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Reivew Article

DEFECTS IN EXTRUSION PROCESS AND THEIR IMPACT ON PRODUCT QUALITY

J G Khan[1], R S Dalu[2] and S S Gadekar[1]*

*Corresponding Author: S S Gadekar, ✉ sandipgadekar77@gmail.com

In the 20th century, the number of manufacturers had established extrusion pipe manufacturing plants on the customer demand. To ensure quality extrusion pipe manufacturing, it is essential to identify, control, and monitor all quality parameters. Some of the important parameters are condition of equipments, operating conditions, temperatures, pressures, quality of dies, materials. Instead of the sincere efforts from the manufacturers, still there are number of obstacles in the process which lead to defects in the product. The purpose of this review paper is to focus on the various defects in the extrusion process, to identify its impact on the product quality and to suggest the remedies for the improvement of extrusion process.

Keywords: Extrusion process, Defects in plastic pipe, Impact of defect, Product quality

INTRODUCTION

Manufacturing of polyvinyl chloride (PVC) in India started 60 years ago with the country's first PVC plant set up in Mumbai in 1951. The plant operated by Calico had a capacity of 6000 metric tonne/year. At present, the Indian PVC industry boasts of a production capacity of 1.3 million mt/year. In India, Chemplast Sanmar, DCM Shriram Consolidated, DCW, Finolex and Reliance Industries have been producing PVC. The latest entrant into the Indian PVC market is the Vivanta group, whose 240,000 mt/year PVC plant is slated for start-up in 2013. PVC, one of the oldest forms of commodity polymers, is today regarded as an infrastructure plastic and finds various infrastructure applications, such as in pipes, ducts, wires, cables, floorings, windows and roofing. Furthermore, the use of PVC in other sectors such as automobiles, medical and health care, packaging, sports and leisure is also increasing. PVC is a thermoplastic composed of 57% chlorine and 43% carbon. It is less dependent than other polymers on crude oil or natural gas, which are non-renewable, and hence PVC can be regarded

1 Department of Mechanical Engineering, SSGMCE, Shegaon.
2 Department of Mechanical Engineering, Government College of Engineering, Amravati, AP, India.

as a natural resource saving plastic. Although PVC can be produced from various hydrocarbons including coal, the bulk of the world's PVC is currently manufactured using ethylene, which is combined with chlorine to produce ethylene dichloride (EDC), the raw material for the manufacture of Vinyl Chloride Monomer (VCM). VCM is further polymerized to produce PVC. PVC is also produced using calcium carbide, which is widely prevalent in China. According to Chemical Marketing Associates Inc. (CMAI), the global consumption of PVC in 2010 was 34.8 million mt from an overall capacity of 46 million mt, and accounted for 18% of the total consumption of polymers. The global demand for PVC is estimated to rise to 44 million mt and the global PVC capacity is expected to rise to 55 million mt by 2015. According to industry sources in India, the country's PVC demand is currently pegged at 2.08 million mt/year and the capacity is pegged at 1.33 million mt/year.

The consumption of PVC in India is expected to increase to 3.1 million mt/year by 2016-17 and the nation's PVC capacity is expected to rise to 1.63 million mt/year. As is evident from the above-mentioned demand and supply numbers, PVC demand is expected to exceed supply (Belofsky, 1995).

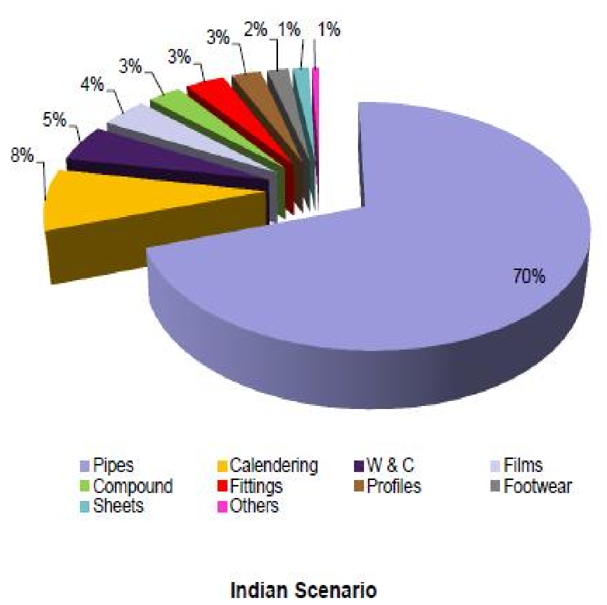
Today's Scenario of Extrusion Plastic in India

PVC Pipes Usage Narasimha and Rejikumar (2013)

PVC Pipe Sector

Pipes have been the biggest end-use sector for PVC with a share of approximately 70%. The use of PVC in pipes results in energy

Figure 1: PVC Sector-Wise Usage



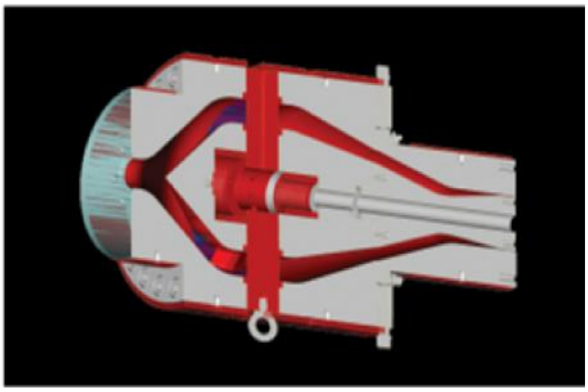
saving at all stages of the life cycle of a pipe, namely, extraction of raw materials, production, transportation, usage and recycling. Besides saving energy, PVC pipes also help protect environment by reducing CO_2 emissions. With an investment of Rs. 20 lakh crore towards infrastructure development in India in 2011-12 and a projected investment of Rs. 40 lakh crore till 2016-17, the consumption of PVC in pipes is expected to progressively increase and reach 10 million mt by 2017 from a current estimated consumption of 6 million mt. Furthermore, energy savings from using PVC in pipes would amount to 51.6 million MWh by 2016-17 from an estimated 31.4 million MWh savings currently and 16 million MWh savings in the period 2002 to 2007. Likewise, reduction in CO2 emissions would amount to 182 million mt by 2016-17 from 57.7 million mt in 2006-07 and an estimated 110.6 million mt currently (Belofsky, 1995).

As per the above data, it may be concluded that the PVC pipe sector has wide range of requirement in India. To fulfil such huge demand, industries require a better extrusion Process. It has been observed that there are lot of problems in extrusion process which lead to defective products. The common defects are Improper System Engineering/Installation, Improper Operation, Resin Defects, Improper Materials Addition, Surging, Poor mixing, Melt toughness or fracture, Overheating, Moisture release, Trapped air, Contamination.

Extrusion Process

The extrusion process converts a solid plastic feedstock material into a molten viscous fluid, and then to a finished solid or flexible film product for practical use. Extrusion equipment consists of a plasticizing extruder, die assembly, a cooling assembly, and haul-off or winding equipment. Extrusion is a continuous process, as opposed to moulding, which is a cyclic process. Extrusion is suitable for many types of continuous plastic products that have a uniform outside shape and can be coiled, cut, or wound. The transformation of a solid plastic feedstock material into a molten viscous fluid takes place in the extruder barrel, through the mechanical shearing action of a rotating screw and the heat provided by electrical resistance heaters clamped to the outside of the extruder barrel and die. The combination of the mechanical, rotating shearing action of the screw and the heat of the electrical heaters causes the solid plastic feedstock to change into a hot molten material. There are two basic types of plastic extrusion: screw extrusion and ram extrusion. This discussion is limited to screw extrusion, because ram extrusion is suitable only for specialized plastics such as Polytetra Fluoroethylene (PTFE) which cannot be screw extruded because of its low friction. In ram extrusion, a plunger goes through a barrel and pushes out the material under pressure. Screw extrusion involves a helical feed screw that turns inside a barrel. This is often called the feed screw or the extruder screw. The screw is a single shaft with helical flights. Sometimes, when more thorough mixing is needed, two screws are used. The screw advances the material through the barrel where it is heated and compressed. This process of extrusion serves two functions: it heats the plastic material above its melting point and puts the melt under pressure. The molten plastic material can then be forced through an orifice, commonly known as the die. This process is common to all types of extrusion. The extrusion process can produce pipe and tubing, a variety of profiles, flat products (thin film to heavy sheet), coatings on paper or other substrates, wire insulation, cable jacketing, and monofilaments. All synthetic fibers are produced by some form of extrusion and plastic raw materials are made (compounded) by extruding strands and cutting them into pellets. Examples are blown film for bags, cast film for packaging materials, tubing for catheters, wire insulation for telephone wire, rod for glue guns, profiles for window frames, and monofilaments for fish line. In all cases, the plastic must be converted from its raw material state—pellet or powder—and melted and pressurized via the extrusion process. After that is done, the material is moved to the die and downstream equipment for completing the desired product. Any discussion of the extrusion process should begin with the extruder itself Narasimha and Rejikumar (2013).

Figure 2: Spider Dies



Defects' in Extrusion Process

To ensure successful extrusion manufacturing, every parameter must be identified, controlled, and monitored. As the extrusion process studied and improved universally, still it is having some problems.

Defect is any form of deviation of the product's characteristic from the specification set up by the manufacturing process. It can be caused by a single source or the cumulative effect of several factors, which may arise at any stage of the processing. The common failure or defects which are normally occurring in plastic extrusion process are due to three main causes: mould design, material selection, and processing. In many cases, the failures occur during the processing and these failures causes some defects that can be found in extruded parts such as: rough surface, extruder surging, thickness variation, uneven wall thickness, diameter variation, centering problem. In extrusion products, defects due to processing include, poor understanding of the processing method, use of inadequate or old machines, lack of trained staff, machine break down, and inappropriate working environments (British Plastics, 1972).

The common defects in extrusion process are: Improper System Engineering/Installation, Improper Operation, Resin Defects, Improper Materials Addition, Surging, Poor mixing, Melt toughness or fracture, Overheating, Moisture release, Trapped air, Contamination.

Improper System Engineering/Installation

- Wrong Clamps used or Clamps too tight.
- Improper die setting
- Improper alignment of die and
- Incompatible fire caulk used.
- Contact of outside of pipe with incompatible material (e.g., solder flux).

Remedies

- Adjust the die setting
- Check for alignment
- Check for uniformity in die heating

Improper Operation (Maddock, 1957)

- Exposure to freezing temperatures without freeze protection
- Over pressurization
- Pulsating water pressure

Remedies

- Use the Digital Pressure gauge.
- Use proper/Digital temperature sensor.

Resin Defects (Maddock, 1957)

- Occlusions, char particles, voids
- Filler/pigment not well distributed
- Improper mixing of resin and additives
- Foreign contamination
- Due to over heating

Remedies

- Screening the resign material
- Exact addition of (Percentage of mixing) resin material

IMPROPER MATERIAL ADDITION

Some of the many problems that can occur during extrusion are traceable to the processed raw material; that is, the raw material is not up to specification. Regardless of any quality assurances by manufacturers of raw materials and countless programs such as ISO 9000, reengineering, and Just In Time (JIT) manufacturing, plastic batches and even bags or boxes within batches have their idiosyncrasies. With all extrusion parameters the same, the tubing or sheet will have a different look, bend, colour, or texture. While this may sound unscientific or preposterous, these problems do occur on the floor. Despite all the computer programs and hardware designed to keep the quality constant, there will be variations. Some materials such as polyurethane, nylon, EVOH and others, are hygroscopic (they absorb moisture from the air). This moisture is undesirable and can cause bubbles in the melt and, in the case of EVOH, can decrease barrier properties. For this reason, the polymer should be kept sealed in nitrogen-purged bags whenever possible. However, some plastics can absorb critical amounts of moisture in the time it takes to open a bag and put it in the hopper. The material must be dried, preferably in a hopper dryer designed for this purpose. Other problems include contamination with foreign materials such as metal chips, screws, bolts, nuts, cardboard, rodents, and rodent droppings. Even so-called medical grade plastics are often contaminated. Of course, the contaminate will end up in the melt, so every precaution must be taken to avoid contamination by closing bags, covering hoppers, keeping a clean area around the extruders, and similar measures.

Remedies

- Exact addition of (Percentage of mixing) resin material.
- Check for foreign material.
- Increase rpm back pressure for better mixing.

SURGING

Surging is a cyclical product thickness variation in the direction of extrusion. The surge cycle time is typically between 30 seconds and 3 minutes, and the cause can be inside or outside the extruder. Outside causes are easier to see and correct. For example, the take-off pull may be irregular; in this case the screw rpm and ammeter readings remain steady. Sometimes screw motor speed varies because its regulation is not working properly. This is rare and will show up as unsteady rpm. Sometimes the feed is uneven because of particle size, light weight, or bridging in the hopper and throat. With very small extruders, the feed channel depth is not much bigger. Than the feed particles, and they may feed erratically for this reason alone.

If none of these outside causes are observed, it is probable that the surging originates inside, typically at the beginning of the compression zone, where the solid bed—the mass of pellets—may be locking and breaking up irregularly. Screw rpm is steady but the ammeter shows variations of ± 5% or more. Sometimes this can be cured by increasing the temperature of the feed to promote earlier melting. Raising the rear barrel temperature may help, too. Make big changes, 25-50 °F (14-28 °C), and see what happens. Sometimes raising the barrel Temperature at the beginning of the compression zone will help by getting better sticking of the pellets to the wall there.

Remedies

- Try to running the extruder slower or faster by at least 10%.
- Altering or replacing the screw.
- Installing a gear pump between the extruder and the die.

POOR MIXING

This often sets the upper limit for output. The screw cannot be run any faster because the material is coming out with an "applesauce" surface, with streaks, parabolic ridges, and perhaps Particles of undispersed additive. Screw modifications, such as pins or separate mixing heads will help, but may raise melt temperature. Running more slowly will always help, as it provides more residence time. A screw with internal cooling mixes better because it has the effect of a shallower channel in the metering zone. The output per rpm drops 30, but may be regained by increasing the screw speed, unless melt temperature gets too high or the drive system cannot safely run faster. High pressure is good for mixing. A valve will do this, or a gear pump pressure control that can serve as a valve. Cooler dies increase the resistance and thus raise the pressure in the system. Finer screens will raise the pressure, but as they keep clogging, pressure is inconsistent.

Remedies

- Exact addition of (Percentage of mixing) resin material.
- Check for foreign material.
- Increase rpm back pressure for better mixing.

MELT TOUGHNESS OR MELT FRACTURE

This refers to fine ridges or rough surface seen when the melt comes too fast out of a narrow die. It is most common with polyethylene, and can be eliminated by running the melt or the die lips hotter, using a longer or more streamlined die, or trying a different grade or source of material. Additives may help greatly in this regard.

Remedies

- Use the Correct additives.
- Maintain the speed of extruder.
- Trying a different grade or source of material.

OVERHEATING

Overheating may limit the rate if the take-off cooling is limited, or it may produce degradation or make dimensional control and sizing difficult. In such a case, stop all barrel heat except in the rear zone as needed for bite (input) control and cool the barrel if necessary. (In a few cases, more barrel heat will yield a cooler melt.) There is a temperature below which the melt will not go at a given screw speed, even if all the barrel heaters are turned off.

See if the controller around 70% down the barrel is overriding. This means over packing of the metering zone—overbite—with much heat generated at the entry to that zone. In that case, reduce the bite by changing the feed temperature, rear barrel temperature, or particle size.

Remedies

- Stop all barrel heat except in the rear zone as needed for bite (input) control and cool the barrel if necessary.

MOISTURE RELEASE

Moisture is absorbed by some plastics. It passes through the extruder and boils when the pressure is relieved at the die lips. The result is a pattern of dotted lines, long bubbles, and pits. To remove moisture, the material must be pre-dry, or a vent must be used in the extruder, or both. A moisture level of 0.1% is usually low enough to avoid such visual problems.

Some plastics, such as PET, the nylons, and polycarbonate, can degrade and weaken if even a tiny amount of moisture is present when they are melted. For these, dehumidifying dryers are used to get moisture down to 0.01% or less.

Remedies

- To remove moisture, the material must be pre-dry.
- Vent must be used in the extruder.
- Keep the moisture level of 0.1% is usually.

TRAPPED AIR

This is not common in pelletized material used with long extruder barrels. However, some old machines have short barrels, and even a long machine can be pushed so fast that the air is carried forward into the product. A trapped-air surface shows bubbles and pits, but little, if any, dotted lines. Such a surface will improve if run more slowly if moisture is not the problem. A cooler head and die may help. Vents and vacuum hoppers will eliminate trapped air and are essential for powders, where passages between the particles are much smaller; the air cannot escape back through these passages and is carried forward instead.

Remedies

- Avoid the over-speed of extrusion.

Table 1: Defects and its Impact

S. No	Defect	Impact on Quality
1.	Improper System Engineering/ Installation	Centring problems Chatter mark on the Product
2.	Improper Operation	Uneven wall thickness
3.	Resin Defects	Blow holes Formation on the product
4.	Improper Materials Addition	Material absorb the moisture from the air which can cause bubbles
5.	Surging	Variation in the thickness of the product
6.	Poor mixing	This Problem create the clogging in the extrusion
7.	Melt toughness or fracture	This refers to fine ridges or rough surface seen when the melt comes too fast out of a narrow die
8.	Overheating	This create the problem in the Cooling of product
9.	Moisture release	The result is a pattern of dotted lines, long bubbles, and pits
10.	Trapped air	A trapped-air surface shows bubbles and pits, but little, if any, dotted lines

- Pre-Dry the material.
- Vents and vacuum hoppers will eliminate trapped air.

CONCLUSION

From the Study and analysis of the various papers on the defect and observing their views of researchers by paper in extrusion process there should be need of minimizing its causes for the best extrusion product. These quality problems (Causes) are become inappropriate setting of operational parameters as per observation. By the application of above remedies the percentage of loss would be improve, as predicted, for the products.

REFERENCES

1. Belofsky H (1995), "Plastics: Product Design and Process Engineering", Hanser Publishers, ISBN: 1569901422.
2. Dowd L E (1962), "How to Minimize Puckering in Polyethylene Cast Films", *Modern Plastics*, Vol. 40, No. 20, pp.142, 147 & 204.
3. Finolex Industries Limited, Corporation Presentation, May 2013.
4. Lekhraj Ghai (2014), *Importance of PVC in Indian Petrochemical Industry*, Dissertation or Thesis.
5. Maddock B H (1957), "Factors Affecting Quality in Polyethylene Extrusion", *Modern Plastics*, Vol. 34, No. 8, pp.123-136.
6. Maddock B H (1964), "Measurement and Analysis of Extruder Stability", *SPE Journal*, Vol. 20, pp. 1277-1283.
7. Narasimha M and Rejikumar R (2013), "Plastic Pipe Defects Minimmization", *International Journal of Innovative Research and Development*, Vol. 2, No. 5, pp. 1337-1351.
8. Tadmor Z and Klein I (1970), "Engineering Principles of Plasticating Extrusion", Van Nostrand Reinhold Company, New York.