Extrusion Operations

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START UP

Start up refers to those procedures involved in getting a machine into full production. It is very important to have intelligent start up procedures, as adherence to such procedures will minimize dangers to the operator and damage to the equipment.

Check the Heating System

Before commencing operations, one should first check that the thermocouples are in their specified positions, of the correct type and are connected to the appropriate instruments in the control panel. If there is a thermoplastic material in the hopper, its feed gate should be closed. Make sure that the drive motor is off and that the speed is at the lowest setting possible. See that the cooling water is on and flowing at the correct rate through the hopper throat and the barrel cooling system. Turn off any cooling water to the screw. Turn on the heating system and set the temperature controllers to a very low value (for example, 50˚C). After this temperature is reached and held, by the control system, one can then begin heating up the machine for production to begin. The actual procedures may differ if the machine contains polymer or, if it is empty.

Warming Up an Empty Machine

Check the records or obtain experienced advice on what machine settings are needed for the job at hand. Turn the main power switches on. Program the heat input to avoid an overshoot (melt temperature over-ride or MTO) while heating up the extruder in a reasonably short time. This is usually accomplished by using temperature controllers fitted with a three term (PID) control. As it is easier to heat a barrel than to cool it down, it makes sense to approach the final operating temperatures slowly to minimize the risk of a temperature over-shoot (unless it is known that the system will not over-shoot). This is most easily done by setting the temperatures about 20˚C/30˚F below the running settings, during initial barrel heat-up. Once the system has stabilized at the preliminary settings then heating to the desired running temperatures is carried out. Such a procedure is necessary with some materials, such as unplasticized polyvinyl chloride (UPVC), where an overshoot can cause serious degradation before processing commences. Once the machine is at the set temperatures it should be allowed to equilibrate before any material is introduced into the barrel. Keep this time as short as reasonably possible. Otherwise, residual material present in the screw flights may burn when heated in the presence of air.

Warming Up a Full Machine

When a full machine is being warmed up, it is important to ensure that it is heated in a way that avoids decomposition of the polymeric material. Decomposition can produce gases that, under pressure, can cause serious accidents by blowing hot material from the die. All temperatures should be set below the melting temperature of the particular material (for example, to 135˚C for LDPE). Allow the machine to reach and equilibrate at these temperatures. Next raise the temperature of the die to above the melting temperature of the resin. Then raise the temperature of the front zone and the rear zone to above the melting temperature. Finally, working towards the center, raise the temperatures of the other zones. Allow the machine to equilibrate at these temperatures for a short time before purging. Only proceed if the purged material looks satisfactory, i.e., sufficiently melted, but not excessively hot.

Barrel Temperature Settings

These are the temperatures set on the control instruments essential to reaching a desired melt temperature. Once an extruder is up and running, most of the heat input required for extrusion is mechanical heat supplied by the screw and drive system. The heaters are used only to warm up the machine and to “fine tune” the system during operation. One should remember that it is the melt temperature that is important and any barrel temperatures quoted in the literature are only guidelines. When there is no experience with the processing of a particular grade of material, one should start with the lowest recommended settings. Unless the records show otherwise, use a flat temperature profile (each zone set at the same value). Recommended temperatures are 100˚C/200˚F above the glass transition temperature (Tg) for an amorphous thermoplastic material and 50˚C/70˚F above the melting temperature (Tm) of a crystalline material. One should always remember that the melt temperature is almost always higher than the highest barrel set-point temperature.

Equilibration

Once the machine is at the set temperatures, it should be allowed to equilibrate for about 20 minutes before material is introduced into the barrel. This time can be used to check that the die is clean and that all parts are operational. Review the production order for color and quantity and check that all necessary tools and equipment are in position. Check that ancillary equipment, such as the hopper or feed system, is clean and is functioning as required.

Initial Purging

Check the records to determine which screw is needed for the job at hand. Ensure that the correct screw is in the machine and that it is installed properly. Once the machine has equilibrated at the running temperatures, start the screw rotating slowly and then introduce some material by hand into the hopper. Do not fill up the screw throat, otherwise the material may not melt completely and the un-melted granules may block the die and destroy any pressure transducers in the die and barrel. If everything appears satisfactory (for example, no melt frothing, spitting or motor overload) slowly increase the amount of material on the screw until it is covered with material. Then fill the hopper with material. Check the melt temperature with a melt probe and also check the general appearance of the melt. Proceed only if this purged material looks satisfactory, the melt temperature is as specified and the motor amperage is not excessive.

Starting Up

Before starting up, a lead piece (produced in a previous run) or a piece of string is threaded through the cooling system and then through the haul off. The operator should wear suitable gloves. It is also useful to have an arrow drawn at the end of each roll that shows the direction of roll rotation and the path taken by the extrudate through the system. The haul off may then be moved to a convenient position in front of the die and the extruder run at a low speed. When the material is extruded from the die it is attached to the lead piece by tying or by melt adhesion. The operator steadily pulls the piece through the system. The nips are often left open so that any joints or irregularities may pass. This drawing, or pulling, requires skill and it is essential that the operator is not distracted as he is guiding the extrudate over obstructions, around hot rolls etc. Usually the extrudate is cooled as it is being drawn away, as this gives the product strength. Once the extrudate has passed through the haul off, the haul off drive is started and the speed adjusted before the nips are closed (save the lead piece for the next start up). Ensure that the haul off cooling system is fully operational and adjust its position to the running position relative to the die. Gradually increase both the screw speed and the haul off speed, providing that the machine operating parameters are within previously stated limits. Adjust the speeds to give approxmately the correct dimensions and then adjust the die to produce the required dimensions. Any adjustments must be made slowly as this usually saves time.

Safety Considerations

One of the most dangerous times during processing is at start up. This is because material being heated in the machine may decompose and spit from the die. The operator is focused on getting the machine running satisfactorily and this involves close contact with machinery. So, great care should be taken at start up. In particular, no one should be allowed to stand in front of the die/nozzle and the hopper lid should be firmly in place, so that the screw cannot be seen (and therefore touched). No unauthorized person should be in the processing area.

Temperature Problems

If the use of a flat temperature profile causes:

- Premature melting and bridging of the material (resin) in the feed throat: gradually decrease the feed zone temperature
- High die pressure fluctuations: raise the feed zone temperature
- Melt temperature fluctuations: raise the transition zone temperature
- The barrel temperature to exceed a set point: slowly raise the set point temperature of that zone (raising the transition zone temperature can, how ever, reduce viscous heat generation and may cause incomplete melting)
- A loss of product gloss: raise the die exit temperature

PROCESS MONITORING

During extrusion both process-based monitoring and product-based monitoring are used to achieve product improvements. Process-based monitoring watches production process conditions such as melt temperature and pressure. Product-based monitoring follows properties of the product, such as, clarity and thickness.

Pressure Measurement

Pressure measurement is now most commonly done with a pressure transducer, or sensor, which senses pressure or pressure changes (Figures 32a. & b.). Several different types of electrical pressure transducer are used, however, the most common type is the strain gauge pressure transducer. Because of its robust nature, accuracy and repeatability, ease of use and universal character, strain gauge pressure transducers are the most frequently used instrument for pressure measurement in extrusion processes. It is usually melt pressure, such as the pressure within an extrusion die or barrel that this transducer is required to measure. The transducer is made in the form of a probe with its tip flush mounted to the inner diameter of the extruder barrel or die. Since, the high temperatures at the transducer tip can complicate temperature compensation, the measuring diaphragm and strain gauge are located away from the tip. The pressure is transmitted from the transducer tip to the measuring diaphragm, by means of an incompressible fluid such as mercury (in a filled capillary), to strain gauges in a Wheatstone bridge arrangement bonded to the measuring diaphragm. The electrical output from this gauge assembly is directly proportional to the pressure on the sensing diaphragm or tip. Cold start-ups and/or rough handling of the transducer will damage the tip relatively easily.

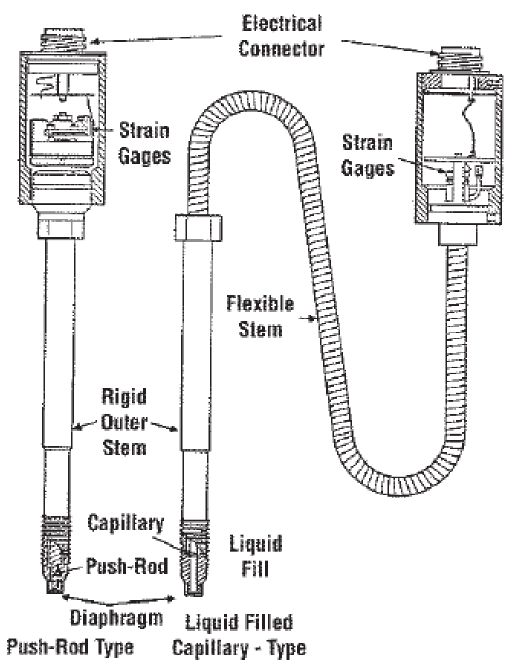

Figure 32a. Pressure Transducers

Figure 32b. Dynisco's Pressure Gauges,Transducers and Transmitters

Important Pressure Measurement Locations

There are several locations on the extruder where pressure measurements should be made. Along the barrel, measurements help determine screw performance and design; before and after the screen pack, measurements warn of potential high pressure situations and avoid flow restrictions between the screw and the die; at the inlet and outlet of the gear pump, pressure measurement ensures a constant melt flow to optimize pump performance and safety; and pressure measurement at the die maintains stable output and reduces scrap and material waste. At every location, pressure measurement helps ensure safety of equipment and personnel and increases machine output and efficiency.

Temperature Measurement

For reasons of cost and convenience, the thermocouple (TC) is the most common temperature-measuring element (Figures 33a. & b.). Basically, a thermocouple consists of two dissimilar wires that are joined to form a thermo-junction. A thermo-electric electromotive force (EMF) is generated at the junction of unlike metals if one thermo-junction (one end of the assembly) is made hotter that the other. The magnitude of the EMF depends on the metals used and on the temperature difference of the junctions. For a given combination, the more the one junction is heated, the greater will be the electrical signal. If one end is kept at a stable reference temperature (by cold junction compensation) then the thermocouple may be calibrated, so that a simple and accurate measurement of temperature can be made. The measurement may be displayed as˚C or ˚F in analog or digital form. Usually, a thermocouple (TC) has the tip protected by a rigid metal sheath and a flexible metal covering protects the connecting wires.

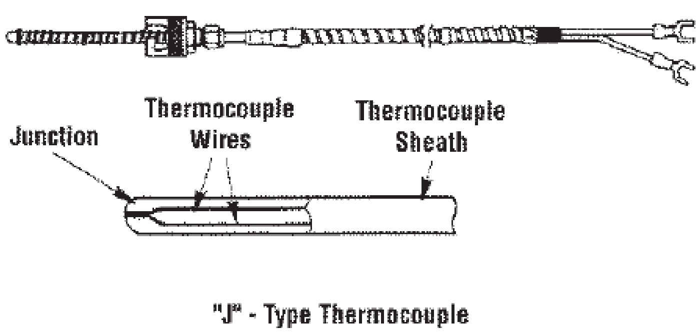

Figure 33a. Thermocouple

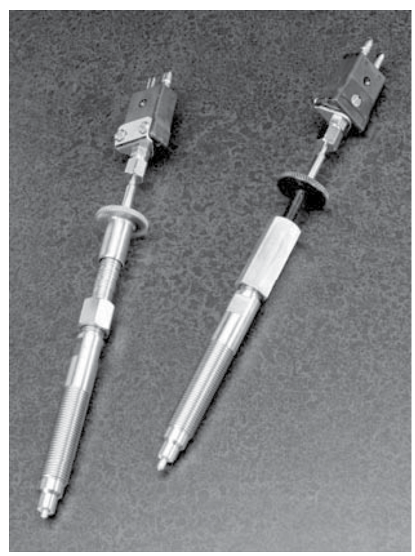

Figure 33b. Dynisco's Melt Thermocouple

The melt temperature is traditionally measured by pumping the material into the air (an air shot technique) and then immersing the tip of the TC into the melt. It may also be measured on-line by the use of a melt temperature thermocouple. Ideally, an immersion thermocouple should be employed unless the use of a surface mounted TC can be justified. It is recommended that the tip of the immersion thermocouple should be immersed approximately 0.25 in/6 mm into barrel/nozzle (so that it does not pick up the temperature of the metal). The sensing tip of such a TC should also be insulated from the body of the sensor. The same adapter as used for a pressure transducer may be used to house an immersion thermocouple. Commercial infra-red temperature transducers (sensors) are now available and their use promises to dramatically improve the extrusion process. Infrared line scanning thermometers may be used to measure the temperature and the temperature distribution across the width of extruded sheet to improve temperature uniformity.

Thickness Measurement

The thickness of sheet is often measured using a beta radiation gauge (β ray gauge). For a given formulation β-ray or particle absorption is directly proportional to mass per unit area. If the extrudate composition is fixed, then the sensor output can be set to continuously read product thickness. To do this, a low energy radioactive source, which emits beta particles, is mounted close to the moving sheet and the transmitted radiation is detected by an ionization chamber. The amount of beta particle transmission varies with the thickness and composition of the material through which it passes. If the composition is constant, the degree of ionization, and hence the conductivity of the chamber, will vary with the thickness. The changes in the conductivity can be converted to give a read-out of thickness or weight per unit area and/or used to actuate a control action. The read-out from such a gauge gives the gravimetric thickness value or nominal average thickness. Gravimetric thickness is obtained from the weight a sample of known area and its density by dividing the weight by the area and the density. For an non-embossed sheet, the gravimetric thickness is the same as the geometric thickness. For an embossed sheet, the gravimetric thickness is not the same and is more relevant. Because of concerns about radioactive emissions, X-rays are being used in place of beta rays. X-rays are more controllable and the X-ray beam can be tightly collimated, which reduces the radiation profile risk. Disposal of the radioactive isotope is also a problem that is eliminated.

Speed Measurement

In extrusion, the screw speed is the screw rotational speed that is usually measured in revolutions per minute (RPM). However, it should be remembered that it is the screw surface speed that is important. Speed must be measured and displayed very accurately as, screw speed controls how much material is pumped, how well it is mixed, shear history, melt temperature and melt temperature variations. Screw speed must, therefore, be set and read accurately and held to the set value. The processing machine must have an accurate display of screw speed (for example, a digital display) and the screw drive system must be powerful enough to keep the speed constant. The speed of the screw may be feedback controlled using a tachogenerator, driven by the motor shaft, which generates a voltage that is proportional to the motor speed. This voltage is used as the feedback signal to control the motor speed. Screw speed may be measured directly by means of a transducer and a gear wheel. The gear wheel is mounted centrally on the screw so that when the screw is rotated, the teeth of the wheel pass the transducer. As each tooth passes the sensor, this creates a change in the magnetic field (a pulse) which is sensed by the transducer. When the number of pulses is counted per unit of time, the screw speed is obtained.

Width Measurement

Several different, non-contacting systems are used to measure the width or size of an extrudate as it is being produced (on-line). A single laser beam can measure pipe and tubing diameters. Two lasers, mounted at right angles, have been used to measure the size and eccentricity of round extrudates such as pipe, tubing, rod or cable. The collimated laser light casts a shadow on a detector that can determine the size to 0.002 mm (if the size is outside previously set limits, the haul off speed or the screw speed may be automatically adjusted). Pipe wall thickness, and uniformity, may also be determined by ultrasonic measurements so that low gauge and more uniform pipe can be manufactured. Monofilament diameter can be continuously monitored with a laser. Several strands can be monitored intermittently using a scanning or traversing laser. When sheet is being produced its width can be determined by infrared measurements. The sheet is hotter than the roll on which it lies and an infrared detector can be used to sense the two edges of the sheet. Lasers are also used for sheet width measurement. Lay flat film width may be determined by ultrasonic measurements. The results of such measurements are used to control bubble size and air exchange in the bubble. The cross-sectional area of irregularly shaped profiles can be measured with a pneumatic area sensor: this uses the Bernoulli effect to make online measurements that correlate with the cross-sectional area of the profile.

Production Condition Recording

This is the systematic recording of all production conditions, so that it is known how a component, or product, was produced. It must not be forgotten that the object of production is to produce component/product of the required quality, at a specified cost, within a specified time, and when required. To do this it is essential to keep accurate records. On many machines, fitted with microprocessor control, this can be done at the press of a button. Where this is not possible then, an appropriate record sheet should be completed at periodic intervals. Production samples should also be retained for future reference. The importance of careful and accurate recording of process settings cannot be over-emphasized. Not only is it useful to have a full and accurate record for machine re-setting, but such records are useful, as well, for product liability reasons or to fulfill ISO 9000 requirements. A microprocessor-based machine will record all relevant data, print it out if required and then, instantly reset the machine when that particular job is re-run. Such instant re-setting saves a great deal of time and gives more accurate settings than that possible manually.

Product Monitoring

The machine operator may make checks on product quality or a control system or a separate system such as a robot-type device can make them. Verification of product quality at the point of manufacture can be documented in statistical quality control (SQC) records. To do this automatically, the system designer must identify what needs to be monitored and then equip the machine with appropriate transducers. The outputs from these transducers are monitored and if the signal from one or more is different from previously set limits, then various quality control (QC) actions may be taken. For example, an alarm may be sounded so that the product may be diverted to an inspection area. Microprocessor systems can ultimately provide total control of the extrusion line if the causes and effects of changes in machine and process parameters are correlated with machine adjustments. Where robots are used for product removal, a robot measuring system (for instance a system based on the measurement of different dimensions) may be used to judge, or assess, the extrudate. The information that the robot measuring system generates may then be transmitted to the microprocessor control system and used for QC charts. On-line QC, based on product measurements, is therefore relatively easy and can be done for every piece of extrudate produced. If the product is judged to be defective, then it can be diverted for re-assessment or re-granulation and re-use.

PROCESS CONTROL

Processing operations in manufacturing must be performed under conditions controlled by documented work instructions that clearly define the manufacturing process, the conditions employed, the variations allowed in production, the inspection procedures and the quality expected.

Temperature Control

In the extrusion shop, or factory, the thermocouple (TC) is the most common temperature-measuring element. When a thermocouple is used to feed a temperature control instrument with information, the well for the TC should be sunk as deeply into the barrel wall, as safety will allow. The base of the well should accurately match the shape of the TC tip. The TC may be spring loaded, so that when inserted into the hole, and twisted, it is locked in place under a controlled pressure. The TC will then sense the temperature of the metal close to the polymer. If a three-term control system (PID) is used, the barrel temperature may be controlled to within ±1˚C/1.8˚F. The temperature control circuit, which uses information from the TC, is commonly kept separate from the remainder of the control system, so that in the event of a stoppage the heat supply to the barrel assembly is unaffected.

Thickness Control

The control of thickness during production is very important. When extruding thermoplastic materials it is usually the rate of cooling that limits the rate of production. Accurate thickness control, therefore, saves not only on material use, but also gives faster cooling as the product can be held to the bottom of the allowed tolerance band. Thickness variations in the extrudate (be it, sheet, cast or blown film) can have two basically different causes. 1. Gauge variations parallel to the extrusion direction (along the sheet). These are mainly due to variations in screw speed (caused by changes in material viscosity), haul-off speed changes, temperature variations and inhomogeneities of the raw material. 2. Gauge variations perpendicular to the extrusion direction (across the sheet), which are primarily due to a non-uniform die gap. The die gap and/or the die temperatures can be adjusted. If sheet is being extruded, it is often preferable to leave the die gap constant and to adjust the spreader bar. Automatic profile control is possible using a system that automatically adjusts itself to control the size of an emerging profile. The die may have a number of heating/cooling units around its circumference, so that melt viscosity can be varied, to give the required output at that point, without adjusting the die gap. The thickness is measured and the temperatures adjusted accordingly. Such a system will improve the stability of the bubble and the output. Changes in conductivity, from a beta radiation gauge, can be used to adjust the motors that control roll speed during sheet extrusion.

Drive Control System

A high-speed motor generally drives an extruder screw via a gearbox and pulleys. Such an arrangement, of a high-speed motor driving through a reduction gearbox, gives considerable speed stability (because of rotational inertia). For many extrusion applications, however, the speed must be held very precisely, in order to achieve a precise output, despite variations in extruder demand. Therefore, the drive system will also contain a regulator that compares input signals from sensors (current, speed and torque) with reference inputs (manually set or computer derived). Corrective signals are then sent to the transformer- rectifier unit and thyristor controls with tacho-generator feedback hold the speed of a motor to approximately 1% from zero to full load. That is, at 1750 rpm the speed is held to ±17.5 rpm. If a digital, rotary pulse encoder together with a microprocessor is used, the speed may be held to ±1.75 rpm at 1750 rpm. As a result of this accuracy, DC and AC Flux Vector motors are widely used as extruder drives. In some specialized systems, a pressure transducer will feed a signal into a process controller which, in turn, provide feedback control of the screw speed. In this way, a specific pressure can be maitained by varying the screw RPM and thus maintain a steady extrudate output. This system is usually used in the case where steady die output is necessary, and a melt pump cannot be used.

Automatic Pressure Control (Figure 34.)

Accurate temperature control can have profound effects on the quality and yield of extruded products. In the last forty years, temperature control has progressed through the original percentage timers, to Proportional, Integral and Derivative (PID) control as adapted by Ziegler and Nichols, to various self-tuning PID control algorithms both with and without the additional simulation of expert operator intervention called fuzzy logic. More recently similar principles of automatic control have become available for the control of extruder pressure. The speed of the extruder screw is regulated to maintain a preset pressure at the die. PI and PID controllers, utilize algorithms more suited to pressure control than Ziegler -Nichols. Automatic tuning has simplified the installation and set up of controllers and control systems. As an example, the Dynisco ATC770 process controller utilizes two automatic tuning algorithms (Figure 34.). Together they are known as the SMART function. The TUNE algorithm is invoked in the Manual mode of operation, and is a "one-shot" algorithm, which will determine the P&I, parameters based on a change in the manual output. The unique ADAPTIVE tuning algorithm is based on the Dominant Poles Theory, and is a direct method based on the analysis of the input signal rather than the error signal. This algorithm is invoked in the Automatic mode of operation, and as the name implies, it is a full-time algorithm that adapts to changes in the extrusion process. Either or both algorithms may be shut off if manual tuning is desirable. In addition to the obvious control of the input to the motor drive, today's controllers offer a number of beneficial auxiliary functions and options - all done without operator intervention. Two or three auxiliary setpoints can be used in a scheme of alarms and interlocks. The use of auxiliary setpoints can prevent starting of the extruder prior to operating conditions having been reached. A setpoint may be set to indicate that it is time for a screen change, thereby avoiding dangerous pressure build-up. An absolute shutdown pressure setpoint may be set and latched to ensure safety of equipment and operator. An analog output directly proportional to the pressure is also available, and digital communications is a frequently supplied option. Parameter information may be sent to another device in either analog or digital form. The controller can be a redundant device in a DCS and can report its activity to an SPC system. The processor who chooses to automate can realize numerous benefits:

- Dramatic increase in safety in the workplace
- Monitor machine and screw condition
- Protect machinery from inadvertent damage
- New controls often enhance the performance of old machines
- Relatively unskilled personnel can operate machines
- Improve yield and maintain consistency of product
- Reduce reject product and maximize return on raw materials
- Allows duplication of conditions from run to run
- Allows one operator to supervise several machines
- Automatic tuning simplifies setup when changing from one product to another

Figure 34. Dynisco's ATC770 Pressure/Process Controller

Automatic Quality Control

Quality control may also be performed automatically by the production machine. Because of the power of the microprocessor used for the control system, it is now relatively easy to incorporate features that verify product quality during manufacturing, using the output from measuring sensors. Verification of product quality at the point of manufacture can then be documented in statistical quality control (SQC) records. To monitor a process on-line, the production machine must be equipped with appropriate transducers and measuring equipment. These may include a melt thermocouple (in the die), pressure transducers (on either side of the breaker plate) and a (product) thickness measuring sensor. During production the output is automatically gathered from these transducers and displayed on a visual display unit (VDU). Production trends can then be easily spotted. If the changes exceed preset limits, the product is then judged to be out of specification. Such product may be rejected completely, or diverted for inspection and subsequent disposal decisions. Changes in the product can be then identified and quantified if the changes are capable of being statistically analyzed. Such analysis is not necessarily difficult, since the use of relatively simple statistics can yield a surprising amount of useful information. This information may be used to adjust the process in order to eliminate defects in the product, by altering die settings, extrusion speed, or some other process parameter.

SHUT DOWN PROCEDURES

It is most important to adopt a sensible shut down procedure as it can save a great deal of time and money. If, for example, the resin is prevented from burning then there will not be so much purging required on re-heating and the cost of a complete shut down and machine clean out may be saved.

After Processing a Heat-Stable Material

If a thermally stable plastic, such as polystyrene (PS) or polypropylene (PP), is being processed then, for a temporary (overnight) stop, it is usually only necessary to perform a few steps:

1. Close the slide at the base of the feed hopper
2. Turn off the cylinder heaters (leave the die heater on)
3. Purge the barrel clean by pumping the screw dry
4. When nothing more comes from the die, put any barrel cooling on maximum, stop the screw, and, when the machine is cool, turn everything off

The machine is then ready for re-heating when required.

After Processing a Heat-Sensitive Material

Decomposition, or burning of polymer in the extruder barrel, may cause color changes that will result in the subsequent product being rejected. If this happens a complete shut down and clean out may be necessary. To prevent this, it may be necessary to purge a heat sensitive resin with another, more heat stable, polymer that will withstand subsequent re-heating. If material oxidation is a problem (with, say polyethylene) then it may be best to leave the cylinder full of the material rather than pumping the screw dry before switching off. Do not shut off the cooling water to the feed throat until the temperature of the first zone has fallen below the melting point of the polymer.

After High Temperature Operation

When high barrel temperatures are used, the shut down procedure should be modified to prevent thermal decomposition of the resin. One should:

1. Turn off the cylinder heaters (leave the die heater on)
2. Put any barrel cooling on maximum
3. Periodically pump resin through the machine while it is cooling, but make sure the barrel temperature remains slightly above the melting point of the resin
4. Close the slide at the base of the feed hopper and purge the barrel clean by pumping the screw dry
5. When nothing more comes from the die, and when the machine is cool, turn everything off

The machine is then ready for re-heating when required.

Display Notices

Before leaving a machine, prominent notices should be displayed if the electric supply to the machine is left on, if the heaters are on or, if parts of the machine are still hot. Water and air supplies should be turned off. The motors and pumps should be isolated so that they cannot be started accidentally.

PURGING

A method of cleaning the extruder screws and barrel, without pulling the screw and disassembling the machine, is through purging. There are several reasons for purging (cleaning). One may want to change from one grade or color of material to another and/or change from one type of material to another. The net result is the same: material is wasted and production time is lost. Therefore, the object must be to minimize such losses by careful planning of the work being done to minimize the effects of changes.

Minimizing Effects

One should try to plan production operations so that the work flows in a logical sequence. Light-colored materials should be processed first. Easy flowing (high melt flow) materials should be processed before stiff flowing (low melt flow) materials. If it is necessary when changing from one material to another, use a polymer that processes at a temperature that is intermediate between those of two widely dis-similar materials. It is very important to keep the materials handling equipment clean and to ensure contamination is not introduced during drying. The screw, barrel and die assembly must be thoroughly inspected to ensure that there are no worn or broken regions where material can stagnate, degrade, and then be released into the fresh polymer stream during production.

Temporary Stops

During a temporary stoppage the extruder may be periodically purged, by passing the material being processed through the machine at minimum screw speed. Do not allow material to build up on, or around, the die lips. If necessary, and allowable, coat the die lips with a light coat of silicone grease or other release agent. If the purged material looks discolored then increase the frequency of this purging. During a minor repair, the heaters on the barrel should be set to low values to minimize thermal degradation.

Purging Procedure

In many cases, when changing from one material to another, the barrel is simply emptied (purged or pumped dry) and the new material is then introduced into the system. In other cases (for example, when changing from polycarbonate (PC) or polyamide (PA)) a faster changeover is obtained if the barrel is purged dry and a purge material is then used. Thermoplastic materials such as polystyrene (PS), high-density polyethylene (HDPE) or cast polymethylmethacrylate (PMMA or acrylic) are widely used as purging materials. Other proprietary compounds are available for purging purposes and these should be used as directed by the manufacturer. In general, when changing from one material to another, for which the processing temperature is higher, set the barrel temperatures to those appropriate for the new material. If, however, they are lower, maintain the old temperature settings until purging is complete. Then discontinue the material supply to the hopper, empty the hopper, (carefully save the material), thoroughly clean the hopper by brushing and wiping, and replace it on the barrel (If it has been removed for cleaning). Any remaining material in the barrel should now be very soft as it has been heated (heat soaked) during the hopper cleaning. Empty the barrel into the air by rotating the screw. Introduce the new material and run a few pounds through the system as quickly as possible (that is, use the new material for cleaning or scouring). Allow the machine to stand (for approximately 10 minutes) and then rapidly run more of the new material through the barrel. Repeat this procedure until there is no sign of the old material. If it is intended to shut the system down after using a purge, the shut down procedure may then be followed once the purge material or compound is coming through.

Purge Materials and Compounds

A purge material is a polymeric resin used for purging. It is usually a high molecular weight (high viscosity) polymeric material that is relatively stable at processing temperatures. Natural, non-flame retardant grades of polymethylmethacrylate (PMMA) or high-density polyethylene (HDPE) are often used as purge materials. A purge compound, also known as a purge, flushing compound or cleaning compound is a compound specifically designed, or used, to assist purging, or machine cleaning. It may contain large amounts of filler such as pumice. Before such purge compounds are used, it is advisable to remove the die as many purge compounds do not melt, or flow, like ordinary thermoplastic materials, and can damage the die polish or the die outlet.

Purge Compound Cleaning

If a proprietary compound is available for purging purposes then the manufacturer‘s instructions should be followed when purging. However, if they are used correctly, such purge compounds can save considerable production time. Their use will speed up the cleaning of the barrel unit when changing from one material to another, or, from one color to another. However, in some cases, purging will not be

enough to remove contamination and stripping and cleaning of the barrel unit will be required. Some purge compounds are intended for use over a specified temperature range. For example, one purge material may cover the range 180˚C to
230˚C/358˚F to 446˚F (which suits PS, PP and PMMA), another 230˚C to
250˚C/446˚F to 483˚F (which suits ABS and SAN) and another 250˚C to
310˚C/483˚F to 590˚F (which suits PC, PPO/PS and PBT).

Safety Considerations

During purging, the die area should be shielded to protect the operator from being splashed by hot material. The operator must be trained in the purging procedures appropriate to the particular machine and must be aware of the dangers to himself and others. At the processing temperatures employed, a thermoplastic material can be easily degraded to give unpleasant, irritating odors and, if seriously overheated, some materials can produce a large amount of high pressure gas. Such gases should not be inhaled, or ingested, and should be treated as harmful. Gloves, long sleeved coveralls, safety footwear and a heat resistant face-mask should be worn during purging. Purging must be done so that there is no danger to the operator or to any others in the vicinity. The purged material should be dropped into a bucket of cold water to minimize the formation of fumes and to protect anyone from touching this hot, sticky, dangerous material.

Note Purging Conditions

During purging, the output and pressure should be noted. These values can be used to indicate screw or barrel wear. If the pressure needed to obtain a known output increases, compared to what was measured on a previous trial, then the screw, and/or barrel, may be worn and the maintenance department should be informed. During purging note if any unusual noises are heard such as might be caused by the screw and/or the screw tip rubbing against the barrel. Note the pressure employed and the output with the new material, to determine if the screw subsequently wears.

STRIPPING AND CLEANING

In some cases, when changing from one material to another, purging is not enough and the barrel unit must be dismantled (stripped) so that it may be cleaned. Cleaning the extruder and die is a long and time consuming operation and, since nothing is produced, it is to be avoided if at all possible. It must be remembered that there is a danger that component damage may occur during the cleaning operation. Before commencing cleaning, the resin supplier’s literature should also be consulted since plastics behave differently when heated: PVC may decompose to give corrosive acids and PC may stick tightly to the metal of the die or extruder.

Safety Considerations

The first stage of this operation is purging and the comments made in that section should be noted. The operator must be trained in the purging procedures appropriate to a particular machine and must be aware of the dangers to him and others. When the barrel, is stripped for cleaning, it should be done in an extremely well ventilated area. Because of this consideration, cleaning is probably best done away from the processing area. Gloves, long sleeved coveralls, safety footwear and a heat resistant, facemask should be worn when the barrel and screw are stripped and cleaned. It should always be remembered that the screw and/or die are heavy and difficult, or awkward, to handle. In many cases such components are also hot enough to cause serious burning. It must be remembered that most hot plastics, when molten, will stick to human skin, and cause destructive burns.

Partial Dismantling

In some cases, good results are obtained if the screw and barrel assembly is only partially stripped and cleaned. The die is removed, or swung to one side, and all accessible parts, including the joint faces, are cleaned. Before the screw cools, remove the screw cooling assembly from the rear of the screw (the rotary union and cooling wand), slacken any locking ring on the drive shaft and carefully extract the screw by either pushing or pulling. A “pusher”, inserted through the hollow drive shaft at the rear of the machine, can be used to drive the screw out. This slowly forces the screw out of the barrel and exposes the front of the screw for cleaning. Alternatively, if the screw is to be pulled out, the nose of the screw must be removed (usually a left-hand thread) so that a “puller” can be inserted. To strip exposed parts of the screw one may remove material by slowly pulling it away using pliers, while the adhering material is at the leathery stage. More material may then be removed by scraping. On non-chromium plated screws a steel wall paper scraper shaped to fit the channel shape may be used. The scraper may be wetted with a little cold water to minimize polymer adhesion. However, if in doubt, use brass hand tools, brass brushes and brass wool to minimize damage to the screw plating. During the cleaning operation, all exposed parts of the screw and barrel should be inspected for wear and damage. This should be noted on the machine records and, if necessary, the maintenance department informed so that appropriate action may be taken.

Heater Handling

In many cases, it is better to dismantle and clean the extruder and die. As dismantling is done while the machine is hot, heat resistant gloves and a face shield must be worn. To keep the die as hot as possible, disconnect the heaters from each zone one at a time. Ideally the power supply should be disconnected by the person who is doing the heater band removal. That is, he/she should pull the electrical plug. Remove the die heaters and thermocouples from a zone. When removing a heater, take special care not to damage it. For example, avoiding excessive flexing and careless handling. One should handle the heaters by the joint flange or terminal box and carefully store the heaters on a flat smooth surface (not the floor). All heaters and thermocouples should be labeled.

Die Cleaning

While hot, the die assembly should be carefully dismantled, taking special care not to damage metal surfaces that contact the melt. Disconnect the heaters and associated thermocouples and remove any pressure transducers, from the first part of the die that is to be removed. Then clean each piece of the die as it comes to hand. Remove as much material as possible from the die surfaces by slowly pulling it (use pliers) away while it is at the leathery stage. More material can then be removed using brass hand tools, brass brushes and brass wool. These may be wetted with a little cold water to prevent clogging. Before each part is removed, the part removed before it should be cleaned and placed on a clean smooth surface. Treat the die lips with special care as any nicks or scratches will introduce die lines, which are immediately obvious, on the product. When cleaning flat sealing faces ensure that their edges are not rounded off by the cleaning treatment. Once the components are clean, each part should be inspected for wear and damage and repaired, or replaced, where necessary. As they are cleaned, the component parts of the die should be checked off against an authorized list before being certified as being ready for use.

Re-assembly

After cleaning, the die should be re-assembled and stored either on the machine or on a bench to minimize the risk of damage. As the die is being reassembled, the alignment between the various parts of the die should be carefully checked. If these components are out of alignment, hang-up and degradation of the extrudate may occur. Also, thoroughly check the sealing faces between the die, the head, and the barrel. Unless there is adequate contact pressure on the flat sealing faces, contamination from the lubricant used on the screw threads may occur. Clean all threads with a wire brush and apply molybdenum disulfide before re-assembly. Do not use oil or grease as these may oxidize and cause a subsequent blockage. If the die is to be stored it may be treated with a rust inhibitor: Storage must be in a clean dry storeroom on a properly constructed rack. If un-plasticized polyvinyl chloride (UPVC) or another halogenated polymer has been processed, then it will probably be necessary to wash the metal with hot water to remove any traces of acid, before the die is protected with a rust inhibitor. Records must be kept of the work done on the die, where and what is stored, the tools required for maintenance and the tools required for use. Note that some dies remain the property of the customer although the extrusion firm is responsible for their use and care. If pressure transducers are installed then these must be carefully handled. Care should be taken to ensure that the correct mounting holes are used and that they are clean. If this is not done the sensing tip may be damaged, resulting in failure of the probe.

Screw Cleaning

After purging the machine with a brittle material such as polystyrene (PS) or PMMA, and when no more material can be squeezed from the screw (See Purging), remove the head assembly from the extruder. Following the manufacturer ‘s instructions, start to remove the screw from the barrel. If the screw can be removed in stages, the material adhering to the screw can be carefully removed with a brass scraper as each fresh portion of the screw comes from the barrel. Drop the scrapings into a bucket of cold water. When it is no longer safe to clean the screw in this way, the screw should be completely removed from the machine and placed on and strapped to a previously prepared rack. The screw may then be cleaned, by scraping with a brass scraper and a brass brush. If the screw was purged with PS, then this relatively brittle material can be easily broken away when cold. Polish the screw with brass wool and/or a brass mesh cloth until the screw is gleaming. Once the screw is clean it should be inspected for wear, and/or damage and repaired where necessary. A light coat of an anti-corrosive spray should then be applied and the screw should be placed into storage on a special rack. If the screw cannot be removed in stages then, after extracting the screw from the barrel, immediately remove as much material from the screw as possible with a brass scraper. Gently break away as much plastic material as possible when the screw is cold. If necessary, carefully reheat the screw as required. The reheat temperature should be approximately 50˚C/100˚F below the polymer's processing temperature where the adhering material has a leathery consistency and can be removed by pulling or peeling. After removing as much material as possible, heat cleaning may be required.

Barrel Cleaning

Prior to cleaning the barrel, make sure that any pressure transducers or exposed thermocouples have been removed while the barrel is hot. Clean the barrel by pushing or pulling a hardwood bung, which is a good fit, through the barrel. Or, one may clean the barrel by pushing or pulling a circular wire-wool brush, 2 mm/0.8 in. larger than the bore diameter, through the barrel several times. Insert the wire brush into the barrel and using a power system rotate the brush while moving the brush back and forth. Periodically clean the circular wire brush and do not push the brush past the feed opening. Then wrap emery cloth (240 to 280 grade) around the brush head and polish the barrel by the same process as above. Finally polish the barrel with a rag wrapped around the brush head until it is clean and gleaming. Then one should remove any particles, broken wires, or fragments, with a vacuum hose, and inspect the barrel for wear.

Other Cleaning Methods

Flame cleaning (with a propane gas torch) should only be used when the polymer is seriously degraded and can be removed in no other way. This is because the die parts may be distorted by uneven heating. Flame cleaning must be gently done, if it is done at all. Use the lowest temperature flame, over as large an area as practical. Do not exceed a temperature of 450˚C/842˚F on the screw flights, as the hardness and wear resistance will be diminished. After flame cleaning, clean the screw with a soft wire brush and then polish with emery cloth (approximately 240 to 280 grade). Oven cleaning, with an air atmosphere, is also best avoided as it can produce fumes and drips. The polymer may also ignite when the oven door is opened. Uniform heating, and cleaning, by pyrolytic decomposition, may be accomplished, in an oven with a nitrogen atmosphere, at temperatures in the region of 550˚C/1022˚F. If solvents are used then great care is required, as the solvent may be flammable and/or toxic. Solvent baths should be treated with respect and a written procedure followed. Ultrasonic cleaning in a heated fluidized bed is preferred for screws and dies if the equipment is available. It should be noted that copper causes rapid decomposition, or degradation, of polypropylene (PP). Therefore, copper cleaning pads should not be used to clean equipment used to process this material.

RECLAIMED MATERIAL

The ability to reclaim out of specification product, produced during the extrusion of thermoplastic materials, is very often a mixed blessing. It can lead to the attitude that the production of offspec product does not matter. ‘After all, the extrudate can be ground up to give reclaimed material and used again’, is an often heard comment. Even if this is true, it should be appreciated that processing may dramatically change the properties of plastic materials. Even if this change is minimized, the lost production time, the cost of producing the scrapped product, the labor costs and the energy costs are considerable and are best avoided since they are directly reflected in the bottom line.

Terms Used

The re-use, by melt processing, of a formed component is only possible with thermoplastic materials. In the thermoplastics industry, a reclaimed thermoplastic material (sometimes called “re-grind”) may be defined as a material that has been recovered from scrapped components and/or the feed system used to produce such components. One of the most common additives used with thermoplastic materials is reclaimed material. That is, the feed to the extruder is a mixture of virgin (new) material, reclaimed material, and a solid masterbatch (to impart color). All three components are generally used in granular form. Many machines run on 100% re-claimed material. Terms other than those used above are:

• Recycled plastics material - This is a thermoplastic material prepared from discarded articles that have been cleaned and ground.

• Regrind material - This is material that has been reclaimed by grinding (usually reworked plastics material). The letter R is used to identify this material. For example, reclaimed high-density polyethylene (HDPE) may be identified as HDPER.

• Reprocessed plastic material - This is a thermoplastic material prepared from industrial scrap by other than the original processor.

• Reworked plastics material - This is a thermoplastic material prepared from rejected production components that has been reprocessed in a fabricators plant after having been processed in that plant.

In this publication, the term reclaim (or reclaimed material) will be used and unless specified otherwise will refer to reworked plastics material.

Re-granulation

Re-granulation is the process of reclaiming output, which is usually achieved by feeding unwanted extrudate to a grinder to give re-granulated material. The grinder consists of a cutting chamber that contains rotating knives. The rotating knives reduce the extrudate in size until the cut pieces will pass through a mesh or screen into a collector. They may then be automatically blended at the required ratio with virgin material and fed directly back into the machine hopper. Such machinery is extremely dangerous, as the rotor assembly is extremely heavy and has considerable momentum. This means that severe injury can be caused even if the rotor is turned by hand.

Re-granulation/Recovery

If the product does not fit the specification to be sold then, in some establishments, it is referred to as scrap, which implies that it is of little or no value. However, any thermoplastic material is expensive to purchase and turn into product. Even if the material can be fully recovered there is a large amount of money invested in the rejected product and extra energy and labor must then be spent on material recovery. Materials for re-granulation or recovery may be of several types or categories:

Type 1 - Edge trim, ends and incorrect product. Edge trim and ends are produced as part of the process and are usually totally recovered by re-granulation It is fed back to the production machine in a definite and prescribed ratio. Incorrect product based on clean, non-degraded resin, but having an imperfection such as the wrong dimensions or an incorrect surface finish, is treated similarly.

Type 2 - Lightly contaminated product generated through process changes such as color or grade changes. This should be stored separately from Type 1 material and, as with all material that is to be recovered, protected from further contamination. It should only be recovered if the granulator can be subsequently cleaned to handle Type 1 materials.

Type 3 - Difficult to handle output and/or contaminated product. This may consist of lumps and irregular pieces produced during start up or shut down which may be difficult to feed to the granulator. It may also contain purging, material generated by machine leakage, material removed from heaters etc. As this type of product is difficult to recover and/or dirty, it is often not recovered in the factory but kept separate and disposed of to another industrial concern.

Type 4 - Spilled raw material. Every effort must be made to avoid spilling the original resin. Although it is easy to collect, it is very difficult to clean or recover, and presents a falling hazard for operators. Within the extrusion shop spilled material is a tremendous safety hazard (danger of falls and/or fire). Once spilled, material must be swept, or vacuumed, up immediately so that it may be sold.

Safety

Everyone who uses the granulator must be trained in its use. Periodic inspections should be made for loose guards or parts. Safety instructions must be available and must be closely followed. If the machine jams and does not clear in, say, 10 seconds, do not push in more material but switch off. Then wait for the machine to stop, pull out the plug and follow the cleaning instructions. Avoid putting your hand or fingers near the blades as they are usually very sharp and, as the rotor is heavy and easily turned, severe injury can be caused even if the rotor is turned by hand. Use long-handled brushes and a vacuum cleaner to clean the rotor and blade assembly. If you must put your hands anywhere near the blades, then ensure that the rotor is clamped, so that it will not move. After cleaning, the blades must be carefully inspected so as to ensure that there is nothing present that will contaminate a subsequent batch of material. A trial run should be performed to ensure correct operation and a clean product. Ideally the granulator should be in a separate room from other equipment as it produces a great deal of noise and dust. A dust mask and hearing protection should be worn whenever a granulator is used.

Material Changes

During the production process there should be little or no change in the plastic material, as any change is usually undesirable. Some of the changes that can occur are:

• Water Contamination - This is caused by the material absorbing water or by condensation.

• Oxidation - This occurs when plastics are heated in contact with oxygen. They will 'oxidize' or combine with the oxygen. The first sign of this is a change in color and then a change in properties.

• Overheating - If overheated, even when no air present, plastics may decompose or degrade. Often gases are produced which can be dangerous.

• Dust Contamination - It is easy to generate static electricity on plastics, which attracts dust, or dirt, very quickly. As changes and contamination are more common with reclaimed material than with virgin material, greater care is necessary when dealing with reclaimed thermoplastic.

Consistent Addition

The exact amount of regrind that is suitable will have to be determined experimentally. Once found, then the content must be held as precisely as possible if consistent product is to be obtained. If the feed to the extruder is not consistent, then inconsistent product will be obtained. The differences may not be discernible to the naked eye, but they are large enough to cause rejection of the product, either because of appearance or thickness variation. So, one must ensure that the agreed ratio is adhered to during production. No matter what ratio is used, the materials fed to the extruder must be clean, dry and consistent. It must be emphasized that to obtain a consistent output, a consistent feed must be used. This is because of the feeding differences experienced with different feed forms.

Regrind Care

Great care should be taken to ensure that reclaimed material (regrind) is clean, dry and of regular particle size. If the regrind is dirty, then die or machine damage may occur and the appearance of the product will suffer. If the material fed to the machine contains unacceptably high moisture levels, the properties of the extrudate will be affected. In the case of a clear material, the clarity may be affected and for all materials (both clear and opaque) the quality of the surface finish may be reduced by streaking or surface imperfections. If the feed is not of consistent particle size, then the material will not feed in a uniform way and an inconsistent product will be obtained. The differences between extrudate batches may not be discernible to the naked eye, but they may be large enough to cause rejection of the product, because the size of the extrudate is incorrect. To get the best results from an additive, such as regrind, it must be very well dispersed throughout the basic polymeric material. Melt mixing, using a compounding extruder, is important to the polymer industry, as it gives the good dispersion required. However, such compounding is expensive, so simple, tumble-mixed blends of virgin and reclaim are frequently used. This produces a lower level of dispersion, but will save on costs and give operational flexibility.

Regrind Stabilization

Care should be taken to ensure that the original material contains sufficient stabilizer, so that reclamation is possible without degradation, or a color change, occurring on re-use. It is particularly important with unplasticized polyvinyl chloride (UPVC), to ensure that adequate stabilizer is present in the original material. For any thermoplastic material, it is very important to avoid a long residence time in the extruder barrel, particularly at high melt temperatures, as it will cause material degradation.

Product Identification

Recyclable products or components should be marked with a symbol or abbreviated term. Legends suitable for the generic identification and marking of plastics products are suggested by standards organizations such as the International Standards Organization (see ISO 1043). In the simplest case, the series of letters associated with a plastic material (See Table 1.) are stamped onto a product between inverted (reversed angle) brackets (for example, >ABS<). ISO has also suggested how to identify fillers, flame-retardant, plasticizers etc. The presence of a flame retardant may be indicated by a molded or printed legend which contains FR, as in >PA 66GF30-FR(52)<. This legend shows that the product is made from a nylon 66 material which contains 30% glass fiber. The FR(52) indicates that the nylon contains red phosphorous (code number 52) as a flame retardant; other flame retardants have their own number.

MACHINE SETTING AND RUNNING

Process settings refer to details, with regard to the material, the die and the machine settings used to produce an extrudate, which are recorded on the process setting sheet. This is a sheet used for keeping a record of data regarding each run. The importance of careful and accurate recording of process settings cannot be over-emphasized. Not only is it useful to have a full and accurate record for machine re-setting, but such records are useful for product liability reasons and for compliance with ISO 9000 requirements. With date marking of extrudate now easily possible, the precise details of how a particular run was produced can be assembled and kept, easily and cheaply. A microprocessor- based machine will record all relevant data, print it out if required, and instantly reset the machine when that particular job is re-run. Such instant re-setting saves a great deal of time and gives more accurate setting. It must not be forgotten that the object of production is to produce components/product, of the required quality and quantity, at a specified cost, within a specified time, and when required. To accomplish this, it is essential to keep accurate records of how a particular extrudate was produced. Also, it must not be forgotten that, to be effective, a quality management system must have excellent record keeping. Accurate documentation helps ensure that specified procedures are being followed and that such procedures are yielding the desired results. Records are the objective evidence to demonstrate that components offered for acceptance meet the purchasers requirements and that the suppliers inspection system complies with the requirements of the ASTM, ISO and any other quality standards required. The following is a general outline of what is recommended for recording. This outline will, however, need to be amended to suit a particular application.

Extrusion Data Record

Personnel Details

Date
Shift
Senior operator
Other operators
Machine setter
Inspector

Material Details

Material used
Supplier
Trade name
Grade
Lot no.
Color
Max moisture content %
Alternative material details

Formulation & Blend Details

Virgin %
Regrind %
Masterbatch %
Other %
Mixing details
Preheat at ˚C/˚F for hours.

Extruder Identification

Manufacturers name
Model no.
Factory ID
Screw type/details
Adapter type
Factory ID
Heater size/type
Screen pack/breaker plate
Air/vacuum required
Special requirements

Die Identification

Manufacturers name
Model no.
Factory ID
No. of zones
Heater type & details
Air/vacuum required
Special requirements

Ancillary & Downstream Equipment

Details
Air/vacuum required
Special requirements

Safety Equipment

Details
Air/vacuum required
Special requirements

Instructions to Machine Operator

During the run watch out for
Inspect the extrudate every _____minutes and if it does not pass the specified tests then take the following actions.
Specified tests

Corrective actions

Machine Settings

		Temps. °C/°F	Set or Target	Actual or Measured at Time 1	2	3	4	5	6
Drier									
Machine hopper									
Material									
Hopper block									
Cold water supply									
Barrel - Rear	Z1								
Middle	Z2								
Middle	Z3								
Front ``	Z4								
Adapter	Z5								
Die	D1								
Die	D2								
Die	D3								
Die	D4								
Die	D5								
Die	D6								
Melt	M1								
Melt	M2								
Water bath - WB 1									
Water bath - WB 2									
Water bath - WB 3									
Others									
Water Flow Rate gals/min or l/s									
Oil cooler									
Hopper block									
Cooling	C1								
Cooling	C2								
Cooling	C3								
Cooling	C4								
Cooling	C5								
Pressures psi or N/m2									
Air									
Water									
Melt - 1									
Melt - 2									
Back pressure									

Air Flow Rate cu ft/min or l/s	
Drier	
Die	
Cooling	1
Cooling	2
Cooling	3
Power	**amps**
Main ext motor	
Others	
Times	**minutes**
Time in drier	
Cooling time	
Take out time	
Speeds m/s or ft/min	
Roll/belt	(R1)
Roll/belt	(R2)
Roll/belt	(R3)
Roll/belt (	R4)
Roll/belt (	R5)
Roll/belt (	R6)
Extrudate speed	
Speeds	**rpm**
Screw speed	
Roll/belt	(R1)
Roll/belt	(R2)
Roll/belt	(R3)
Roll/belt	(R4)
Roll/belt	(R5)
Roll/belt	(R6)
Distances mm or inches	
Die gap	
Die to haul off roll	
Freeze line height	
Length of water bath-1	
Length of water bath-2	
Length of water bath-3	
Others	
Weight kg or lbs	
Total extrudate	
Trim	

Product

Critical Dimensions mm or inches

1

2

3

4

5

Visual appearance

Observations