking before purging is also not required. (**http26**)

With applications that require more than one PurgeMax it is necessary to place one PurgeMax into the hopper and follow with a small amount of purging resin, and repeat it until t)he entire dosage has been added, and then charge the barrel with purging resin. The user can also place a small amount of purging resin before using PurgeMax. (**http26**)

For hot runner and manifold systems, a small amount of the compound must be purged from the nozzle before proceeding to open mold purging or injection. (**http26**)

Injection Moulding: Maintain processing profile for resin in the machine. (Minimum temperature 135°C); Empty the screw and barrel of residual resin; Place PurgeMax directly into the hopper and follow immediately with purging resin; The Purging process can be done by purging or injection; Maintain continuous purging until resin appears natural and clean; The Purging process is complete. (**http26**)

Extrusion: Maintain processing profile for resin in the machine. (minimum temperature 135°C); Empty the screw and barrel of residual resin; Place PurgeMax directly into the hopper and follow with purging material immediately; Maintain continuous purging until the resin appears natural and clean; The Purging process is complete. (**http26**)

Blow Moulding: Maintain processing profile for resin in the machine. (minimum temperature 135°C); Empty the screw and barrel of residual resin; Place PurgeMax directly into the hopper and follow with purging material immediately; The Purging process can be done by purging or injection; Maintain continuous purging until resin appears natural and clean; The Purging process is complete. (**http26**)

Figure 3.1.2 PurgeMax purging compound. (http16)

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3.2 Methods

3.2.1 Types of Plastic Extruders

For a plastic extruder, there is the option of using either a single-screw or twin-screw extruder. The ability to carry out all the previously discussed processes is shared by both devices. However, the production speed, mixing capacity, and overall operational flexibility may be impacted by the type of extruder being used. (**http17**)

Single Screw Extruder: Single-screw extruders are simple machines with one rotating screw in the barrel, as their name suggests. In general, simple profiles such as pipes and sheets are best produced using single-screw extruders. Despite their good performance, single screw machines are slow, poor at mixing, and may not be the best option for complicated shapes.(**http17**)

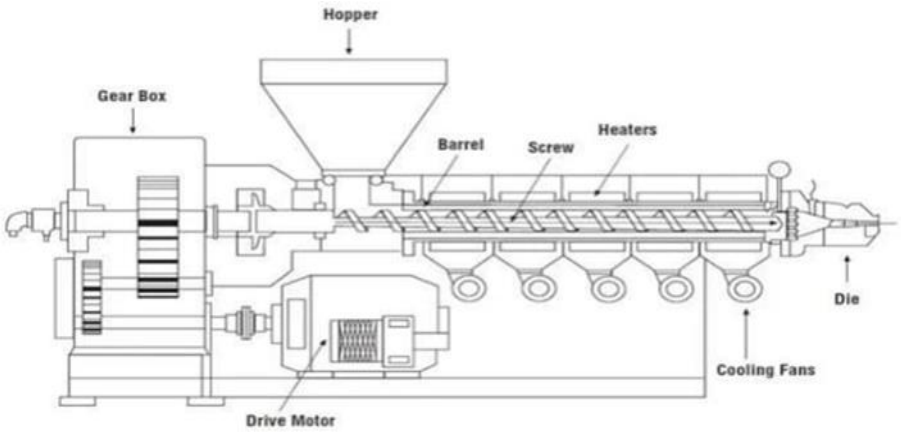

Figure 3.2.1 Single Screw Extruder.(http17)

Twin Screw Extruders: Twin-screw extruders have parallel screws in the barrel, as suggested by their names. The twin screws may rotate in the same direction or in different directions depending on the application. Twin-screw extruders provide better stability, exhaust performance, speed, and mixing performance as a result of their design.(**http17**)

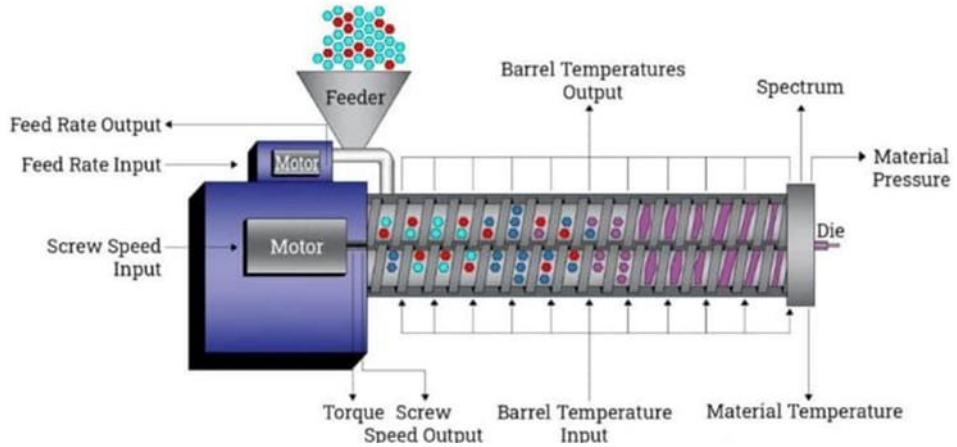

Figure 3.2.2 Twin Screw Extruder. (http17)

3.2.2 Plastic Extrusion Working Principle

Filling the hopper with smaller, easier-to-process plastic pieces initiates the plastic extrusion process. Gravity is used by the feed throat to move that plastic to the barrel for additional processing. (**http17**)

At least three intensity zones, where the temperature intensity rises as the material is moved away from the feed throat, warm the material when enters the barrel. The barrel uses a continuously rotating screw to push the melting plastic toward the following part of the machine as the temperature rises. The intensity zones themselves do not need to be nearly as hot as the projected extrusion temperature because the screw and pressure also produce heat, which saves energy and speeds up the extrusion process. (**http17)**

Through a screen that is held up by the breaker plate, the liquid plastic exits the barrel. This screen keeps the internal pressure constant while removing foreign objects from the material. The material is fed through a feed pipe into the specially-made die, which is shaped to match the desired extrusion profile for the project. (**http17**)

The extrusion process is complete when the molten material forms the same shape as the die opening when it is forced through the die. To ensure that the shape of the thermoplastic extrusion profile becomes permanent, the extrusion profile is cooled after passing entirely through the die using a water shower or several cooling rolls. (**http17**)

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3.2.3 Types of Plastic Extrusion Materials

Lack of proper mechanical qualities and strength is another frequent issue with extruded plastics. This was a big issue in the past, but technological advancements improved the situation. Due to its ability to produce products with the level of quality, consistency, and functionality required for contemporary industrial applications, custom plastic extrusion is now the method of choice. (**http17**)

The majority of plastics that are extruded are thermoplastics, although thermosets can also be extruded by heating them. There are several high-performance, engineering-grade, and commodity plastics available under that classification, all of which can have either amorphous or crystalline molecular structures. (**http18**)

High-performance plastics are the rarest and most expensive types of plastics to be extruded, high performance plastics are designed for harsh environments and have particularly superior thermal and mechanical properties. Polyetherketone (PEK) is one such plastic, used in the aerospace and automotive industries due to its resistance to chemicals, flame, and shrinkage, as well as its ability to maintain strength over a wide range of temperatures.(**http18**)

Engineering plastics, specialty plastics created to have special properties without being as expensive as high-performance materials, are one step below. TPE, ABS, nylon, and polycarbonate are a few of these. The majority of extrusions are made of commodity plastics, which are more universally useful materials. These plastics, which include PVC, polypropylene, and polyethylene, are the most affordable ones. (**http18**)

Several thermoplastics can be extruded. The temperature of these materials is raised just enough to melt them without causing thermal decomposition. Depending on the extrusion plastic, this temperature varies. Similar to those used for injection molding, extrusion plastics are typically fed into the extruder as plastic pellets. Powders, flakes, and granules are some additional forms. (Ronan Ye 2021)

Typical plastics for extrusion include: Polythene (polyethylene) extruded between 400°C (low density) and 600°C (high density); Polystyrene ~450°C; Nylon - Between 450°C and 520°C; Polypropylene ~450°C; PVC - Between 350°C and 380°C. (Ronan Ye 2021)

In some circumstances, an elastomer or a thermoset may be preferred to a thermoplastic as the desired extrusion plastic. (Ronan Ye 2021)

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3.2.4 Advantages of Plastic Extrusion

Extrusion is a high-volume production method that provides the optimal combination of adaptability, flexibility, and consistency. The plastic extrusion process has several key benefits, some of which are listed below. (**http17)**

Cost-Effectiveness: Extrusion is very cost-effective in comparison to other methods. In most cases, either extrusion or injection molding is used to create plastic parts. Extrusion, however, is much simpler and requires less complex tooling, which leads to lower costs. Extrusion machines can also operate continuously without stopping, enabling 24-hour production that decreases the likelihood of inventory shortages. (**http17)**

Unparalleled Flexibility: The plastic extrusion process allows for the creation of any shape or profile as long as there is a constant cross-section. Extrusion can produce almost any type of design, including complex shapes, sheets, pipes, and other products. Alterations: Before the cooling process, hot plastic remains quite malleable. This implies that additional shaping operations can be easily carried out to guarantee the finished product is the right size.(**http17**)

3.2.5 Injection Molding

Injection molding is a manufacturing technique that enables mass production of parts. It operates by injecting molten materials into a mold. Usually, it is used as a mass production process to create thousands of identical items. Although it is most frequently used with thermoplastic and thermosetting polymers, injection molding can also be used with metals, glasses, elastomers, and confections. The creation of the mold itself is the first step in the injection molding process. The majority of molds are made of metal, typically steel or aluminium, and are carefully machined to match the characteristics of the product to be produced. (**http19**)

In injection molding the material for the part is fed into a heated barrel and mixed using a helical-shaped screw after the mold has been created by the mold maker. The material in the barrel is melted by heating bands, and the molten metal or molten plastic material is then fed into the mold cavity, where it cools and hardens to match the shape of the mold. Cooling lines that circulate water or oil from an external temperature controller can help to shorten the cooling time. Mold tools are attached to plate molds (or platens) which open once the material has solidified, allowing ejector pins to eject the part from the mold. (**http19**)

A two-shot mold is an injection molding technique that allows different materials to be combined into one part. This process can be used to give plastic products a soft touch, add color to a part, or create products with different performance qualities. Molds can be made of single cavities or multiple cavities. It is possible for multiple cavity molds to have similar parts in each cavity or it can be unique to create parts of different geometries. (**http19**)

Injection molding is used for a range of applications that require a repeatable manufacturing process. Wire spools, packaging, bottle tops, toys, combs, musical instruments (and components), chairs, small tables, storage containers, mechanical parts, and automotive parts and components are examples of manufactured items. The most popular method for producing plastic parts, especially in large quantities, is injection molding. (**http19**)

3.2.6 Injection Molding Machine

The four main parts of an injection molding machine are as follows: The Base, The Hopper, The Barrel, and the Clamping. (**http20**)

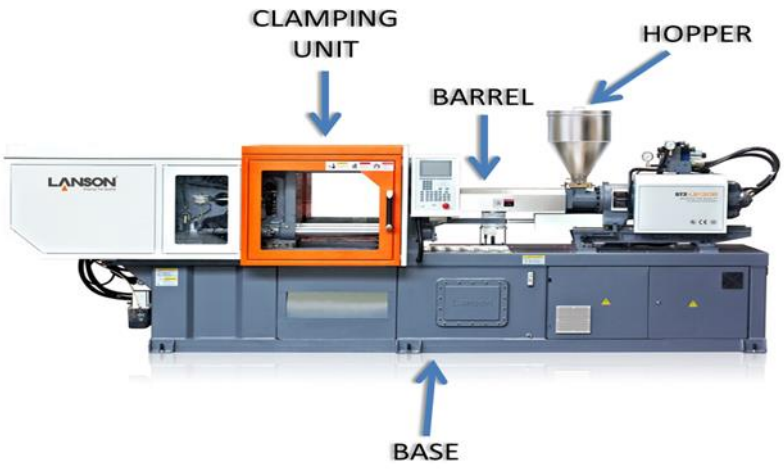

Figure 3.2.3 Injection Moulding Machine. (http20)]

- Base: All of the other components and the electronics for all of the machine's control systems necessary to run the machine, are supported by the base of the injection molding machine. This machine's electronics are responsible for controlling the injection pressure as well as a range of heaters, hydraulics, and sensors. (**http20**)

- Hopper: The plastic is poured into the machine's hopper before the injection molding process can start. A dryer unit is usually included in the Hopper to keep moisture away from the plastic material. It also has small magnets to keep any potentially harmful metallic

particles from entering the machine. The plastic material is poured from the Hopper into the next major component, the Barrel. (**http20**)

- Barrel: The Barrel is the component of the injection molding machine that melts the plastic material. This allows the plastic to flow through the barrel, where a screw inside the barrel injects it into molds or cavities in the Clamping Unit. To maintain the proper temperature for different types of plastic material, the temperature in the barrel must be properly regulated. A Nylon base plastic, for example, will require a higher temperature than an HDPE (High-Density Polyethylene) plastic. The process eventually arrives at the Clamping Unit. (**http20**)

- Clamping unit: The clamping unit is made up of two large plates that hold the mold in place. A mold is made of two steel parts that are attached to each of the clamping unit's large plates. When the Injection Molding machine is ready to inject plastic into the mold or cavity, the clamping unit closes the two independent plates, allowing the plastic to flow into the cavity and form the part. The plastic component is then solidified by cooling. The clamping unit simply opens the mold when the plastic is sufficiently cooled, allowing the part to fall out and be collected in a bin. (**http20**)

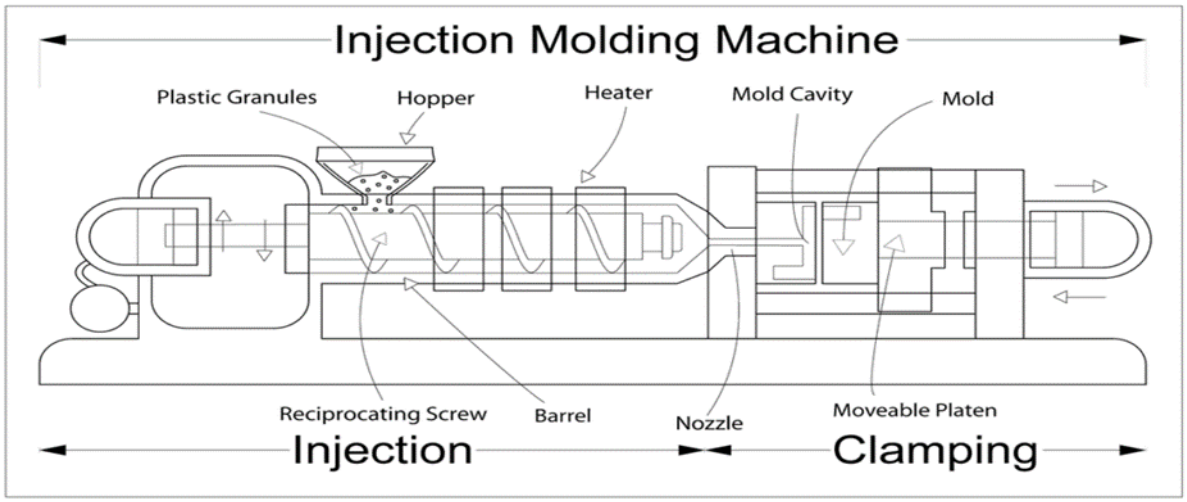

Figure 3.2.4 Schematic diagram of an Injection Molding Machine. (Ali Abbas Khan 2023)

3.2.7 Injection Molding Process Steps

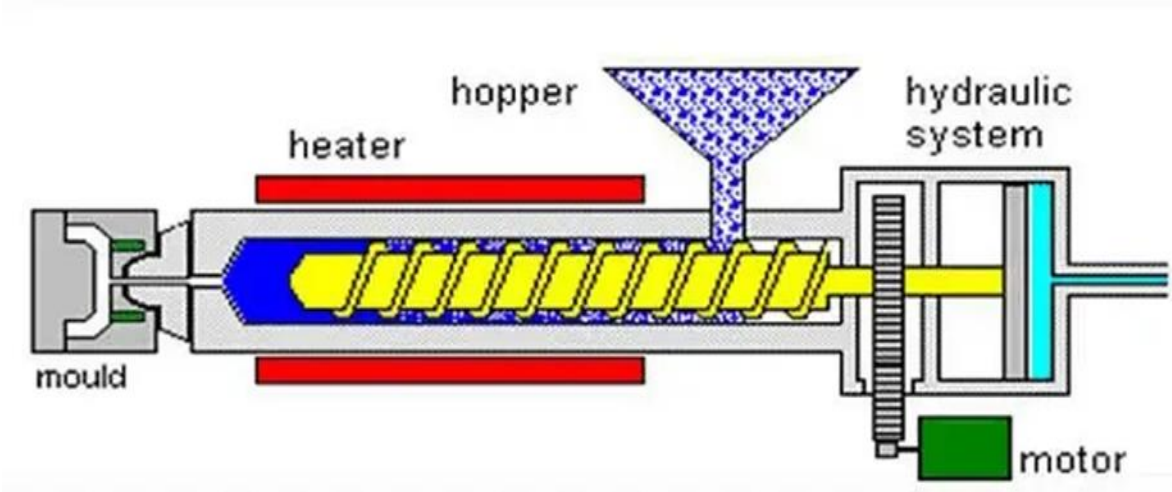

Figure 3.2.5 Diagram of the Injection Molding Process. (Ali Abbas Khan 2023)

These are the steps for the Injection Molding Process:

- Material particles are nourished into a hopper and then from the hopper come into the system.

- There is an Archimedean screw that rotates and pushes the current material forward.

- The heated area is now reached, where it is heated between the constituent's plastic polymer.

- The temperature at the nozzle is high that it immediately delivers to the mold cavity. The cooling process is completed here.

- Extraction pin now removes the mould cavity parts before forming the product.

This technology can be used to create a bucket, mobile parts, a helmet, and many other products. Injection Moulding is a modern technology in which the grain is produced of the desired material such as PVC, Plastics, and so. (Ali Abbas Khan 2023)

3.2.8 Types of Injection Molding

Following the five major types of injection moldings:

Metal Injection Moulding - To make the metal part, first is combined metal powder with a material known as a polymer binder. This mixture is then used to create a material known as feedstock. The feedstock is then injected into a special mold with the shape of the final metal part. This results in a green metal mold part. (Ali Abbas Khan 2023)

Figure 3.2.6 Metal Injection Moulding. (Ali Abbas Khan 2023)

To account for any shrinkage that may occur as the metal is cooling, the mold cavity is typically made larger than the actual desired shape. It is necessary to separate the metal part from the polymer binding powders after injection molding. This can be accomplished by dissolving the green metal part in chemicals or by heating it. The final step proceed, called sintering. The metal part is heated in a special chamber during sintering to reduce empty spaces. (Ali Abbas Khan 2023)

A high volume of production can be obtained using this type of molding process. The metals and alloys used in this process are: Low alloy steels, Stainless steels, High-speed steels, Irons, Cobalt alloys, Copper alloys, Nickel alloys, Tungsten alloys, and Titanium alloys.

Die Casting - Perfect dimensional accuracy can be achieved and an excellent surface finish using this process. In the die casting process, the molten metal is pressed inside the dies to achieve the desired shape. Die casting can be done by two methods, die casting hot chamber and die casting cold chamber. (Ali Abbas Khan 2023)

Hot chamber casting is a die casting method that is only suitable for low melting point alloys such as lead, tin, zinc, and a few magnesium alloys. Aside from this method, there is also the cold chamber method, which is appropriate for alloys with high melting points. (**http23**)

Because of its structure, a hot chamber casting machine is also known as a gooseneck machine. It contains multiple components, including: Furnace; Burner; Cylinder; Plunger/Piston; Nozzle; Gooseneck; Dies; Ejector Pin. (**http23**)

The machine's fixed die is also known as the cover die, and the movable die is known as the ejector die. The gooseneck machine is a metal feed system that is linked to the machine's

furnace. This machine handles the entire process, from melting the metal to solidifying it in the die. (**http23**)

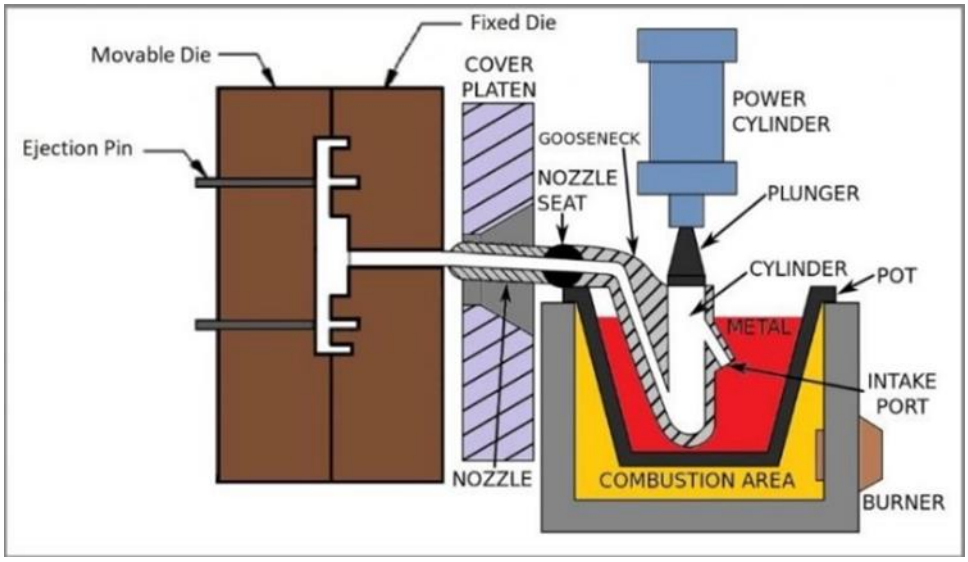

Figure 3.2.7 Hot chamber die casting machine components. (http23)

The following are the steps in a typical hot chamber casting process:

- Melting the metal;

- Pressing with plunger;

- Solidifying;

- Ejecting the part. (**http23)**

To begin, the metal or metal alloy is pressed on the pot inside the furnace. Then sufficient heat is applied to the furnace using the burner to melt the metal. The machine then lifts the piston or plunger, allowing the molten metal to enter the cylinder through the intake port.(**http23**)

Next, it pushes the plunger down so the melted metal can reach the nozzle through the cavity. Continuous pressure is applied to the piston/plunger until the die cavity is filled with liquid metal. The liquid metal solidifies inside the cavity after that. Finally, the ejector pin is used to eject the solid part and begin post-processing if necessary. (**http23**)

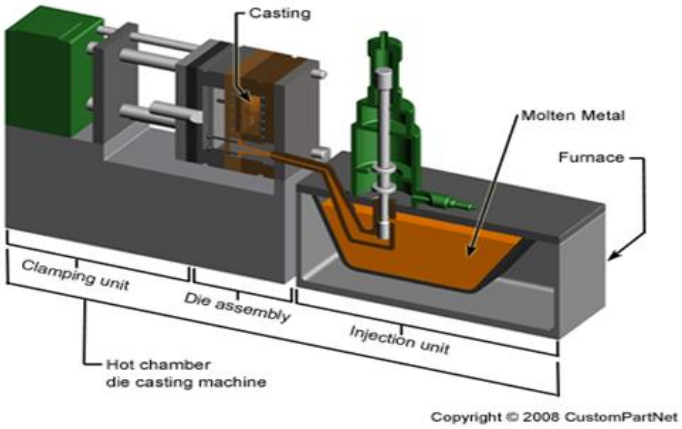

Figure 3.2.8 Hot chamber die casting machine. (Ali Abbas Khan 2023)

Cold Chamber Die Casting is a manufacturing process for metals with a high melting temperature. It is one of the two primary die casting processes with the other being Hot Chamber Die Casting. (**http24**)

Metal is melted in a container apart from the machine, which is used in a Cold Chamber Die Casting Machine to complete the process. The method became known as cold chamber die casting because the die casting machine itself remains cool throughout the process.(**http24**)

These are the components of a cold chamber die casting machine: Moving Die Half; Fixed Die Half; Cold Chamber/Shot Chamber; Ejector Pins; Die Cavity; Hydraulic Piston (Plunger). (**htttp24)**

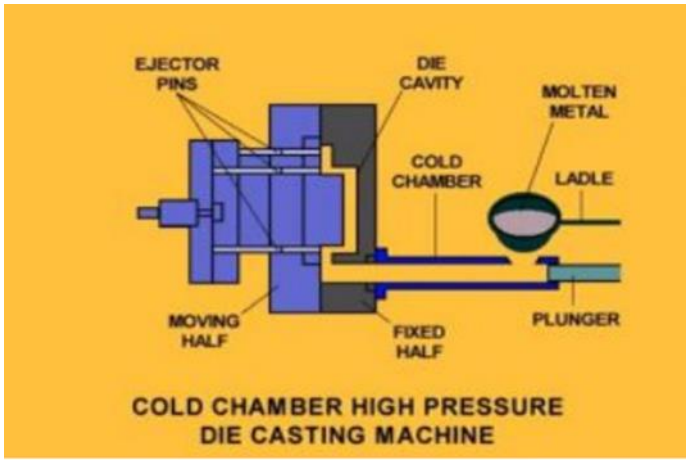

Figure 3.2.9 Cold chamber die casting machine components. (http24)

The process of cold-chamber die casting is the following:

- The metal to be cast is melted inside a separate container;

- A specific amount of molten metal is poured into the shot chamber connected to the die cavity using a ladle;

- The molten metal is pushed into the die cavity by a plunger under high pressure;

- The molten metal will spread throughout the cavity and take shape;

- Then it is left for solidification and cooling;

- The casting is then collected from the ejected moving half of the die;

- The dies are then clamped again to begin the next casting cycle in a similar manner.(**http24**)

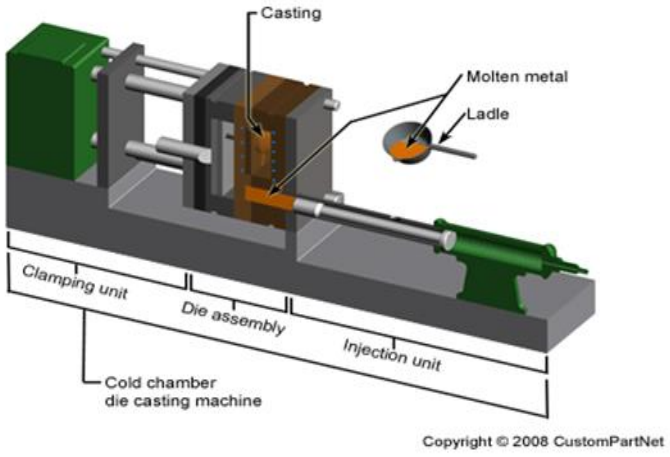

Figure 3.2.10 Cold chamber die casting machine. (Ali Abbas Khan 2023)

Generally, for die casting the following alloys are used: Zinc, Aluminum, Magnesium, Copper, Lead, and Tin. (Ali Abbas Khan 2023)

Injection Moulding of Liquid Silicone Rubber - Durable material parts are produced using this process. (Ali Abbas Khan 2023)

Thin-Wall Injection Moulding - Because it is less expensive than other types of molding, this type of molding process is used to produce thin plastic parts. This method is widely used in industries such as food packaging, medical equipment manufacturing, and computer housing manufacturing. (Ali Abbas Khan 2023)

Reaction Injection Moulding - In an impinging mixer, two types of materials are mixed at high pressure. The resulting mixture is then injected under low pressure into the mold. (Ali Abbas Khan 2023)

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3.2.9 Plastic Used in Injection Molding

High-density polyethylene (HDPE) and low-density polyethylene (LDPE) are the two plastic types that are used the most frequently. High ductility levels, good tensile strength, strong impact resistance, resistance to moisture absorption, and recyclability are just a few advantages that polyethylene offers. (**http19**)

The following list of commonly used injection-molded plastics:

Acrylonitrile Butadiene Styrene (ABS): In many industries this impact-resistant plastic is used. ABS has good acid and base resistance as well as low shrinkage rates and high dimensional stability. (**http19**)

Polycarbonate (PC): Low shrinkage and good dimensional stability are characteristics of this strong, impact-resistant plastic. PC, a transparent plastic with different optically clear grades available, can offer a high level of cosmetic finish and good heat resistance. (**http19**)

Aliphatic Polyamides (PPA): PPA (or nylons) come in a range of forms, each of which has unique benefits. In general, nylons offer high strength, high temperature resistance, and chemical resistance, with the exception of strong acids and bases. Some nylons offer good hardness, stiffness, and impact strength while being abrasion resistant. (**http19)**

Polyoxymethylene (POM): This plastic, also known as acetal, is highly hard, stiff, strong, and tough. It is also lubricious and resistant to organic solvents and hydrocarbons. For some applications, good elasticity and slipperiness are also advantages. (**http19**)

Polymethyl Methacrylate (PMMA): PMMA, also referred to as acrylic, has excellent optical qualities, has a high gloss, and is scratch-resistant. For geometries with thin and thick sections, it also offers low shrinkage and less sink. (**http19**)

Polypropylene (PP): In some grades, this low-cost resin material offers high impact resistance, but it can become brittle in cold weather (in the case of propylene homopolymer). While PP is also flexible, wear-resistant, and capable of very high elongation in addition to being resistant to acids and bases, copolymers offer greater impact resistance. (**http19**)

Polybutylene Terephthalate (PBT): PBT is excellent for electrical applications in both power components and automotive applications. Depending on the glass fill, the strength can range

from moderate to high, with unfilled grades being tough and flexible. PBT also exhibits many solvents, oils, fats, and fuels but does not absorb flavours. (**http19**)

Polyphenylsulfone (PPSU): Resistant to radiation sterilisation, alkalis, and weak acids, PPSU is a dimensionally stable material with high toughness, temperature, and heat resistance. (**http19**)

Polyether Ether Ketone (PEEK): This high-temperature, high-performance resin offers excellent strength and dimensional stability, heat resistance, and flame retardancy, as well as good chemical resistance. (**http19**)

Polyetherimide (PEI): PEI (or Ultem) has excellent strength, dimensional stability, and chemical resistance, as well as high temperature resistance and flame retardancy. (**http19**)

3.2.10 Advantages and Disadvantages of Injection Molding

Advantages: Fast production; Minimal labor wages; Mass production of the product; Multiple particles or materials are used simultaneously; It is easy to manufacture different small product parts; Small amount of scrap is produced during product production; Ability to create a hole in the product; The color is easily controlled in production; The finishing of the product required is relatively low; Dimensions are closely appropriate. (Ali Abbas Khan 2023)

Disadvantages: The cost of tooling and machinery is high initially; Molds are very expensive; The designs need to be created before starting the process; This might cause delays in production or increase costs for the company. (Ali Abbas Khan 2023)

4. Results

On the date of 03.03.2023, in Kecskemét (city), at Phoenix Mecano (company), it was made a purging compounds test for color change from black to green. The type of plastics used for this test were PBT and POM.

Polybutylene Terephthalate (PBT) is excellent for electrical applications in both power components and automotive applications. Depending on the glass fill, the strength can range from moderate to high, with unfilled grades being tough and flexible. PBT also exhibits many solvents, oils, fats, and fuels but does not absorb flavours.(**http19**)

Polyoxymethylene (POM), this plastic, also known as acetal, is highly hard, stiff, strong, and tough. It is also lubricious and resistant to organic solvents and hydrocarbons. For some applications, good elasticity and slipperiness are also advantages. (**http19**)

The purging compounds used for the test were the Ultra Purge 1220 and the Purgemax purging compounds.

The Ultra Purge 1220 is a simple to use and a high efficient purging compound with a rapid cleaning effect. Ultra Purge 1220 can be used for the cleaning of screw, barrel, and head of blow molding lines with and without an accumulator head. This purging compound is suitable for color and material change as well as for the removal of black specks. (**http13**)

The Ultra Purge 1220 does not contain abrasives and is made up of high-quality thermoplastic resins and highly efficient cleaning additives. It has industry food certification, all Ultra Purge 1220 formulation components are safe for direct or indirect food contact.(**http25**)

It is recommended for polymers, such as (High-density polyethylene) HDPE, LDPE (low-density polyethylene), PP (Polypropylene), (Polyoxymethylene) POM, PVC (Polyvinyl chloride or vinyl), TPU (Thermoplastic Polyurethanes), TPE (Thermoplastic elastomers), ABS (Acrylonitrile Butadiene Styrene), Nylon Etc. Ultra Purge 1220 can be used at processing temperatures ranging from 160°C to 350°C. (**http13**)

The Ultra Purge 1220 is suitable for injection molding, sheet extrusion, and blow molding. However, it is advised to use the product with caution and to wear appropriate personal protective equipment. (**http25**)

The PurgeMax is an easy-to-use and high quality grade purging compound formulated for fast color change and contamination effectively at lower overall costs for purging injection molding, extrusion, and blow moulding machines. It is compatible with the most commonly used resin. PurgeMax processing temperatures range from 150 °C to 400 °C. (**http16**)

PurgeMax is compatible with most engineering plastics resin, such as ABS (Acrylonitrile Butadiene Styrene), PPS (Polyphenylene sulfide), TPE (Thermoplastic elastomers), TPU (Thermoplastic polyurethane), PC (Polycarbonates) , PBT (Polybutylene Terephthalate), PEI (Polyetherimide), PET (polyethylene terephthalate), FR (Flame Retardant) Compound, Fluoropolymer, Filled Reinforced Resins. (**http26**)

PurgeMax does not need to be mixed with purging resin during the standard purging process. Soaking before purging is also not required.

With applications that require more than one PurgeMax it is necessary to place one PurgeMax into the hopper and follow with a small amount of purging resin, and repeat it until the entire dosage has been added, and then charge the barrel with purging resin. The user can also place a small amount of purging resin before using PurgeMax. (**http26)**

For hot runner and manifold systems, a small amount of the compound must be purged from the nozzle before proceeding to open mold purging or injection. (**http26**)

The diameter of the screw used during the test was 50mm, and the machine type was E150/3.

4.1 PurgeMax Test Results

In the following Table 1. It shows the test results from PurgeMax.

PurgeMax		Time/Weight	Cost Per Unit/g	Total Cost
1	Full purge	0:03:15		
2	Purging mixture with the green start	0:13:25		
	PurgeMax packet cost	4 packets	5 €	20
	Purging material with black	1.035g	3.90 €	4.0365
	Weight of scrap parts(10)	1.780g	4.60 €	8.188
	Machine hour fee	0:13:25	5.00 €	1.117
	Labor hour fee	0:13:25	15.30 €	3.42
				36.7615

Table 1. PurgeMax test results. Source: Own editing.

Time/Weight: The full purge time was three minutes and fifteen seconds, and the time of the purging mixture with the green start was thirteen minutes and twenty-five seconds. Was used 4 packets of the Purgemax purging compound, the weight of the purging material with black was 1.035g, the weight of ten scrap parts was 1.780g, the machine hour fee and the labor hour fee was thirteen minutes and twenty-five seconds.

Cost: The cost for one packet of the Purgemax purging compound was 5 €, the cost of the purging material with black was 3.90 €, the cost for the ten scrap parts was 4.60 €, the cost for the machine hour fee was 5.00 € and the cost for the labor hour fee was 15.30 €. To determine the total costs is time/weight * the cost.

Total Cost: The total cost of the Purgemax purging compound test was 36.7615. Which was the sum of all total costs from the time/weight and cost. (20+4.0365+8.188+1.117+ 3.42)

4.2 Ultra Purge 1220 Test Results

In the following Table 2. It shows the test results from Ultra Purge 1220.

Ultra Purge 1220		Time/Weight	Cost	Total
	Full Purge setting without modification and exit	**0:15:45**		
	Ultra Purge Purging Material	**1.077g**	**10 €**	**10.77**
	Purging material with black	**0.900g**	**3.90 €**	**3.51**
	Weight of scrap parts(3)	**0.534g**	**4.60 €**	**2.4564**
	Machine hour fee	**0:13:25**	**5.00 €**	**1.117**
	Labor hour fee	**0:15:45**	**15.30 €**	**3.83**
				21.6834

Table 2. Ultra Purge 1220 test results. Source: Own editing.

Time/Weight: The full Purge setting without modification and exit time was fifteen minutes and forty-five seconds. The weight of the Ultra Purge Purging material was 1.077g, the weight of the purging material with black was 0.900g, the weight of the tree scrap parts was 0.534g, the machine hour fee was thirteen minutes and twenty-five seconds, and the labor hour fee was fifteen minutes and forty-five seconds.

Cost: The cost for the Ultra Purge Purging material was 10 €, the cost of the purging material with black was 3.90 €, the cost for the three scrap parts was 4.60 €, the cost for the machine hour fee was 5.00 € and the cost for the labor hour fee was 15.30 €. To determine the total costs is time/weight * cost.

Total: The total cost of the Ultra Purge 1220 purging compound test was 21.6834. Which was the sum of all total costs from the time/weight and the cost. (10.77+3.51+2.4564+1.117+3.83)

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4.3 Comparing the Test Results of PurgeMax and Ultra Purge 1220

The goal of this test was to compare the purging time for the color change, the amount of the used purging material, and the total costs for both Purgemax and Ultra Purge 1220 purging compounds.

With Ultra Purge 1220, 1.077g was used, the purging time was fifteen minutes and forty-five seconds, and scrap to tree parts. The total cost for the Ultra Purge 1220 purging process was 21.6834 €.

With Purgemax four packets of the purging compound were used, the purging time was thirteen minutes and twenty-five seconds, reducing two minutes of the purging time in comparison to the Ultra Purge 1220 and scrap to ten parts. In return, the PurgeMax was more expensive than the Ultra Purge 1220, with a total cost of the purging process equal to 36.7615€.

The Ultra Purge 1220 saved up to 15.0781€ more than Purgemax, but the Ultra Purge 1220 purging process took two minutes longer than the Purgemax

Typically, the cost of an entire purging process can be determined by different factors such as the type of material being purged, the type of equipment used for the purging process, the amount of scrap parts and the amount of material being purged. Another factor that can also affect the cost of the purging process can be the efficiency, because the more the efficiency rate the less the time resulting in reduced costs for the process.

In this case, the amount of the purging material with black and also the amount of scrap parts was higher for PurgeMax in comparison to the Ultrapurge 1220, resulting this way in higher costs for PurgeMax compared to Ultra Purge 1220 because as mentioned above, the amount of material being purged and also the amount of scrap parts can influence the total costs of the purging process.

Despite the test results, Purgemax and Ultra Purge have some notable advantages and disadvantages as shown in the following table 3. And table 4.

4.4 PurgeMax and Ultra Purge 1220 Advantages and Disadvantages

Purgemax - Advantages	Purgemax - Disadvantages
Cost-effective - PurgeMax is unquestionably a product that anyone can afford, unlike the majority of screw and barrel cleaning products.	Can not be placed inside of an empty cylinder.
Can be use in hot runners; No smell and no toxicity; Suitable for All Resins.	Tabby pieces after going to the hot runner.
Reduce Machine downtime; Reduce Waste - Large amounts of waste essentially result in higher costs; Soaking time is not necessary.	Characterized by unpleasant noise and smoke.
Increase productivity; Improve Customer Satisfaction and Profit at the Same Time by Reducing Reject Rate.	When used, it can grab the auger.
Easy to use; Fast and efficient cleaning, it can take approximately 3 minutes for the cylinder cleaning.	Can not be put all at once.

Table 3. Advantages and disadvantages of PurgeMax Purging Compound. (http21, http22)

Ultra Purge - Advantages	Ultra Purge - Disadvantages
Wide range of temperature 160°C -350°C; No machine setup required; No need to heat when changing ABS color.; No need to cool when changing POM (Polyoxymethylene) color.	It seems more expensive at first sight, however, significant differences in efficiency can be noticed (such as time, number of scraps)
Purging material easily escapes from the cylinder, resulting in minimal waste; appropriate for hot runner cleaning;	
The cleaning material that has undergone the greatest development in the world in the last 3 years. It has industry food certification.	

Table 4 Advantages and disadvantages of Ultra Purge Purging Compound. (http13, http14)

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5. Conclusion

Overall, it may be said that purging compounds play an important role during the extrusion process, and injection molding, and not only, because of their capacity to reduce the machine downtime and increase the capacity of the machine without drawbacks or waste of time.

However, despite the several benefits, it is strictly necessary to make preventative maintenance for better results during the purging process. It is also important to select the right purging compound for the right equipment or machine. Even though all purging compounds have the same function of cleaning the machine in general, using the wrong purging compound in the machine can lead to a problem.

For extrusion equipment, it is typically advised the mechanical purging compound type because extrusion is a continuous process and the cleaning is focused on the barrel and the screw, to avoid equipment malfunctions is not recommended other types of purging compound. The mechanical purging compound is highly recommended for cleaning extrusion equipment because it is exclusively created for thermoplastic injection molding and extrusion equipment and its cleaning capacity is effective.

6. Summary

Extensive changeovers with lengthy pauses between production runs during the extrusion process can increase the scrap rate. The primary benefit of using purging compounds for extrusion is that they help to reduce machine downtime and improve the quality of the extruded product. By removing any residual material that may be left behind from previous runs, purging compounds help to ensure that the extrusion line is clean and ready for the next run. Purging compounds can also help to reduce the amount of time needed to switch between different materials, as well as to reduce the amount of scrap produced. Additionally, purging compounds can help to reduce the amount of energy needed to run the extrusion process.

To sum up, purging compounds are essential for extrusion processes, as they help to reduce downtime and improve the quality of the extruded product. There are different types of purging compounds available, each designed to remove different types of residual material. By using purging compounds, extrusion processes can be more efficient and cost-effective, resulting in higher-quality products.

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