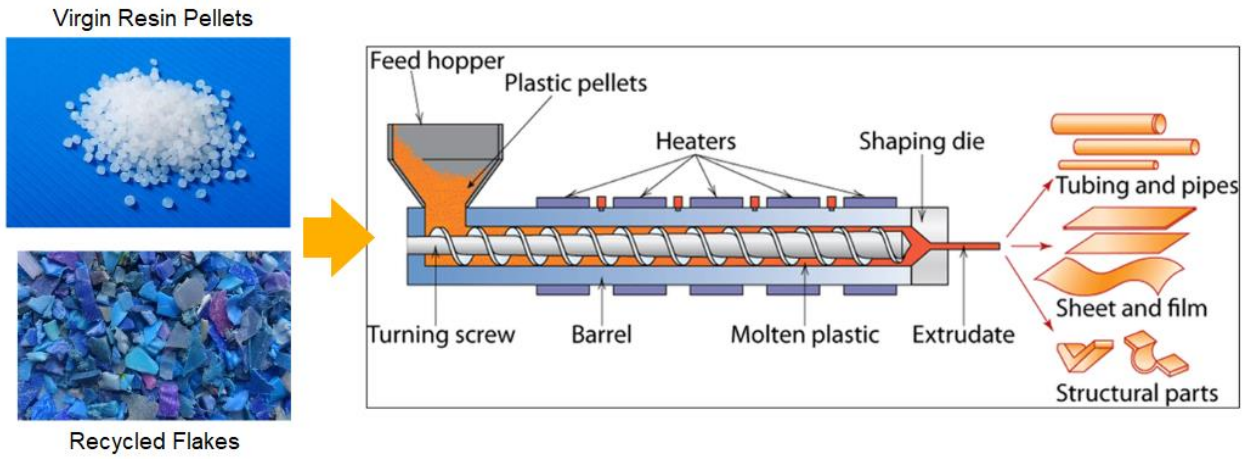
Plastic Extrusion Degassing

Tie Duan, EW Klein & Co.

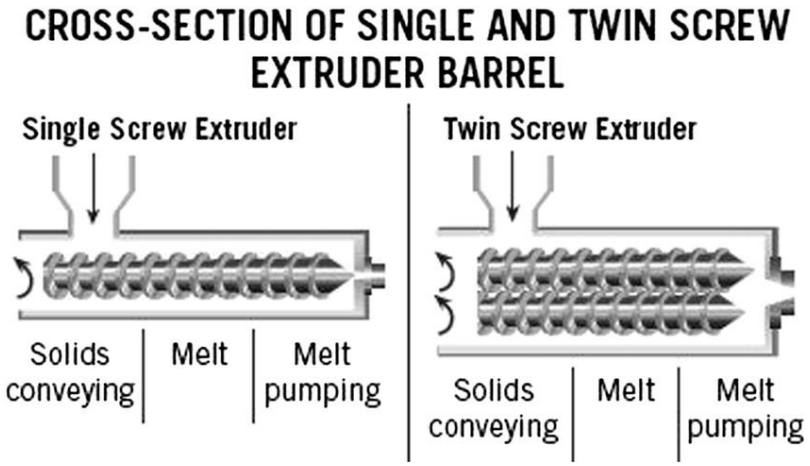
tie@ewklein.com 478-508-2017

I plan to add in a few articles that dives deeper in various industrial applications of vacuum and heat transfer systems in the future Learning Vacuum series. I remember when I was working as an engineer on the manufacturing floor, having colleagues with diverse professional background have been crucial in borrowing bits of knowledge from different industries to come up with unique solutions to meet challenging problems. I hope you will find bits of useful knowledge from these applications to help solve your problems and improve your processes as well. Because I came out of plastics extrusion, I will start these articles with the vacuum degassing application in extrusion.

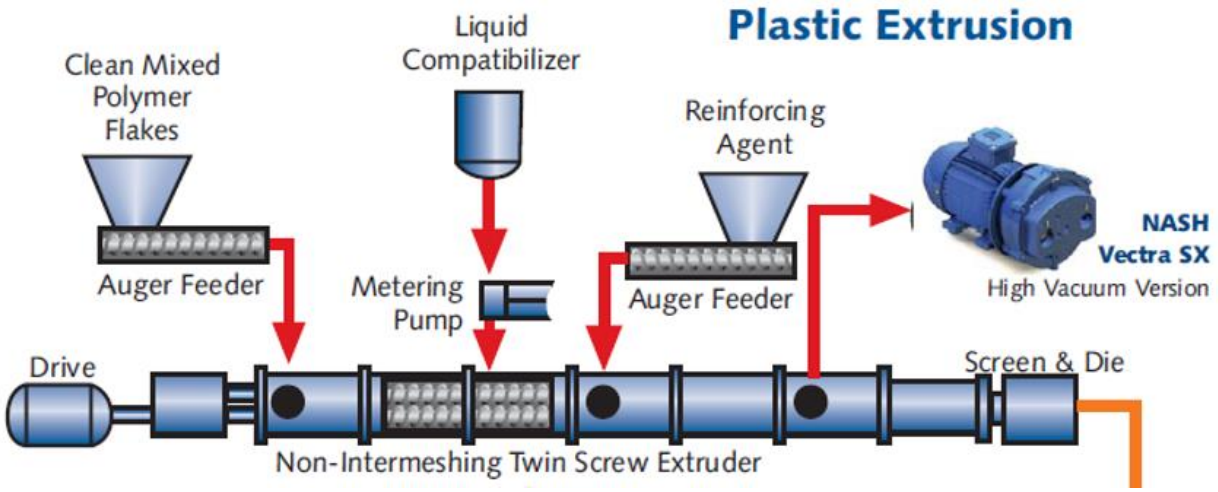
The simplest way I used to explain most of the thermoplastic extrusion processes is putting plastic pellets or recycled flakes inside a heated barrel with a screw (an extruder), using the screw's friction and compression force to melt the pellets or flakes into molten plastic melt, which is pushed through a die or into a mold to give it the product shape, then cooled down quickly to set the shape in. The below illustration is a typical single screw extruder, which is commonly used for pipe, sheet, film, and profile extrusion, due to its high-pressure capability as an efficient pump.



A twin-screw extruder, on the other hand, has excellent capability in mixing, which is commonly used for compounding: mixing various types of raw materials into one homogenized material mostly in pellet form. Here is an image showing the difference between these two common types of extruders.



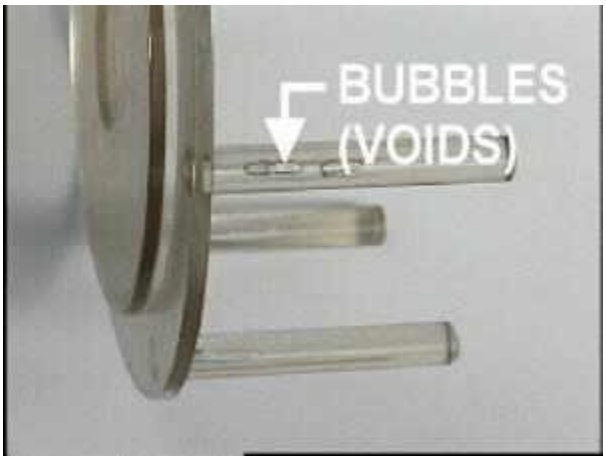
As raw materials melt under heat and pressure inside the extruder, the polymer chains and chemical compositions are going through changes, a variety of gasses can be released. The basic function of vacuum degassing is to remove the vaporized gas and moisture from the extruded material. This is more typically applicable for a twin-screw extrusion operation, rather than a single screw, because a twin-screw extruder can be designed to have sections of the screws with less internal pressure so vacuum can be applied. There are some recent innovations in single-screw technology where vacuum can also be applied.

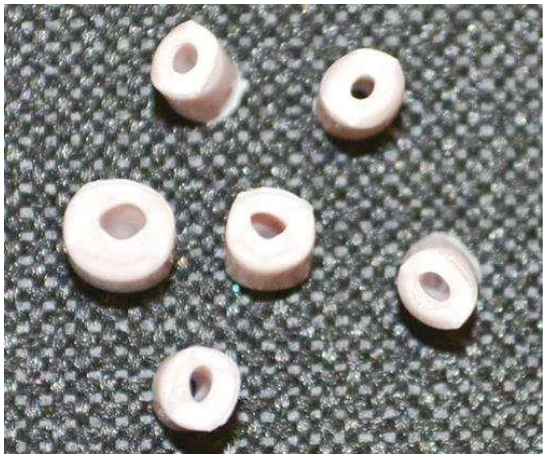


While most of the vapor removed from an extrusion process under vacuum is moisture, in situations where the polymer material is going through degradation due to overheating or over-shearing in the extruder, some harmful chemicals also can be released. For example, vinyl chloride monomer can be a damaging monomer released from PVC extrusion, and if mixed with water it can become a corrosive agent. Hydrogen cyanide can be released from nylon extrusion, which is a carcinogen. When designing a vacuum system for an extrusion process, it is important to consider the affect of process off gassing on the pump's material of construction, as well as the disposal of the removed gases and vapors.

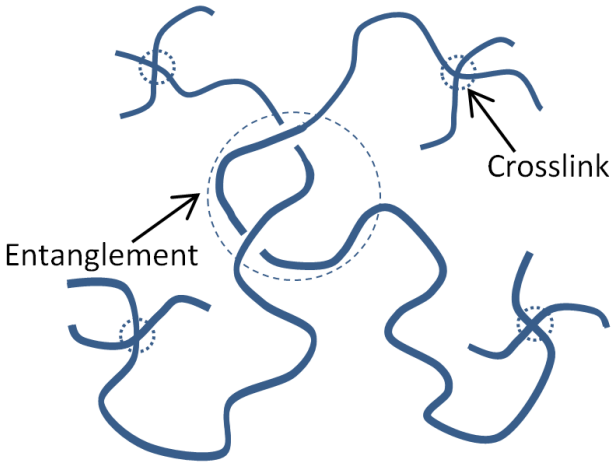
If insufficient vacuum is applied in a process, gas and vapor can be trapped in pockets in the plastic melt as it's been pushed through final compression zone of the extruder, result in visual defect of the finished

plastic parts. These can be air bubbles in injection molded parts, voids in plastic pellets, and a host of visual defects in plastic sheets or films. Below are some images of these examples.





Another damaging effect of not sufficiently removing moisture by vacuum is advanced polymer degradation through hydrolysis. Although plastic products appear to be solid pieces to our naked eyes, on the microscopic level they can be visualized as a mess of entangled and crosslinked spaghetti noodles, or polymer chains. These entangled and crosslinked polymer chains is what gives a plastic product its physical properties: rigidity, ductility, impact resistance, flexibility, etc.



Hydrolysis is the process in which polymers are broken down into monomers when water molecule is introduced. It essentially breaks a long polymer chain to smaller chains, therefore reducing its ability to entangle and crosslink with other polymer chains. Therefore, reducing a plastic product's physical properties, making it more brittle, less flexible, or not withstand against impact.

Hydrolysis

This process can happen to certain thermoplastics during extrusion process. Polyester, for example, is vulnerable to hydrolysis, which is why PET film extrusion operations would normally require large pre-drying systems to remove moisture from resin pellets before extrusion. There have been some innovations in Europe and Asia where vacuum is applied to the extruder to remove moisture without pre-drying the raw material. These innovations have also made their way into the US market in recent years.

Besides choosing the most suitable vacuum technology for degassing an extrusion process, there are a couple of simple improvement ideas to help ensure proper vacuum.

1. Seal around the extruder's vacuum ports. A typical vacuum port on a twin-screw extruder would come with a manual access flap that can be opened for inspection or atmospheric venting. However, the machined surface on this flap can easily get material build-up overtime, creating imperfect seals, causing significant loss in vacuum depth. It would be recommended to install high temp seal around the vent port flap or conduct rigorously cleaning on the machined surface.
2. Have a set of spare piping between extruder vent port and vacuum inlet. Like any manufacturing operation, things will go wrong with extrusion. It does not take much to overflood the vacuum port with molten plastic, then this plastic melt can get sucked into the pipe connecting to the vacuum pump. It would cool down and harden to create a clog, robbing your process of vacuum. Having another set of pipes that is already plumbed to fit between the extruder and the pump can save a lot of down time, because cleaning up a pipe that is clogged with hardened plastic takes a long time. I learned this one the hard way…