Plastics Topics – Introduction to extrusion

TANGRAM TECHNOLOGY Consulting Engineers

Tangram Technology Ltd.
33 Gaping Lane, Hitchin, Herts., SG5 2DF
Phone: 01462 437 686
E-mail: sales@tangram.co.uk
Web Pages: www.tangram.co.uk

Plastics Topics – Introduction to extrusion

Contents:

Plastics Topics – Introduction to extrusion

1. Introduction – The last 'black art' of polymer processing

Extrusion is used in all methods of polymer processing as either the main method of forming or as the method of transporting and metering the molten plastic before it is formed. The extrusion process is not difficult to visualize and we use it every day when we extrude toothpaste onto our toothbrush. This is analogous to 'ram extrusion' that is used in many applications but most processing of plastics uses 'screw extrusion' and the best model for this is the meat grinder. The grinder takes in large lumps of meat and uses a screw to reduce the size of the meat, mix it all up and then extrude the result out as a fine stream of meat through the die at the face of the meat grinder. The very simplicity of these examples might imply that extrusion is simple but extrusion is as much art as science and in many cases, it is the last 'black art' of polymer processing. This document introduces the basics of extrusion and hopefully throws a little light on what is possible to achieve with this remarkable process.

2. Extrusion processes.

Whilst extrusion is used for processes as varied as wire coating and film blowing, this document will concentrate on profile extrusion, one of the largest volumes areas for extruded products.

The typical extrusion line described above can be used. with modifications. to produce a wide variety of products. Some typical examples are:

- Wire coating: for all types of wires and cables.
- Monofilament: for rope. bristles and synthetic textile fibres.
- Blown film: for plastic bags, plastic film and heat shrinkable film for food packaging.
- Sheet extrusion: for sign production, refrigerator interiors and even small boat hulls. When a clear sheet is produced it can be used in glazing or lighting applications.
- Pipe and tube: plastic tubing is used for garden hose, industrial hose, food and drink, transport and hydraulic or pneumatic control. Plastics pipe is used for water, gas, agricultural drainage, sewers and drains. New developments allow plastics pipe to replace copper pipe for heating and hot and cold-water services.

3. Profile extrusion

This is probably the most interesting area for engineering designers and the possibilities are virtually limitless. The initial constraint of a constant cross section is overcome in many applications by fabrication techniques such as cutting, drilling welding and stamping and by innovative processing techniques such as co-extrusion of soft and hard polymers, multiple colour extrusion and in-line application of decorative foils or adhesive tapes.

Materials

Most common thermoplastic polymers can be used for extrusion and the material choice is dependent on both the performance requirements and on the economic constraints. It is here that the designer should seek specialist advice from the extrusion company or material suppliers.

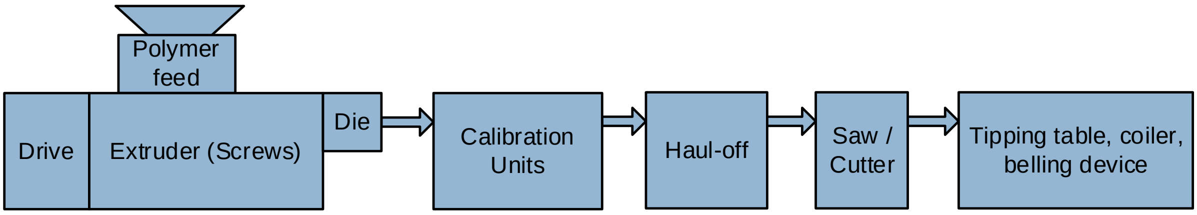
The most commonly used material for general purpose extrusions is PVC. The wide application of this material is due to cost, chemical resistance and its availability in various hardnesses and colours. The hardness of PVC can vary from the rigid type used for windows (Shore 'A' hardness of 100 or British Standard softness of 0) to the plasticised or soft version used for garden hoses (generally Shore 'A' 80 deg or BSS 38) and even down to very soft materials of Shore 'A' 60 deg (BSS 75) which have limited uses. The colour can be either matched to a colour sample or chosen from several hundred standard colours. PVC is a very versatile material but, as with all materials, there are limitations and again specialist advice should be sought for critical applications.

Tolerances

While plastics extrusions can be produced to consistent tolerances the designer must be aware that these are not the same as for machined parts or for metals extrusion and are generally greater. The tolerance bands applicable vary with the relevant dimension, the material used and with the manufacturer but in general BS 3734:1978 for extruded rubber products (Table 2 Class E 2) can be used as a guide. Specific tolerances for critical areas and non-critical tolerances must be discussed and agreed between customer and producer. Inevitably, the unit price increases with the number of toleranced dimensions and the tightness of the tolerances specified.

4. The extrusion line

The components of the extrusion line are relatively similar whatever type of extruder is used and a typical layout is shown diagrammatically below.



The basic components of an extrusion line

A typical extrusion line consists of the material feed hopper, basic extruder (drive, gearbox and screws), the extrusion die, the calibration units, the haul-off, the saw (or other cutting device) and finally the treatment devices for final finishing and handling.

The hopper holds the raw plastic material (in either powder or granule form) and continuously feeds this into the extruder, which has a heated barrel containing the rotating screw. This screw transports the polymer to the die head and simultaneously the material is heated, mixed, pressurized and metered. At the die, the polymer takes up the approximate shape of the article and is then cooled either by water or air to give the final shape. As the polymer cools it is drawn along by haul-off devices and either coiled (for soft products) or cut to length (for hard products).

The components in detail

- The extruder drive is electrical in operation and is geared via a thrust bearing to produce the rotational movement of the extruder screw. The thrust bearing limits the output of the extruder because the back pressure generated by the melt increases with the output rate. If the output and the back pressure become too high then the thrust bearing will fail.
- The polymer feed to the screw is from the feed hopper and the feed may be by gravity, metering screw or simple conveying spiral. The feed must be consistent to avoid too much air being drawn into the extruder throat.
- The extruder barrel and screw are of high strength steels and are protected from wear and corrosion by a variety of hardening and coating treatments such as nitriding and hard chroming.
- The barrel and screw are zoned into between 3 and 7 sections which are individually heated and cooled depending on the material and process parameters. In many cases there is no great need for heating because of the shear heating that takes place as the material is moved along the extruder barrel and in some cases the extruder barrel needs to be cooled to prevent overheating of the material. The multiple functions of the extruder screw are given in more detail below.
- The die channels the polymer melt from the front of the screw to form the basic shape of the desired product.
- The calibration units stabilize the form of the output to the detailed shape whilst the polymer is being cooled.
- The haul-off provides the dragging force to overcome the frictional forces in the calibrators and to pull the profile through the calibrators.
- The saw/cutter cuts the profile to the desired length.
- Additional operations may be performed in the line or at the end of the line depending on the final product requirements.

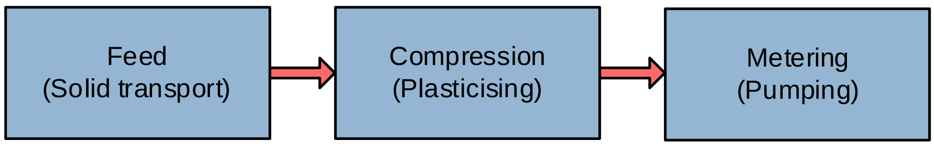
Major advances have taken place in all components of the extrusion line in the past decade but perhaps the most important have been in the output rates possible and in the command-and-control segments of the extruder. The advances in output rates have been driven by the demands of processors and the improved control systems have resulted from the availability of low-cost computer processing power.

The functions of the extruder screw

The extruder screw has the following basic functions:

- To bring the feedstock into the extruder and to move the material along the screw whilst at the same time compressing it and removing volatile gases.
- To soften the melt by heating it (both from internally generated shear forces and additional externally applied heat if required).
- To mix the melt and produce a homogeneous melt without impurities.
- To meter the melt into the die area.
- To apply the constant pressure (free of pulsation) required to force the material through the die.

These functions, at least for the single screw extruder, are generally achieved at different sections of the extrusion screw as the material progresses along the barrel are shown below:



The major functions of the extruder screw

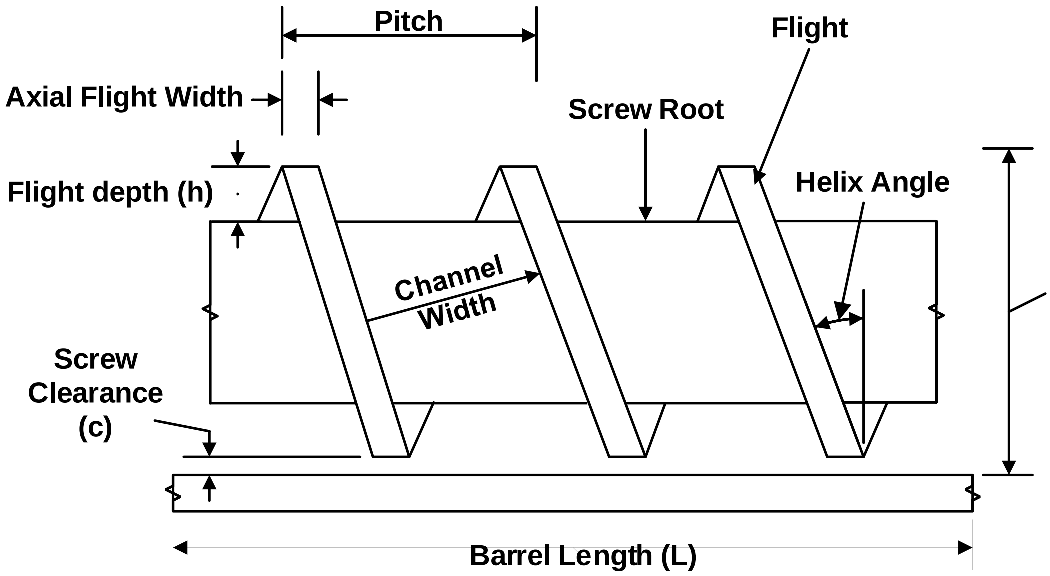
A twin-screw extruder carries out the same functions but with this type of machine the functions often take place simultaneously.

Extruder key dimensions

It is obvious that the detailed design of an extruder screw is extremely complex in order to perform all the functions required of it and it is useful to understand the main features of the extruder screw in order to understand the process.

In absolute terms probably the most referenced number for extruder specification is the L/D ratio (barrel length/barrel diameter) as this defines many of the operating characteristics of the extruder for all types of extruders The L/D ratio is a major factor in the effectiveness of the extruder and of the types of material that it can process. For most extruder types the L/D ratio has increased as technology has advanced. The limitation to high L/D ratios is the torque available from the motor (longer screws mean higher friction) and the capacity of the thrust bearings of the extruder. As advances have been made in these areas then the L/D ratios have steadily increased from L/D's of around 15 in the early 1960s to up to 30-35 at present.

It is important to realize that an extruder screw will not have constant dimensions along the length of the screw. The dimensions will change depending on the particular function being carried out by the screw at that stage. As an example, the flight depth will generally decrease in the metering area to provide an accurate material feed rate to the die area. Some of the key dimensions of the extruder screw are shown below.



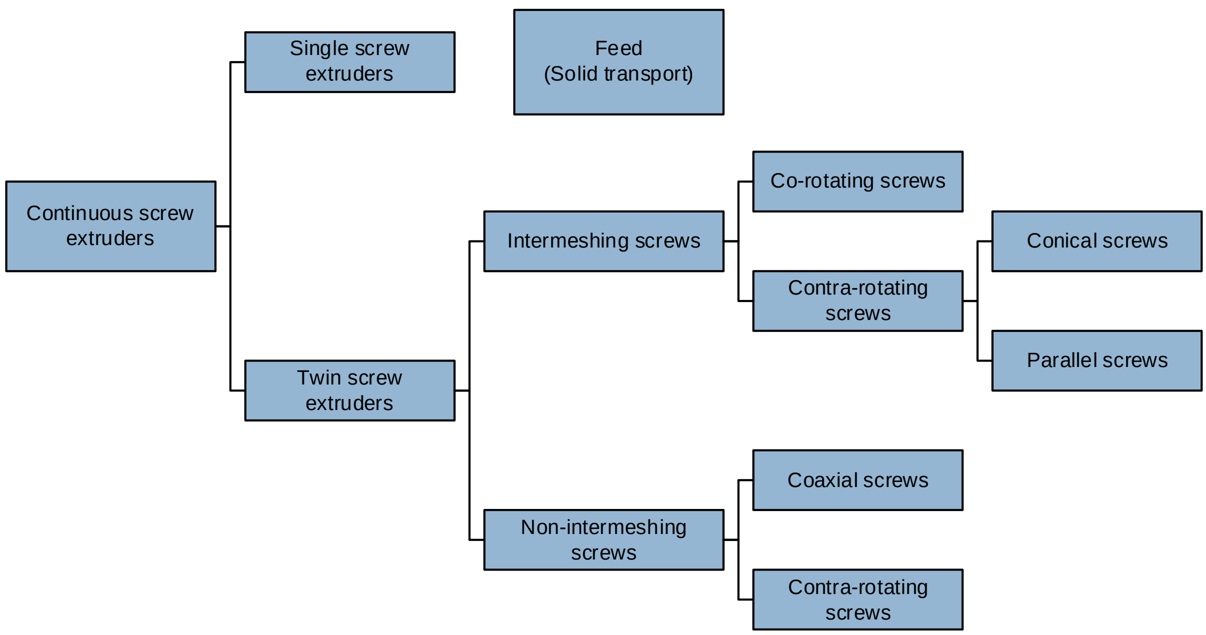
The key dimensions of an extruder screw

Basic extruder types

The basic extruder is available in many different versions depending on the material being processed and the application.

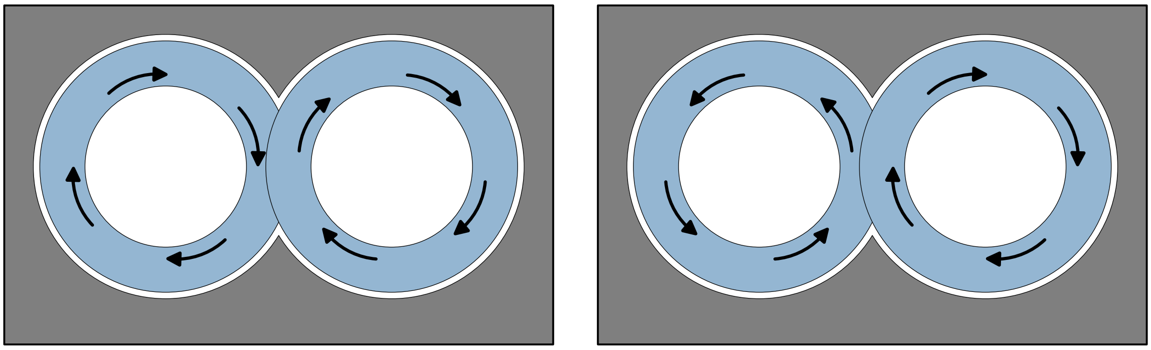
Single screw extruders are generally used for simple extrusions using granules and pre-prepared compounds. The single screw extruder can be regarded as the most basic form of extruder that simply melts and forms the material.

Twin-screw extruders provide excellent mixing of the material as well as being a forming process and are widely used to process powder blends that need to be thoroughly mixed as well as being melted and formed. The twin-screw extruder is available in a wide variety of formats depending on the manufacturer and all have been developed to meet specific market needs. The range of formats is shown below:



The main types of extruder

The two main types – co-rotating and contra-rotating screw machines have different screw rotations in the barrels and these are shown below:



Co-rotating Screws **Contra-rotating Screws**

The development of the conical screw extruder was driven by the need for large thrust bearing as the rear of the machine – a larger diameter screw at the rear of the extruder allows the use of a larger thrust bearing and therefore greater output before thrust bearing failure occurs.

5. The advantages and limitations of extrusion for product design

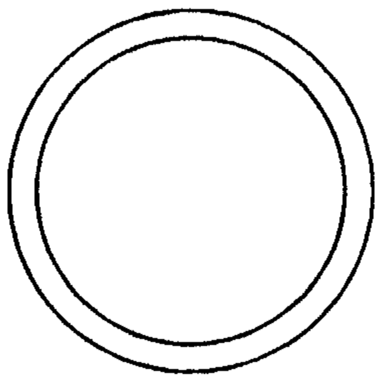
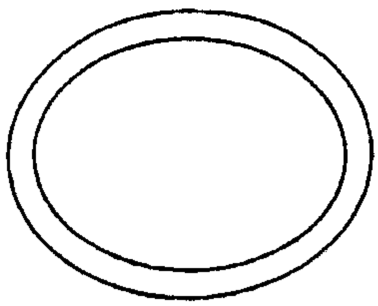
Whichever type of extruder is used, the process has some common features that designers need to understand and these are listed below with some explanatory notes where applicable:

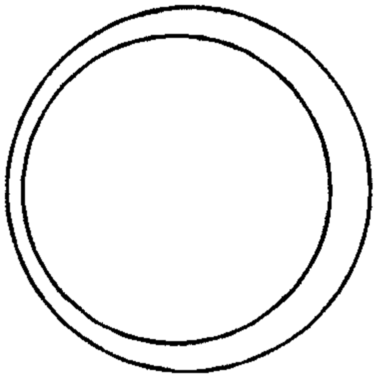
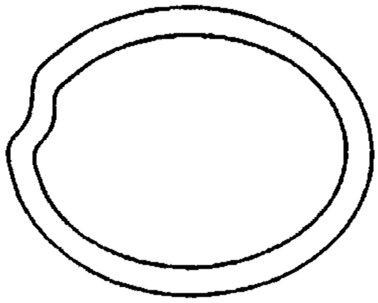
Feature	Result	Notes
Equipment Cost	High	
Tooling Cost	Moderate	
Cycle Time	Continuous	Production rates can be high for tubing (many meters per minute) or low for complex profiles (less than a meter per minute).
Economic Quantity	>5000 m	Extrusion equipment and die costs are high and the minimum economic length is also generally high. 200,000 cable holders of 10 mm long may appear a large order but the total extrusion length is only about 2200 m (allowing for the saw cut), injection moulding may well be cheaper and provide more design options. There may also be a minimum order quantity to cover setting up production.
Tolerances and precision	Good	Extrusion can produce excellent repeatability but achievable tolerances are greater than for many other processes. Critical areas should be noted and the producers' advice on achievable tolerances sought. Tolerances of less than +/- 0.01 mm are not generally realistic. The addition of more tolerances increases the cost of the product.
Wall Thickness Control	Yes	Good within the achievable tolerances.
Open-ended Hollows	No	Extrusion can only produce products that have a constant cross-section.

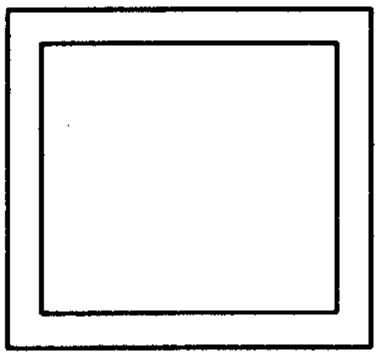
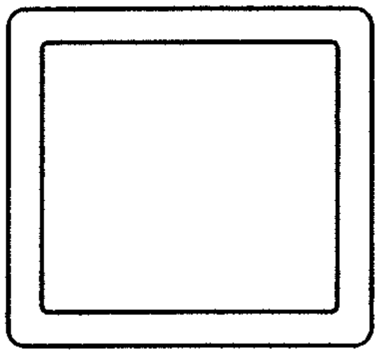
Enclosed Hollows	No	Extrusion can only produce products that have a constant cross-section.
Very Small Items	No	Extrusion can only produce products that have a constant cross-section.
Complicated / Intricate Shapes	Yes	Complicated and intricate shapes are easily possible provided they have a constant cross-section.
Large Enclosed Volumes	No	
Inserts	No	
Molded-in Holes	No	
Threads	No	

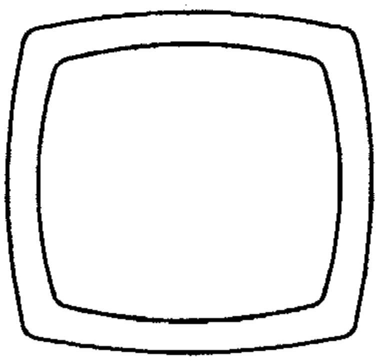
6. Designing extrusions for production

The design of extrusions is not complex but product designers need to be aware of some simple potential problems in order to produce designs that are both economical and easy to manufacture. The table below gives some guidelines for good product design practice:

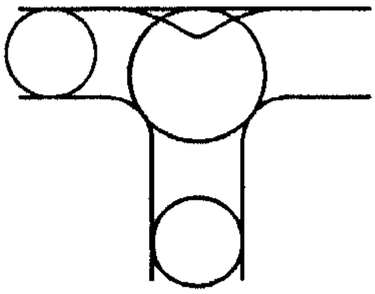
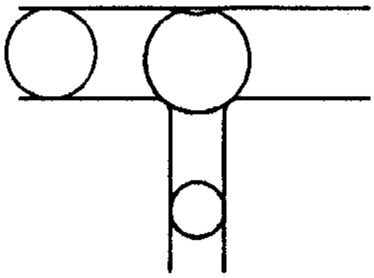
Wall thickness and stability in tubing	
This is the desired output but variations will occur during production and give concerns with in producing even a simple tube.	
This illustrates a potential concern with thin-walled tubes, the haul-off can deform and flatten the section because the pressure necessary to grip the output. Forming the haul-off belts to mirror the form of the section thus increases the surface area contact and can reduce deformation.	

The wall thickness may vary around the section if the centre pin of the die is incorrectly set. This may cause excessive shrinkage in the area that is thickest and even bending of the profile because the thick and thin sections will cool at different rates. Concentricity is a key measure of tubing accuracy.	
If a tube suffers from lack of concentricity, then the grip of the haul-off can locally and uncontrollably deform the tube.	

Squares and rectangles	
The internal and external corners are shown as sharp but this condition is not always desired or always possible to achieve. The plastic melt will not reliably fill sharp corners as it flows through the die and the resulting corners will vary in sharpness.	
This illustrates the more acceptable result, small internal radii, slightly larger external radii and straight sides. The wall thickness should be constant or as near constant as possible to avoid shrinkage and bending of the section (in length).	

Convex (or concave) sides can result from die swell after the plastic exits the die head. To counteract this, the calibrator must pre-form the section the opposite way. This condition is very difficult to predict so a certain amount of testing is necessary with all extrusion tooling.	

Internal walls and chambers

This illustrates ‘sinkage’, a concern encountered with thick internal walls meeting thick outer walls. Where the two walls meet there is a large mass of material. This larger mass of material will shrink more than the thinner areas and create a ‘sink mark’ along the length of the extrusion.	
The thickness of the internal wall needs to be reduced to keep it in proportion with the outer wall. If the inner wall thickness is less than 2/3 the outer wall thickness then any sink marks will be minimized.	

Areas within the chambers - Areas within the chambers are difficult to control.

A screw port of this shape is easy to produce but will not be sufficiently strong to retain screw. Two solutions are shown below:	
Solution 1: This will add sufficient strength to the port, but manufacturing the die is more complicated.	
Solution 2: This shows the best solution, strong screw port and simpler die manufacture.	

7. Applications of profile extrusion

The limiting factors may appear restrictive in some instances but the amount of extruded profile in daily use proves that good design can provide economical and useful products in all areas of activity. The initial design constraint of a constant cross section is overcome in many applications by fabrication techniques such as cutting, drilling welding and stamping and by innovative processing techniques such as co-extrusion of soft and hard polymers, multiple colour extrusion and in-line application of decorative foils or adhesive tapes.

Some example applications are:

Window profiles

The basic frame of the window is an extruded, unplasticized PVC (vinyl) section. This section contains chambers that are carefully designed to give the necessary thermal and sound insulation. The normal colour is white and the polymer is UV stabilized to prevent fading. New developments with co-extrusion and printing techniques allow the profile to be produced with wood-effect or coloured finishes. This basic profile is mitre cut and welded into a frame to fit the windows of the house exactly. Extrusions are also used to provide the essential sealing lips on the profile. By skilled design a system of extrusions is built up to provide products for the complete glazing of a house.

PVC-U windows show the ability of extrusions to be fabricated (in this case welded) to form 3D structures and also show how to circumvent the low stiffness of most plastic. The outer frame of a window is generally fixed to the window aperture and thus no problems with stiffness arise. The opening lights must bear the load of the glass and may not be stiff enough in large windows. In these cases, the profile is stiffened by steel or extruded aluminium sections and the composite profile provides excellent stiffness.

Hot and cold water piping

New plastics now allow applications in both central heating systems (underfloor using pumped hot water) and in hot and cold-water distribution, both in houses and for district heating schemes. The most common plastics used are polybutylene, chlorinated PVC and crosslinked XPE. Performance varies with individual dimensions but the general rule is that at 80˚C flow temperature a life of 25 years is obtained at 6.3 bar operating pressure. This is far in excess of the normal UK operating pressure for unpressurised or vented systems and actual service life should be more than 50 years. The temperature and load effects in this instance are not short term and detailed design calculation and testing are necessary to avoid any concerns with creep or service malfunctions. This example also illustrates the resistance of plastics to common chemicals and the pipes are not affected by any normal corrosion inhibitors present in the water. One of the normal advantages of plastics, electrical insulation, is in this case a potential problem, as the cold-water system cannot be used as an electrical earth although this is also being affected by the use of the PE pipes in water distribution in any case.

Electrical profiles

The use of plastics in electrical and electronics applications is almost endless and the advantage of electrical insulation by plastics means that without plastics the modern electrical/electronics industry would not exist. Extrusions are seen in lighting tracks (where high temperatures sometimes require the use of PPO), trunking, cable management and, most importantly, in wire coating.

Sealing sections

Extrusions are applied in many sealing applications where the designer has considerable choice in fixing method. A co-extrusion of hard and soft materials allows the hard material to be screwed, nailed, stapled or glued to one sealing face and the soft material will still provide the required seal. A single hardness soft extrusion can also be punched or stapled. Alternatively, it may be clipped into one sealing face using a groove in the face as a location/fixing area. Typical application areas are refrigerator door seals (which incorporate a magnetic extrusion for an airtight seal), car door and boot seals and acoustic cabinet seals.

Modular drawer profiles

Drawer systems utilising extrusions are available both as DIY and professional kits. These illustrate important options for the designer: the ability to use an extrusion to provide variable length and width and the use of injection moulded corner pieces to provide the necessary jointing. The requirements for light weight and easy assembly rule out the use of welding and the assembly is built up using the clip-in corner pieces which give rigidity and professional finish.

Decorative trim

Decorative trim strips illustrate two important techniques. The first is the ability to apply a foil to the extruded plastic to give a bright and attractive finish and the second is the use of double-sided adhesive tape for rapid and strong mounting of the profile.

8. Appropriate use of plastics extrusions

Plastics have many advantages over more traditional materials, for example low density, good insulation and corrosion resistance, price and so on, but unwise or uninformed use of plastics in substitution applications has sometimes led to the word ‘plastic’ having derogatory implications. It is important to realise the limiting factors with plastic design in order to maximise the considerable advantages of designing with plastics.

The limiting factors

Temperature

Thermoplastics, by their very nature, have an upper limit on temperature above which softening occurs and functioning is impaired. In considering temperature it is important to consider not only the operating conditions but also the production, storage and transportation conditions. For example, products destined for inside use only may spend some time in a container on the dockside in the sunny Middle East and the temperatures reached may be quite astronomical. The limiting long term service temperature for most commercial plastics is between 60˚C and 100˚C, and above the 100˚C boundary the options for plastic selection rapidly diminish. Above 1500C the only applicable materials are the engineering plastics such as polysulphones, polymides and polyetheretherketones (PEEK). The cost effects of using these materials are severe, from £5000 - £15,000 per tonne.

The correct specification of maximum long-term service temperature thus has an enormous effect on the price of the finished article. It is not enough, however, to just specify a temperature; consideration must also be given to the following factors:

- Is the article to be under load at high temperature?
- Is the temperature constant, cyclic or transient?
- What happens when the material expands and contracts due to thermal expansion?
- Will regression due to moulded-in stress occur?
- Are there chemicals present?

For many applications these factors may be critical and successful economic production requires careful consideration and possibly investigation of temperature at the design concept stage. If in doubt Tangram Technology, the material supplier or the potential processor should be contacted for expert advice at an early stage.

Mechanical properties

Compared to metals, plastics generally tend to have low absolute mechanical properties at room temperature in terms of tensile strength, impact strength, Young's Modulus and hardness. If, however, the comparison is to be made on the basis of cost per unit of tensile strength then the choice is not as clear cut and depends on the materials being compared. This means that a plastics article may be made thicker than a metallic article to give the same functional response for a given cost.

The real problem emerges when the Young's Modulus (E) or stiffness is an important factor. Plastics have typical E value of 1.1 to 14 GN/m^2, compared with metal values of 70GN/m^2 and upwards. In this the variation is so great that increasing the thickness of the article is not a realistic option because the cost per unit stiffness for plastics is approximately 10 times that of metals. If stiffness is a requirement, then this must be provided by shape factors such as good design for stiffness, rather than simply relying on the material characteristics. The available engineering plastics provide excellent mechanical properties, but the high costs involved make sensible design and value engineering procedures at an early stage even more crucial.

As visco-elastic materials, thermoplastics experience creep or flow phenomena, which means that while a load below the yield stress (however this is defined) may be acceptable in the short term it may be unacceptable in the long term. This is due to the possibility of creep of the material resulting in loss of function. As with all mechanical properties and responses of plastics, creep is highly temperature dependent and becomes more of a problem at elevated temperatures.

An important point to note with the response of a plastic to any mechanical stress is the concept of strain rate temperature equivalence. This means that a plastic's response to higher operational strain rates is similar to its response to lower operating temperatures and vice versa.

Chemical resistance

Most plastics have excellent chemical resistance and this is largely complementary to metals, meaning that what attacks metals will not generally attack plastics and vice versa. As a general rule plastics provide excellent resistance to water, salt solutions, weak acids and bases, but are affected by solvents and oxidising agents.

Tolerances

Extrusion as a process can produce excellent repeatability but the tolerances achievable are not as fine as for machined or other similarly produced items. It is important that critical areas be marked and the producers' advice on achievable tolerances be sought. Requests for +/- 0.01 mm are not generally realistic. If a guide is required, the BS 3734 (Table 2 Class E2) should be used but specific instances may require variations to this. The addition of more tolerances almost invariably increases the cost of manufacturing the product.

Volume demand

An important factor in the choice of any production method is the volume demand. In general, extrusion equipment and die costs are high and depending on the profile considered the minimum economic quantity is approximately 300 -10,000 m. While 200,000 cable holders of 10 mm long may appear a large order, the total extrusion length required is only approximately 2200 mm (allowing for the saw cut) and injection moulding may well be cheaper (and allow for inclusion of other features such as a screw hole). In many cases there will also be a minimum order quantity to cover the costs and time of setting up production. In this context a total demand of 1000 m in call-offs of 100 m is almost certainly uneconomical for the producer.

9. Appendix – Extrusion definitions

- Adiabatic Extrusion – A method of extrusion in which the sole source of heat is the conversion of the drive energy through the viscous resistance of the plastics mass in the extruder.
- Barrel – The portion of the extruder surrounding the screw or plunger.
- Barrel Liner – A sleeve forming the internal surface of the barrel.
- Compound – Plastics material as prepared for a further manufacturing operation particularly for extrusion, moulding or calendering.
- Compression section – Part of the transition section in which there is a reduction in screw channel volume.
- Cooling tank/bath – A tank commonly containing water through which extrusion is continuously passed for cooling.
- Crosshead die – An extrusion die which produces an extrudate the axis which is at an angle to that of the extruder barrel.
- Cure – The process of cross-linking a plastics material.
- Decompression section – In a two-stage extruder that part in which there is an increase in screw channel volume.
- Die – A part or assembly of parts held, contained or fitted to the extruder head to form the melt to the desired profile.
- Die plate – In moulds, the main support for the punch or mould cavity.
- Discharge section – The flighted portion of the screw at the discharge end in which the melt is forced towards the die.
- Draw down – Reduction of thickness of plastics emerging from the die by control of haul off speed.
- Drive – The entire system used to supply mechanical energy to the screw.
- Dry blend – A free flowing mixture of resin or compound and other ingredients as prepared for a further manufacturing operation particularly for extrusion or moulding.
- Embossing – The production of embossed film or sheeting.
- Embossing roll – A roll having a patterned surface used to produce embossed sheeting.
- Extrudate – The product of an extrusion process.
- Extruder head – A component which may be attached to the discharge end of the extruder barrel to house the die.
- Extruder size – The nominal inside diameter of the extruder barrel.
- Extrusion – A continuous shaping of plastic material by forcing it, as a melt, by pressure through a die.
- Extrusion coating – A method of coating in which molten plastics is fed direct from an extruder die into a nip-roll assembly together with the substrate.
- Extrusion pressure – The pressure of the melt at the discharge end of the screw.
- Gelation (compounding) – A stage in compounding material, at which it first becomes a coherent mass.
- Haul off or caterpillar – A device for taking away extrudate continuously from the die.
- Heating zones – Parts of the barrel, head and die arrange for independent temperature control.
- Internal mixer – A mixer consisting of specially shaped rotors operated in a closed chamber.
- Length-to-diameter ratio (L/D ratio) – Effective screw length divided by the screw diameter and commonly expressed as a ratio to unity.

- Masterbatch – A compounding ingredient resin and additives with the additives present in higher concentration than are required in the final plastics material.
- Matting – The process of rendering a polished surface uniformly dull.
- Melt – Extrusion material when heated to a plastic condition.
- Metering section – The flighted portion of the screw at the discharge end, in which the melt is forced at a controlled rate towards the die.
- Outer die ring – The part of tubing die which shapes the external surface of a tube.
- Post cure – To continue the cure of a moulded article by a subsequent heating process.
- Processing aid – An additive to, or a component in, a resin to facilitate processing.
- Ram extruder – A machine consisting essentially of a barrel with means of temperature control, in which a plunger operates to force material as a melt to a die.
- Ram pressure – Used colloquially for the total force applied by a hydraulic ram, equal to the hydraulic pressure multiplied by the ram area.
- Screen pack – Wire gauzes supported by the breaker plate and used for filtering the melt and increasing back pressure.
- Screw – A helically grooved rotating member housed in the barrel of a screw extruder.
- Screw diameter – The diameter developed by the rotating flight land about the screw axis.
- Screw extruder – A machine consisting essentially of a barrel with means of temperature control and housing one or more rotating Archimedean screws which convey plastics materials from feed aperture and deliver it as a melt under pressure to a die.
- Take up (extrusion) – A device for reeling extruded material.
- Torpedo (extrusion) – A device at the discharge end of the screw for completing mixing and homogenising of the melt.
- Transition section – The flighted portion of the screw between the feed and discharge sections in which the extrusion material becomes a melt.
- Travelling saw – A saw which travels with the extrudate while cutting it to length.
- Twin screw extruder – An extruder with a pair of screws working together in a common barrel.
- Two-stage extruder – A screw extruder so designed that the pressure of the extrusion material drops substantially, part way along the screw.
- Two-stage screw – A screw for use in a two-stage extruder comprising a decompression section before the final metering section.
- Vacuum sizing – A process using a sizing die with vacuum applied to the external surface of the extrudate.
- Vacuum tank – A cooling tank operating under reduced pressure to control the dimensions of the extrudate.
- Vent – A hole or groove in a mould provided to allow air or volatile matter to escape during the moulding operation.
- Vented extruder – A two-stage screw extruder having an opening part way along the barrel for the removal of air and volatile matter from the plastics material.
- Weld line – A mark formed by union of two or more streams of material flowing together.