Co-funded by the European Union

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Norwegian Embassy
Islamabad

PLASTIC PROCESSOR

Learner Guide

National Vocational Certificate Level 2

Version 1 - September, 2018

NAVTTC

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Published by
National Vocational and Technical Training Commission
Government of Pakistan

Headquarter
Plot 38, Kirthar Road, Sector H-9/4, Islamabad, Pakistan
www.navttc.org

Responsible
Director General Skills Standard and Curricula, National Vocational and Technical Training Commission
National Deputy Head, TVET Sector Support Programme, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Layout & design
SAP Communications

Photo Credits
TVET Sector Support Programme

This document has been produced with the technical assistance of the TVET Sector Support Programme, which is funded by the European Union, the Federal Republic of Germany and the Royal Norwegian Embassy and has been commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ). The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in close collaboration with the National Vocational and Technical Training Commission (NAVTTC) as well as provincial Technical Education and Vocational Training Authorities (TEVTAs), Punjab Vocational Training Council (PVTC), Qualification Awarding Bodies (QABs)s and private sector organizations.

Document Version
September, 2018
Islamabad, Pakistan

PLASTIC PROCESSOR

Learner Guide

National Vocational Certificate Level 2

Version 1 - September, 2018

Introduction

Welcome to your Learner's Guide for the Plastic Processor level 2. It will help you complete the training and go on with further study or go straight into employment.

The Plastic Processor level 2 training is to engage young people with a program of development that will provide them with the knowledge, skills and understanding to start their career in Pakistan. This qualification will not only build the capacity of existing workers of manufacturing engineering sector but also support the youth to acquire skills best fit in manufacturing industry.

The main elements of your learner's guide are:

- **Introduction:**
  - This includes a brief description of your guide and guidelines for you to use it effectively
- **Modules:**
  - The modules form the sections in your learner's guide
- **Learning Units:**
  - Learning Units are the main sections within each module
- **Learning outcomes**:
  - Learning outcomes of each learning units are taken from the curriculum document
- **Learning Elements:**
  - This is the main content of your learner's guide with detail of the knowledge and skills (practical activities, projects, assignments, practices etc.) you will require to achieve learning outcomes stated in the curriculum
  - This section will include examples, photographs and illustrations relating to each learning outcome
- **Summary of modules**:
  - This contains the summary of the modules that make up your learner's guide
- **Frequently asked questions**:
  - These have been added to provide further explanation and clarity on some of the difficult concepts and areas. This further helps you in preparing for your assessment.
- **Multiple choice questions for self-test**:
  - These are provided as an exercise at the end of your learner's guide to help you in preparing for your assessment.

Frequently Asked Question

1. What is Competency Based Training (CBT) and how is it different from currently offered trainings in institutes?	Competency-based training (CBT) is an approach to vocational education and training that places emphasis on what a person can do in the workplace as a result of completing a program of training. Compared to conventional programs, the competency-based training is not primarily content based; it rather focuses on the competence requirement of the envisaged job role. The whole qualification refers to certain industry standard criterion and is modularized in nature rather than being course oriented.
2. What is the passing criterion for CBT certificate?	You shall be required to be declared “Competent” in the summative assessment to attain the certificate.
3. How can I progress in my educational career after attaining this certificate?	You shall be eligible to take admission in the National Vocational Certificate Level-3 in Plastic Processor. You shall be able to progress further to National Vocational Certificate Level-4 in Plastic Processor, and take admission in a level-5, DAE or equivalent course. In certain case, you may be required to attain an equivalence certificate from The Inter Board Committee of Chairmen (IBCC).
4. What is the importance of this certificate in National and International job market?	This certificate is based on the nationally standardized and notified competency standards by National Vocational and Technical Training Commission (NAVTTC). These standards are also recognized worldwide as all the standards are coded using international methodology and are accessible to the employers worldwide through NAVTTC website.
5. Which jobs can I get after attaining this certificate? Are there job for this certificate in public sector as well?	You shall be able to take up jobs in the manufacturing and Plastic Processing Industries as a processor for the production of plastic parts and household goods.
6. What are possible career progressions in industry after attaining this certificate?	You shall be able to progress up to the level of shop supervisor after attaining sufficient experience, knowledge and skills during the job. Attaining additional relevant qualifications may aid your career advancement to even higher levels.

7. Is this certificate recognized by any competent authority in Pakistan?	This certificate is based on the nationally standardized and notified competency standards by National Vocational and Technical Training Commission (NAVTTC). The official certificates shall be awarded by the relevant certificate awarding body.
8. Is on-the-job training mandatory for this certificate? If yes, what is the duration of on-the-job training?	On-the-job training is not a requirement for final / summative assessment of this certificate. However, taking up on-the-job training after or during the course work may add your chances to get a job afterwards.
9. What is the examination / assessment system in this program?	Competency based assessments are organized by training institutes during the course which serve the purpose of assessing the progress and preparedness of each student. Final / summative assessments are organized by the relevant qualification awarding bodies at the end of the certificate program. You shall be required to be declared “Competent” in the summative assessment to attain the certificate.
10. Does this certificate enable me to work as freelancer?	You can start your small business as a Plastic Processor. You may need additional skills on entrepreneurship to support your initiative.

PLASTIC PROCESSOR

Module-6

Learner Guide

National Vocational Certificate Level 2

Version 1 - September, 2018

Modules

Module 6: 072200911 Produce Injection Moulded Plastic Parts

Objective of the module: The aim of this module to provide skills and knowledge to operate injection moulding machine in accordance with the manufacturer's manual

Duration: 150 hours **Theory:** 30 hours **Practical:** 120 hours

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1: Interpret Work Order	**The trainee will be able to:** Obtain work order Verify production quantity available Ensure raw material available as per work order Ensure machine setting for production as per data sheet provided	i) Basic literacy skills • Be able to read instructions about product, quantity and raw material • Be able to identify rolling required to produce different components as per work order ii) Reporting procedure • Understanding the work order contents • Knowledge of units (Kg, inches, etc.) iii) Work order process • Understand the top-down stream of task assignment • Knowledge of what the work order represents • Who generates the work order? • Where can it be obtained from? iv) Material handling and storing procedure • Understanding where to obtain raw material for the required production quantity • How to handle raw material? v) Set machine parameters as per data sheet provided • Be able to input machine parameters as	Injection Moulding Machine Mould Utility documentation. Service Manuals. Operational Manuals. Basic Hand tools Job card/PPS

		mentioned in work order or datasheet	
LU2: Perform Production	**The trainee will be able to:** Start machine on auto-cycle Perform periodic quality checks as per requirement	i) Machine operation in automatic mode • Be able to perform dry-run • Be able to perform semi-auto operation • Up on successfully obtaining required product, switching the machine to auto mode ii) Maintaining product quality as per specifications • Be able to measure components for identification of dimensional defects • Usage of measurement tools is critical: Vernier caliper, micrometer gauge, scale, etc. iii) Recognize different defects and their causes • Be able to visually identify commonly occurring defects, such as gating, flashing, orange-peel, etc. • Gain knowledge of rectification of commonly occurring defects.	Injection Moulding Machine Mould Utility documentation. Service Manuals. Operational Manuals. Basic Hand tools
LU3: Perform follow-up procedure for machine production	**The trainee will be able to:** Ensure product packed in assigned packaging Check feed level hopper/bin, etc. Ensure machine lubrication as per requirement	i) Knowledge of product packaging • Understand different types of packaging, e.g.; flexible packaging, packing in cartons, etc. • How to pack final product? ii) Raw material input in moulding machine • Ensure consistent raw material feed into hopper/feeder • Be able to use overhead crane or	Injection Moulding Machine Machine Mould Utility documentation. Service Manuals. Operational Manuals.

		moveable lifts/ladders • Understand the importance of cutting tools in opening raw material bags. • Concept of 'clean slits' using sharp tools to ensure particles of bag don't get mixed in raw material iii) Lubrication requirements and procedure of machine • Understand the concept of lubricating moveable parts of machines • Carefully use mould lubricant sprays • Ensure spray cans are stored in a secure location after pre-shot application • Be able to identify different mould release agents as per raw material • Be able to provide first-hand feedback to maintenance department for periodic machine maintenance	Basic Hand tools
LU4: Submit Production report	**The trainee will be able to:** Record production report as per given format (kg/nos, hours) Submit report to concerned department	i) Production report writing • Understand the importance of reporting accurate production quantity • Be able to fill-in relevant production reports • Be able to identify waste generated along with identification of machine downtime with reasons ii) Data sharing with relevant departments • Understanding the concept of producing accurate data and benefits of the same	Injection Moulding Machine Mould Utility documentation. Service Manuals. Operational Manuals. Basic Hand tools

		on a larger scale • Submission of production reports to production planning department or the supervisor for timely actions.	
LU5: Transport finished product to concerned department	**The trainee will be able to:** Place finished product in designated area Take approval of finished product from Quality Control Deliver relevant packaging documents to store personnel	i) Understand QC protocols • Understand and appreciate the importance of producing products as per specification • Be able to implement the first quality control protocol on machine to ensure elimination of defective products at sight ii) Inter-department co-ordination • Be able to co-ordinate with QC department with produced batches for relevant approvals iii) Be able to hand over final products to store • Familiarize with handing-over protocols and paperwork.	Injection Moulding Machine Mould Utility documentation. Service Manuals. Operational Manuals. Basic Hand tools

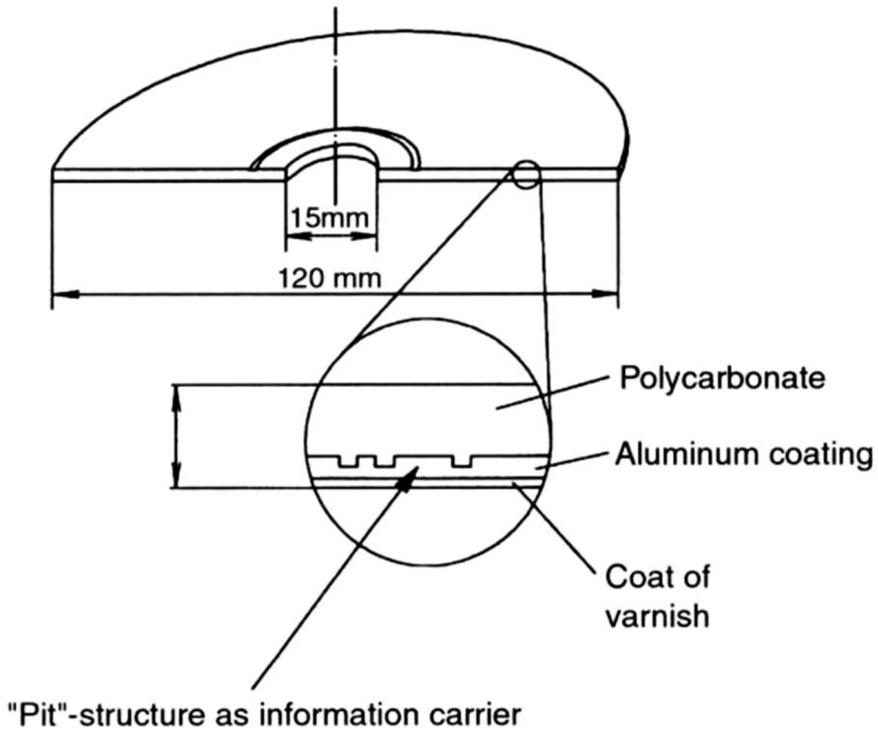
Examples and Illustrations:

For more details please refer to the book: Training in Injection Moulding, 2nd Edition, by HANSER Publishers, Munich.

Some key introductions:

the most important processing method for plastics	In comparison to the classic methods of metal fabrication and processing (such as milling, drilling, turning, etc.), injection molding represents a manufacturing method which is still young. However, injection molding has already become the most important method in plastics processing technology
plunger machines	The early injection molding machines were plunger machines. The plastic was melted in a heated cylinder and injected into the mold by the plunger. This type of machine is no longer found, except in research laboratories, for making very small quantities of experimental articles.
screw principle	Most modern injection molding machines operate on the screw principle. The molding compound is melted by band heaters and the frictional heat produced by the rotating screw, In the injection operation, the rotation of the screw is stopped, and the screw begins to function as a plunger. The screw must therefore fulfill the functions of conveyance, mixing, and injection. Separate plasticating screws and injection plungers are often used in the processing of elastomers.
thermoplastics	Thermoplastics represent the most important group of plastics to be processed in injection molding. Typical injection-molded parts made from thermoplastics include automobile hubcaps and bumpers, gears in kitchen appliances, screw-on caps and lids, bottle crates, printer cartridges, and ball-point pens.
Compact Disk (CD)	Even the Compact Disk (CD) is produced from polycarbonate (PC) by the injection molding method.
elastomers	Another important materials group are the cross-linked polymers, such as elastomers and thermosets. Typical elastomer molded parts manufactured by injection molding include bellows, shock-absorbing components in automobiles, seals, and molded tubes,
thermosets	Thermosets consist of densely crosslinked polymers, that can also be processed by injection molding. Thus, produced articles are used in boats, in the automotive field and in the electrical industry (insulation). Thermoset moldings find particular application, where their non-conductive properties and heat-resistance are essential. Injection molding provides a cost-effective mass-production process of articles for the electrical industry.
Injection Molding -A Discontinuous Single-Stage Process	
primary processing method	Injection molding, as a primary processing method, is particularly well suited for the mass-production of molded articles, because the conversion of the raw material into a finished product usually requires just a single operation. Little or no finishing is required, and even complicated geometries can be produced in a single operation.
ideal production process	It is an ideal production process with the proviso, that large batches are produced, because the injection molding tool is usually made for a single article only.

expensive molds	It is typical within the context of primary processing technology, that each mold is unique. Molds are therefore very expensive in comparison to most forming tools and dies used in metals fabrication, because they are not universally employable.
production process	The process for molding thermoplastics proceeds as follows: • The material is fed into the hopper on the machine. • Within the heated cylinder, the material is conveyed, melted, and mixed thoroughly by the rotating screw. • The molten molding compound (melt) is then injected into the mold under high pressure. • The melt cools within the heat-balanced mold and thus gains the inherent stability needed for its removal. • The article is now removed from the mold, and a new injection molding cycle can begin.
high degree of accuracy	Parts produced by injection molding display a very high degree of dimensional accuracy- for example, to 1/100mm (4×10^{-4} in). Even greater accuracy is possible in special applications.
CD	With the Compact Disk, information is stored in minute pits formed in the surface. These pits, produced as direct reproductions by the injection molding process, are only a few microns wide and deep.
Injection Molding -The Injection Molding Machine and Mold	
main components	• The injection molding machine • The mold
injection molding machine	The injection molding machine is in turn divided into the following: • Plasticating (plastification) unit and the injection unit • Clamping unit • Controls (hydraulics, electrical system)
mold	Different molds are needed for different injection-molded articles. It is therefore necessary to replace the entire mold in order to produce a different part from the one currently being made.
profitable production	Production of certain articles (e.g., household appliances, certain automotive subassemblies, CDs) would not be profitable at all without the means, of producing them from plastics by injection molding.
special features	When articles hitherto produced from classic materials (such as wood or metal) are to be made by the injection molding process, it is advisable, to give serious consideration to the special properties of plastics materials, as well as the more salient points of injection molding as a production method. This plastics-oriented procedure requires an understanding of the basic principles of the manufacturing and production processes involved, and also of the plastics material's behaviour. The book provides a comprehensive overview of the principles involved in injection molding.
CD	For that purpose, we follow a modern plastics article (a Compact Disk) from the starting material to the form, in which it will ultimately be used. The possibilities for recycling will also be explained. As a high-tech product, the

	CD is particularly well suited to serve as an example of modern plastics processing and injection molding technology. The diagram shows a CD and its dimensions. 

Aside from viscosity, other factors also influence the processability of plastics in the injection molding process. The summary table below shows some of the types of plastics used in injection molding, as well as the characteristic material properties which are important in processing (e.g., shrinkage in processing, flowability, and processing temperature range).

Chemical name composition	ISO 1043 DIN 7728	Density [g/cm^3]	Processing temperature [°]	Flowability g = good m = medium p = poor	Shrinkage in processing [%] r = glass-fiber reinforced
Polystyrene	PS	1.05	180–280	g	0.3–0.8
Styrene-butadiene copolymers	SB	1.05	180–280	g	0.4–0.7
Styrene-acrylonitrile compolymers	SAN	1.07	200-260	m	0.4-0.7; 0.1–0.3r
Acrylonitrile-butadiene-styrene copolymers	ABS	1.08–1.12	210–270	m p	0.4–0.7 0.2–0.4r
Polyethylene	PE	0.91–0.97	180–270 240–300	g m p	1.2–2.8; 1.2–2.5
Polymethyl methacrylate	PMMA	1.18	170–240	m	0.3–0.7
Polyamide	PA	1.04–1.15	230–290	g	0.7–2.0; 0.2–0.8r
Cellulose acetate	CA	1.31	180–230	g	0.4–0.7
Polycarbonate	PC	1.20	280–320	p	0.6–0.8; 0.2–0.5r
Polyvinyl chloride, rigid (unplasticized)	PVC	1.38	190–210	p	0.4–0.7
Polyoxymethylene	POM	1.41	180–230	m	1.8–3.0; 0.2–0.6r
Polypropylene	PP	0.91	240–300	m p	0.5–1.2r

It can be seen from the table that the range of processing temperatures is very narrow for some thermoplastics but very broad for others. For example, PVCU (unplasticized or rigid PVC) can only be processed within a very narrow temperature range (190-210°C), while POM can be processed between 180 and 230°C.

The subsequent Table shows the material properties of PC, from which CDs are produced, as well as the setting parameters, which were used for programming the injection molding machine employed.

Material properties
Solid, rigid, impact resistant up to −100°C, (−148°F), high heat resistance, crystal clear, non-toxic.
Resistant to
Oil, gasoline, diluted acids, alcohol, waxes, fats, simple soaps
Not resistant to
Strong acids, alkali solutions, benzene, amines, ammonia, some solvent components.
Material characteristics
Flame retardant, extinguishes away from flame, burns brightly, produces soot, chars, forms blisters, smells of phenol.
Cylinder temperature

Heating zone 1	230–260°C
Heating zone 2	250-300°C
Heating zone 3	260–320°C
Heating zone 4	260–320°C
Nozzle zone	280–330°C

Injection pressure
Very high injection pressures (1300–1800 bar = 19.000–26.000 psi) are required, as the material is extremely viscous.
Holding pressure
Pressure usually amounts to about 40–60% of the injection pressure.
Back pressure
50–150 bar (725–2175 psi)
Injection speed
Subject to length of flowpath and wall-thickness. Fast injection for thin walls. Where good surface quality has been specified, injection should be a little slower.
Screw RPM
High screw torque required, therefore medium screw speeds should be applied.
Melt cushion
2–6 mm (0.08–0.24"), subject to feed volume.
Mold temperature
Not lower than 85°C (185°F). Mold filling and article quality improve with increasing temperature. High mold temperature increases cycle time only marginally, as the glass transition temperature is at 145°C (293°F).
Pre-drying
4–12 hours (high-speed drying oven 2–5 hours) at 100–120°C (212–248°F). Optimum elongation, hardness and notched impact strength are obtained at a moisture content below 0.02%.
Shrinkage
0.7–0.8%; 0.1–0.5% with PC-GF (glass filled).
Injection volume
15–85% of the respective cylinder volume.
Shutting the machine down
If production is stopped over night, purge the cylinder of material and keep heat on at 160–180°C (32–356°F).

It will be obvious by now, that many factors must be considered in order to produce high quality moldings. The processing values can also vary within wide ranges. The molding of CDs requires a PC of very low viscosity and a processing temperature range of 320-360°C. Low viscosity is needed, in order to enable the melt to reproduce the fine geometry of the pits on the information side of the CD with high precision. If this is not accomplished, data will be lost. Although CD-players have built-in error correction, this is capable of correcting lost information (non-existent or only partially formed pits) to a limited extent only.

Machine size:

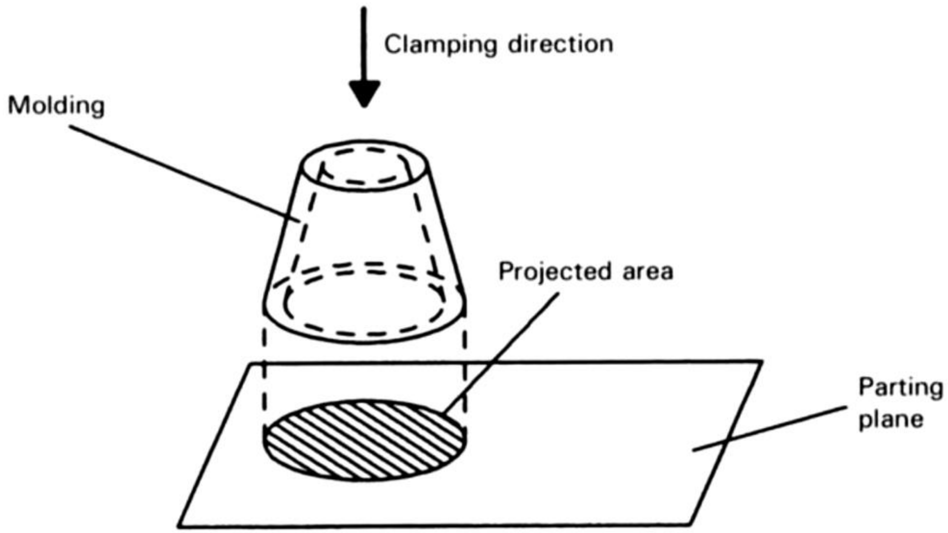
In principle, of course, it could be stated that the size of the machine must be chosen in accordance with the size of the molded article: the larger the molding, the larger the machine. But this isn't always true, especially where small molded parts are concerned. It is usually much more economical to manufacture many small moldings simultaneously on a large machine, than to manufacture just one article at a time on a small machine.

Article Weight:

The size of the molded part-especially in its relation to machine selection requires a closer examination. It should first be explained that 'size' is defined as volume. The heavier the article, the more molding compound must be provided by the plasticating and injection unit within a given period of time.

Projected Article Area:

Apart from a molding's volume, its dimensions must also be considered. The selection of a machine for the production of a given molding is primarily determined by the 'projected area' of that article - i.e., the area which projects in the clamping direction. Meaning of this concept is illustrated in the following figure:



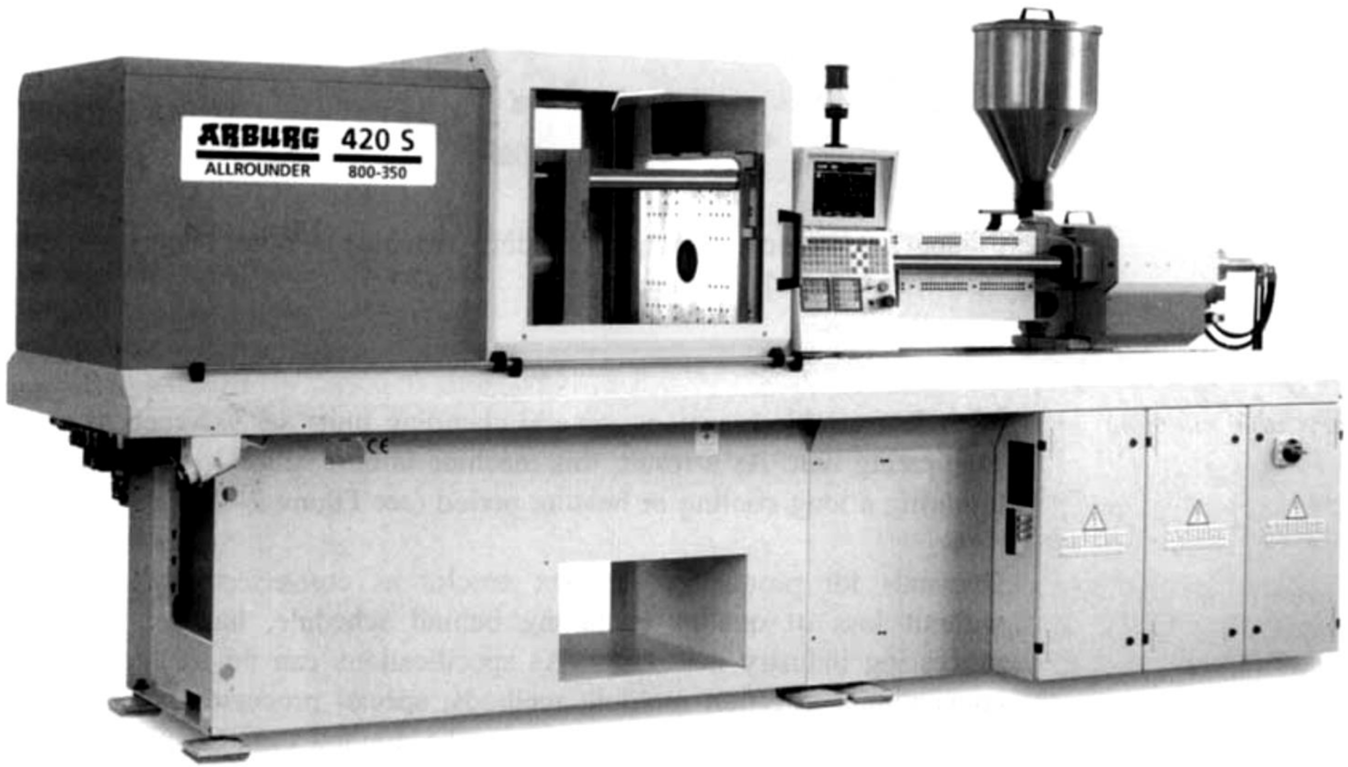
With the CD, the projected area equals the circular surface formed by the CD. Because diameter of the CD is 120mm (4.75 in), the projected area is 113 cm^2 (17.5 in^2).

With injection molding, the molding compound is injected into the mold under high pressure, which can be in excess of 2000 bar (29,000 psi) or 200 N/mm2 (1 bar = 10^5 N/m^2 = 10^5 Pa). By way of comparison, an automobile tire holds a pressure of approximately 2 bar (29 psi). The mold must be held shut against the injection pressure so that no molding compound escapes at the parting line between the mold halves (flash). This clamping force is provided by the clamping unit. Injection molding machines are classified into sizes which correspond to this clamping force (12 - 8000 t).

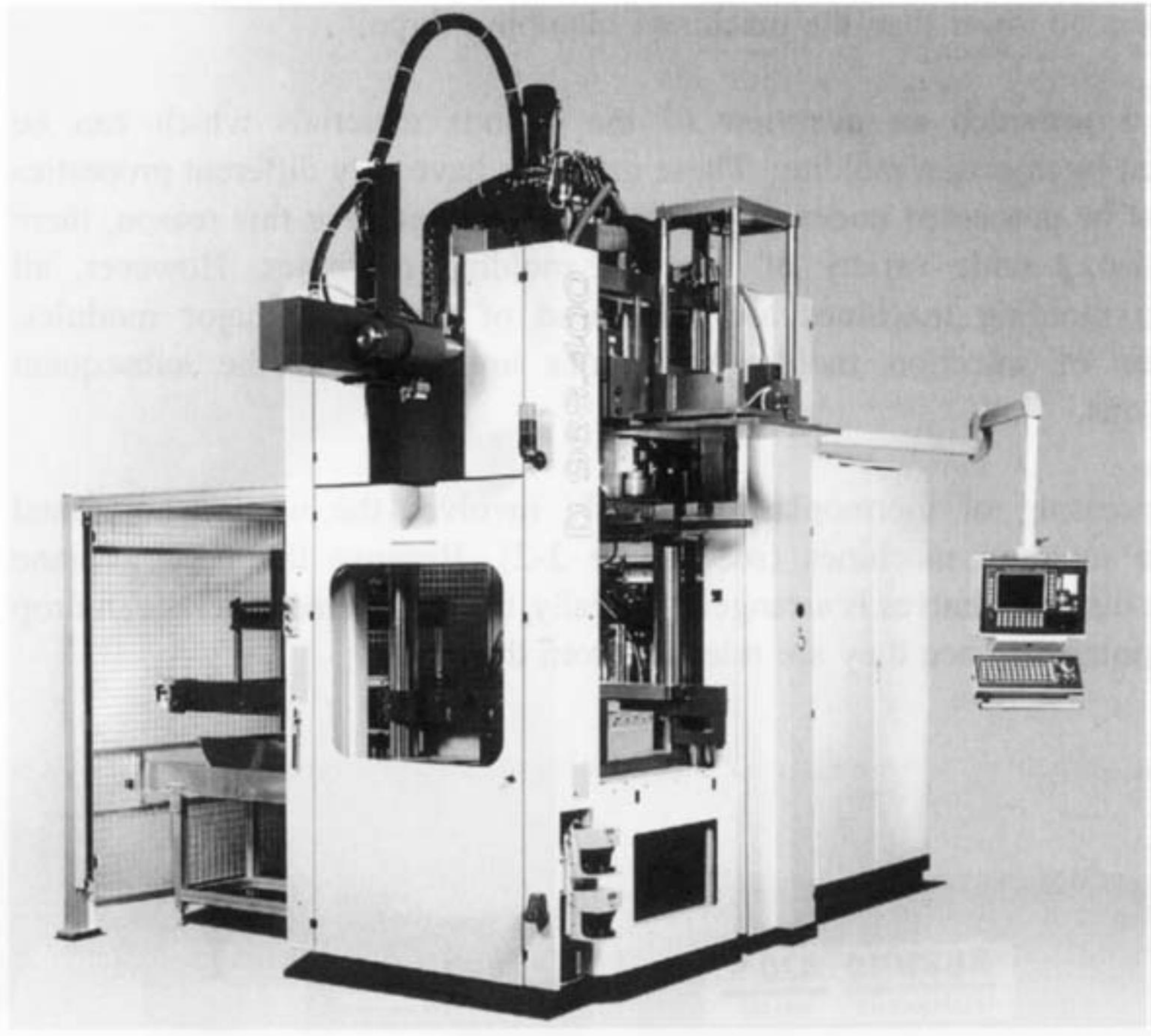
The force acting against the clamping force, thereby attempting to part the mold, is known as the mold parting force. It results from the pressure acting upon the melt, multiplied by the article's projected area, which lies in the clamping movement direction.

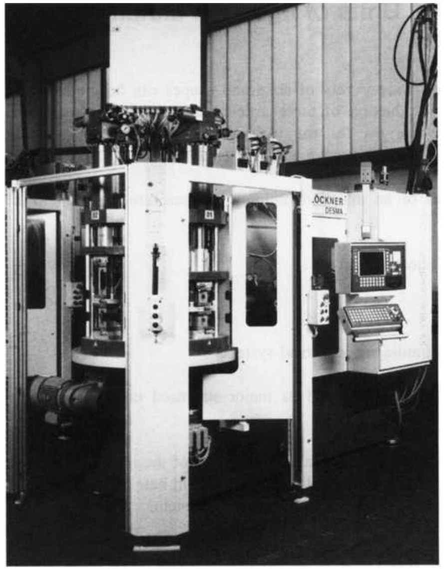
In order to achieve good quality moldings, i.e. without flash, the mold parting force must be lower than the machine's clamping force.

The processing of thermoplastics usually involves the use of horizontal injection molding machines. Because the parting plane between the mold halves is arranged vertically, the completed articles can drop into a container, once they are released from the mold.


ARBURG 420 S
ALLROUNDER
800-350

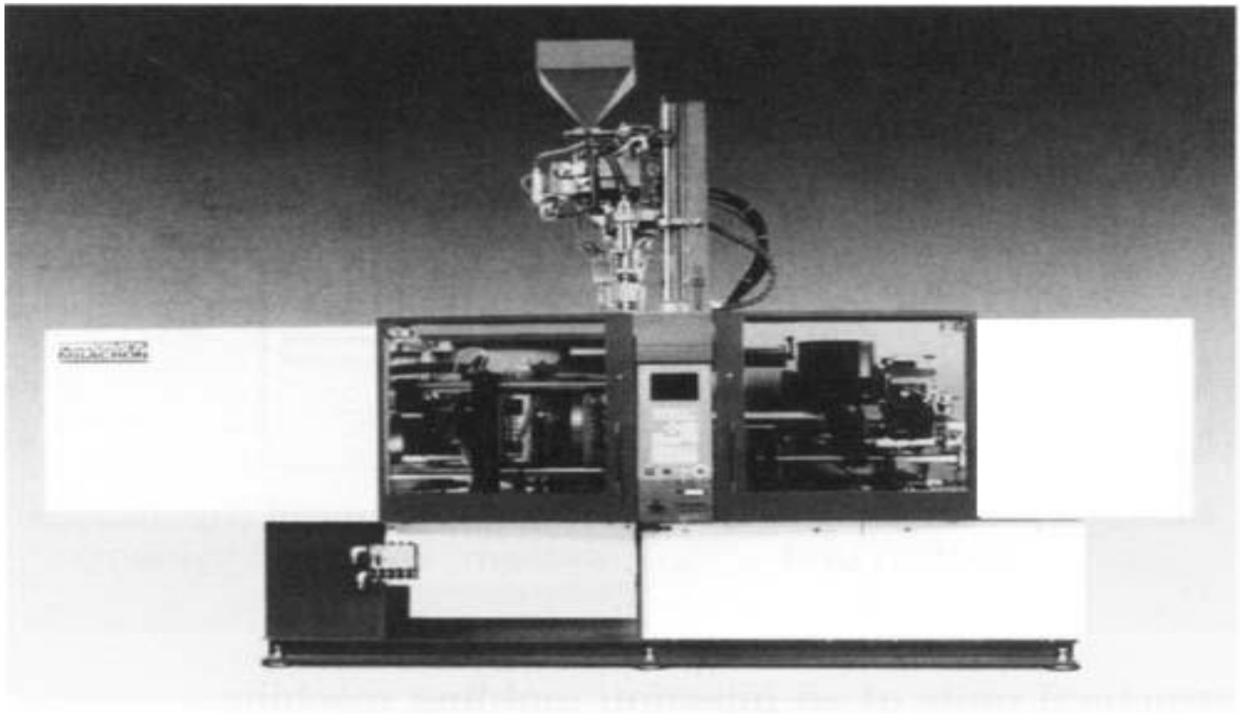
In the vertical machine, the parting plane between the mold halves runs horizontally. As a result, this machine is especially well suited to the production of insert moldings (e.g., electrical plugs) (see Figure 2-3). Most moldings made of elastomers are produced on vertical machines.





With rotary table machines, several clamping units are assigned to a single plasticating unit. As a result, this machine is best suited to molding articles requiring a long cooling or heating period (Figure on left).

Demands for producing complex articles as cost-effectively as possible, without loss of quality or falling behind schedule, has set the plastics processing industry new tasks. As specifications can no longer be met by conventional injection molding methods, special processes -such as multicomponent injection molding - have to be applied (Figure below). With multi-component injection molding, at least two plasticating injection units are assigned to a single clamping unit. This method allows two differently colored plastics materials (automobile rear-lights) to be injected one over the other, forming a single molding.



Structural Units of Injection Molding Machines

Molded articles in a wide variety of sizes and shapes can be produced by injection molding. Production of these articles under optimum conditions requires alternative designs for the various sizes of injection molding machines, as well as their respective auxiliary equipment.

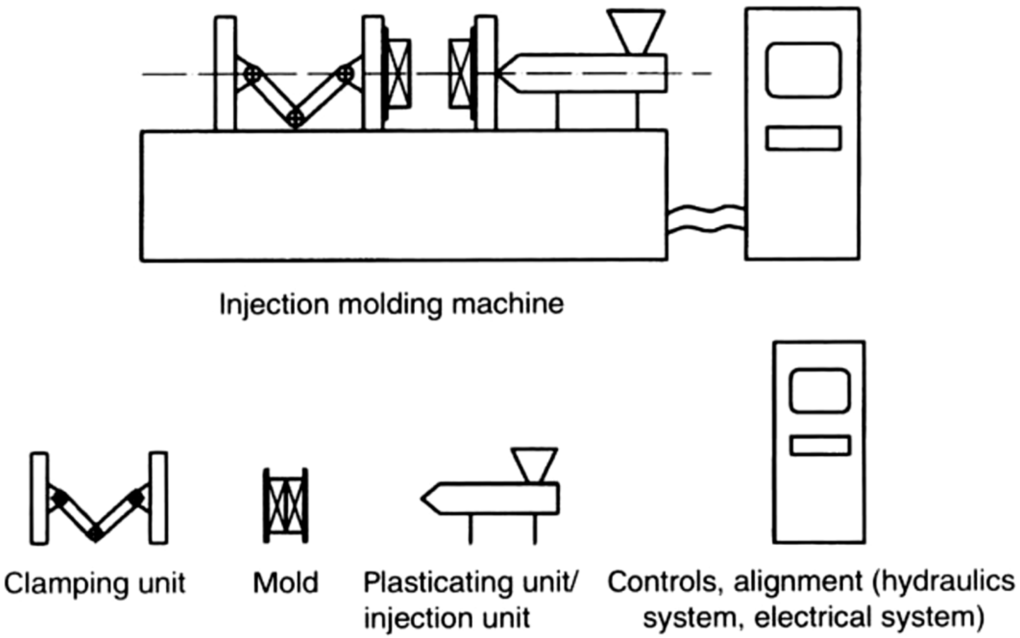
The major modules of an injection molding machine are common to all designs:

- Plasticating and injection unit
- Clamping unit
- Controls with hydraulic and electrical systems

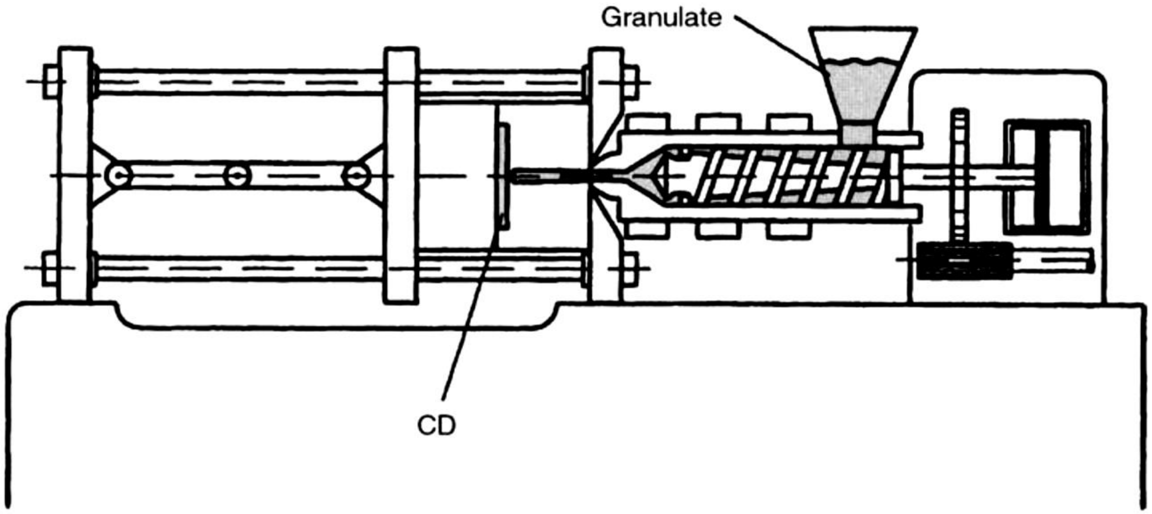
An injection molding machine and its major structural units is shown in figure.

The mold is ordinarily not seen as a structural unit of the injection molding machine. However, in order to simplify matters, it will here be considered as part of the ‘‘overall’’ injection molding machine’s system.

The moldings to be produced determine the relative positions of these structural or modular units to each other, as well as their sizes. Various articles can be produced on a single injection molding machine, but each part requires its own (different) mold. The individual structural units of injection molding machines and their functions will now be described in greater detail. By way of an example, this description will refer to a machine used for molding CDs.



To understand the functions of individual modules, it is best to trace the path of the polymer through the machine from the raw resin (usually in granular form) to the finished product. The basic principle is demonstrated with the diagrammatic cross section of a CD-producing injection molding machine in Figure 2-7. The complete path of the material from hopper to mold is highlighted.



Production of the completed CD is much more complicated, of course. After it has been injection molded, it is given a metal coat by “sputtering”, which is necessary for reflecting the laser beam. The CD is subsequently subjected to quality checking and is then printed.

Controls:

The control and regulatory unit of the machine is usually housed in a separate control cabinet alongside the machine. In addition to the display instruments, the control cabinet also contains the electrical and electronic circuit elements and controls.

On older machines it is customary for the desired machine parameters to be set with limit switches located directly on the major modules or by push buttons on the control cabinet.

On modern injection molding machines, the keyboard and display screen have become the preferred devices for inputting and monitoring of set-values. With CNC-controlled machines, the heart of modem open-as well as closed-loop control is the microcomputer or a PC (Personal Computer). Apart from open loop and feedback control of the injection molding process sequences, these computers are also capable of monitoring and saving data.

Computer controls of this type employ interfaces, that enable them to exchange information for the production data acquisition (PDA), for instance, or quality data management (CAQ), handling devices or heat-balancing data. They can also enable hardcopy of production data to be printed.

Phases of an Injection Molding Cycle:

This lesson introduces the injection molding process in all of its phases (stages): injection phase, holding pressure phase, cooling phase, feed phase, and removal. The lesson also describes the machine motions associated with these process phases. In processing elastomers and thermosets, the cooling phase - as it applies to the processing of thermoplastics -is replaced by a heating phase.

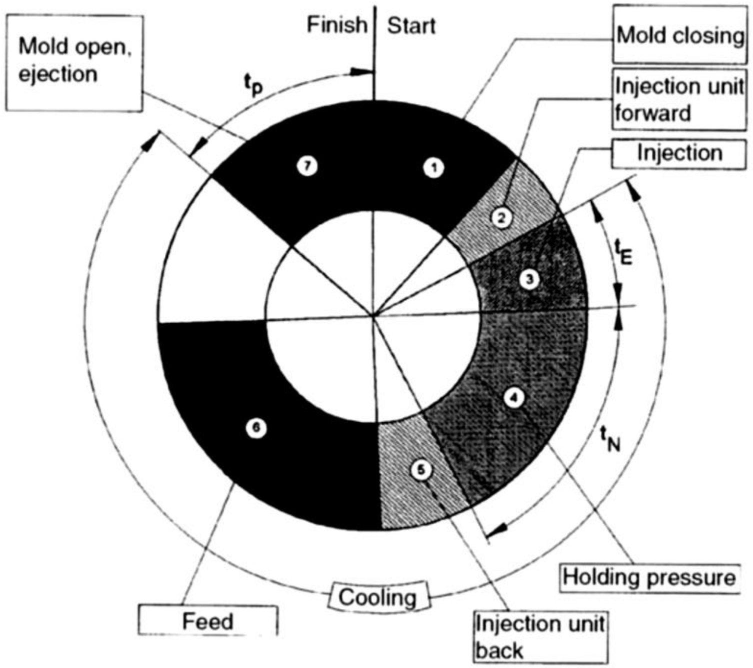
To manufacture an injection-molded part, the machine’s structural units must work together in a practical manner. This cooperation between the units results in the injection molding process during which the molded part is formed.

The injection molding process consists of individual phases or stages which follow one another, overlapping to some extent, and are continuously repeated. We refer to a process of this type as a cycle and therefore speak of a repeating injection molding cycle. Nowadays, it is customary for the injection molding cycle to proceed automatically from phase to phase.

In most cases the cycle also repeats itself automatically. Only under certain conditions or for special molded parts may it be necessary for the machine to stop at the end of a cycle. After manual intervention by the machine operator, the machine is prepared for the next cycle and then restarted. This is done with molded elastomer parts, for example, which generally must be removed by hand.

The CD is produced by a fully automatic method, for example. In this case the machine operator intervenes only when problems arise.

The various times making-up an injection molding cycle are shown with the example of a CD:



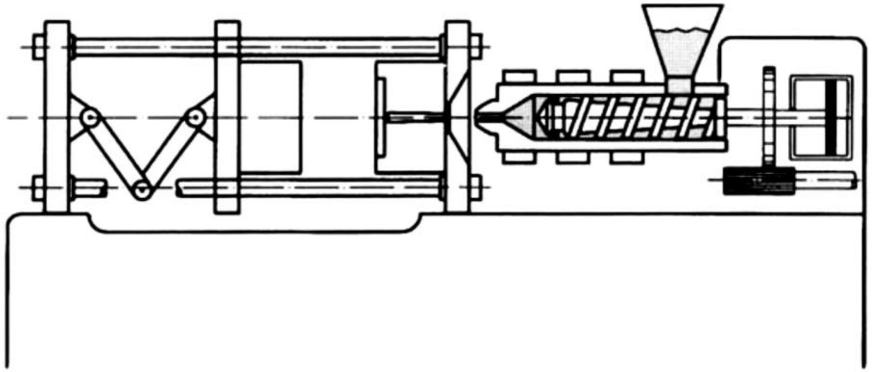
Phase	*Time [s]*
Mold closing	0.4
Injection	0.3
Holding pressure	0.3
Remaining cooling time	2.1
Mold opening	0.4
Handling (plus sprue punch-off)	0.4
Total cycle time	3.9

Due to its short cycle time, the CD is counted amongst fast cycling articles, similar to those produced for the packaging industry (e.g. cups). However, cycle times of other moldings may take from half- to several minutes. This depends on many influencing factors, such as article volume, material, gating design and demolding possibilities, amongst others.

The way the article is actually being molded cannot be observed directly. However, the machine's structural units can provide clues to the phase of the injection molding cycle the machine is currently executing.

Therefore, parallel to the description of the injection molding cycle phases, as seen from the material aspect, an explanation will also show, in which form the machine's structural units are involved.

To start molding production, all machine modules must be in their respective home position



Mold and Clamping Unit

The clamping unit is open. There is no molded part in the cavity of the mold. The ejectors are in the retracted position. The mold has been adjusted to the prescribed temperature.

Plasticating Unit

The screw and cylinder of the plasticating unit have been heated to the prescribed temperature. The screw is in the retracted position. Plasticated, molten material is present in the injection chamber in front of the screw. The nozzle has been closed off so that no material can escape.

Controls

If only one cycle is to be executed, the controls are in the semiautomatic mode. If a practically unlimited number of cycles are to be executed, the controls are in the fully automatic mode. The machine operator must start the process by pressing a button. Usually the process will start only if all machine components are in their respective starting conditions. If this is not so, the controls issue an appropriate error message or automatically restore the components to their starting conditions.

Hydraulic- and Electrical Systems

Of course, one precondition for the start of production is that the hydraulic and electrical systems of the machine must be switched on. Furthermore, the machine's hydraulic oil must be up to the set operating temperature.

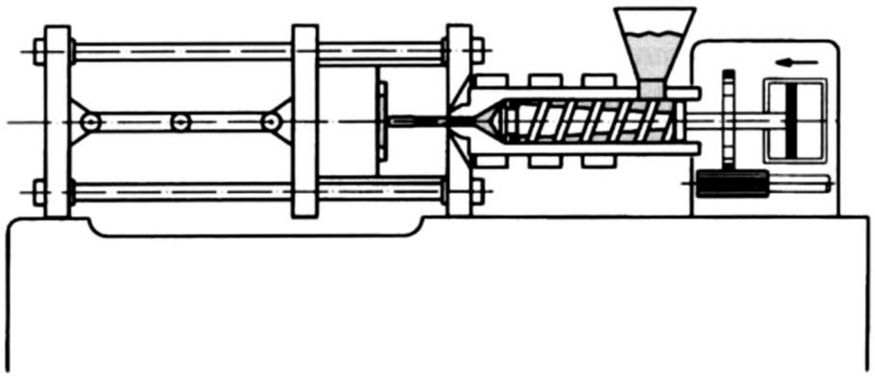
The material, i.e. the molding compound, is present in the screw's antechamber as thoroughly mixed melt. In processing conventional thermoplastics (PS, PVC, PE), the material is at approximately 200-300°C. The material, from which CDs are produced, is heated to approximately 330°C. The consistency of the plastics melt is roughly comparable to that of honey.

Once the machine operator issues the starting signal, the injection molding cycle begins with the closing of the mold.

Injection Phase

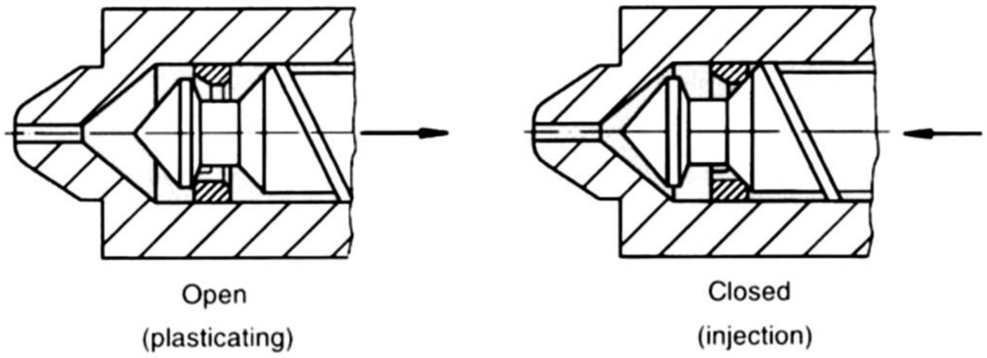
Mold and Clamping Unit

The clamping unit moves the two halves of the mold together. A clamping force is built up, thus locking the mold tightly.



Plasticating Unit

The plasticating unit moves up to the mold's sprue bush. The nozzle is opened, and the material located in the screw's ante-chamber is injected into the mold by the forward movement of the screw. As soon as the screw moves forward, pressure is exerted upon the non-return valve (check-ring valve) on the screw-tip by the material in the ante-chamber. As a result, the check ring of the non-return valve is pushed back onto its seat, thus stopping any melt escaping rearward over the screw flights. The screw now functions as a plunger during the injection process (figure below).



Controls

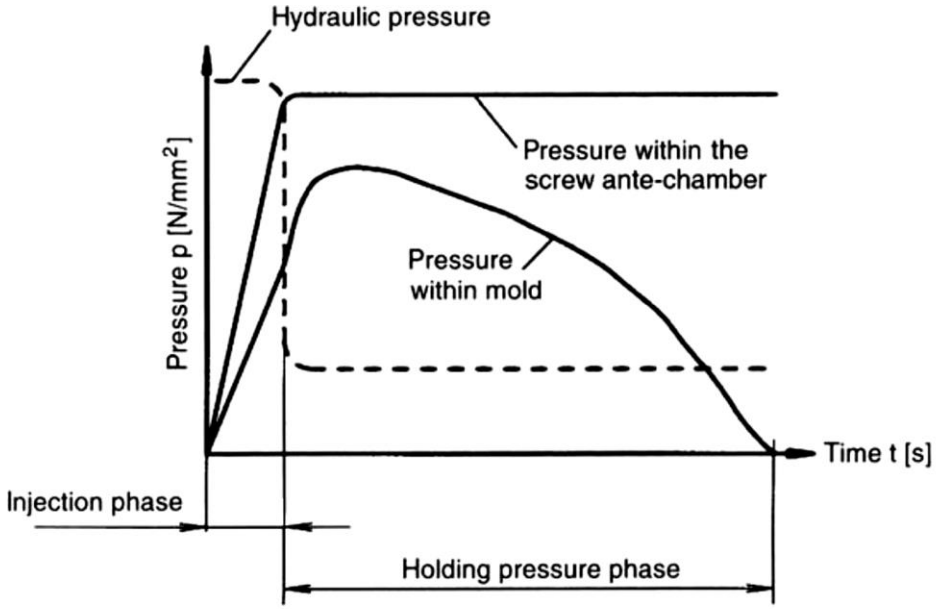
The controls must ensure that the structural unit movements are coordinated, while proceeding at the intended speeds and pressures. This places high demands on the precision of the controls.

Hydraulics

The hydraulic system must exert its highest power-output during the injection phase. Besides maintaining the clamping force, the hydraulic system must also be able to inject the plastics melt into the cavity at high, but precise, speed. To accomplish this, the hydraulic system must overcome the resistance offered by nozzle and mold. At the start of the injection process, the molten, homogenized material is poised in the injection chamber. The nozzle is closed, so that no material can escape. As soon as the plasticating unit has been moved against the mold's sprue bush, the nozzle can be opened to allow the melt free passage into the mold. At the same time, the hydraulic system exerts pressure on the screw, which moves in an axial direction, i.e. forward towards the nozzle. The material is thus forced out of the screw's ante-chamber and pushed into the mold cavity. The fluid, molten material must re-solidify within that cavity, so that the finished article can be removed later. Therefore, molds employed for thermoplastics are cooled or heat-balanced, in order to dissipate the heat introduced into the material during the melting process, thus allowing it to solidify.

As soon as the melt contacts the mold during the injection operation, it begins to cool and solid. Therefore, injection must occur quickly so that the cavity is filled while the compound is still fluid. This requires very high pressure, because the melt is merely viscous, despite the high temperatures used. The melt flow must overcome the resistance offered by the nozzle, sprue, and cavity, as well as some other obstacles, such as wall friction. The pressure in front of the screw may therefore exceed 2000 bar (29,000 psi) in the injection operation. The resistance in the nozzle, sprue, and cavity causes this injection pressure to decrease gradually in the direction of flow. Despite this, high pressures also occur within the mold. The clamping unit must be capable of holding the mold tightly shut against these pressures.

Figure below shows the pressure-curve inside the mold, in front of the screw, and in the machine's hydraulic system. The pressure inside the mold reaches its maximum value, when sufficient melt has been injected to completely fill all cavities.



The pressure in the hydraulic system is actually much lower than that shown in above Figure. The reason is, that this pressure is intensified to a higher value by the hydraulic ram's projected area. The hydraulic pressure acting on the hydraulic ram's large projected area transmits a great amount of force to the screw's "ram" tip. This force produces the high pressure within the injection chamber. The most critical point of the injection phase has now been reached. Most of the molding compound is still in a fluid state, so almost all of the pressure applied by the screw can be transmitted to the mold. If the injection pressure were maintained beyond this point, the resulting pressure within the mold could be great enough to overcome the clamping force. The mold would be forced apart in the parting plane, allowing melt to escape from the cavity.

This can have serious consequences. Flash forms on the molding, which will require finishing work, or the article may even have to be rejected. The consequences for the mold or the machine can be considerably more critical. The high forces applied can result in serious damage to mold or clamping unit.

It is therefore critical, that the injection pressure is switched off at the right moment. If this occurs too soon, it will result in the production of incompletely filled parts. Change-over to holding pressure asks for particularly high precision of the machine's control and hydraulic systems.

Holding Pressure Phase

As soon as the plastics melt fills the mold, it begins to cool. This cooling process begins at the mold wall and proceeds toward the center. For a certain period, the melt remains fluid inside the molding. As it cools, the molding material decreases in volume; in other words, it 'shrinks.' If the pressure were completely switched off after the injection phase, the molding would detach itself from the wall as it cools. There would no longer be any control over the molding's dimensions. It is easy to imagine the consequences in the example of the CD: the surface would become uneven, the scanning by laser would become less reliable-in short, the CD would be utterly useless.

This can be avoided. As long as the internal region of the molding remains in a fluid state, the pressure on the melt is maintained. Supplemental fresh material is forced into the mold in sufficient quantity to compensate for shrinkage. Of course, this works only as long as the sprue's inside remains soft enough. That is one reason, why the sprue should be positioned at the thickest point of the molding, if possible. Besides this, it should also be dimensioned accordingly. Holding pressure phase is the term for the phase in which just enough pressure is applied to compensate for shrinkage by the supplemental injection of material. This phase must last until the sprue has solidified-in other words, until no more melt can be supplementally forced into the molding. That event is known as 'sealing point'. In contrast to the injection phase, no flow resistance must be overcome in the holding pressure phase. Furthermore, practically no movement of material occurs in this phase. For these reasons, the holding pressure can generally be set to a lower level than the injection pressure. It is important to set the pressure to the proper level. If the holding pressure is too low, or if the holding pressure period is too short, this would result in the production of a defective molding.

It is important, to take a closer look at the position of the screw in the holding pressure phase. At the start of the holding pressure phase, the cavity has already been filled with most of the melt, that it is meant to receive. A small quantity is subsequently injected to compensate for shrinkage. But even at the end of the holding pressure phase, some residual material should still be in the injection chamber. This 'melt cushion' enables pressure to be transmitted between the screw and the cavity or sprue. This melt cushion is absorbed in the next shot.

Controls

During the holding pressure phase, the machine controls must ensure that the hydraulic pressure, which moves the screw, remains at the prescribed level. This will allow the supplemental injection of just enough material into the cavity to compensate for the shrinkage of the molded part. For this purpose, most machines offer the option of running a sequence of different stages of holding pressure levels. These stages are adapted to the geometry of the molded part.

Hydraulics

The hydraulic pressure is at a lower level during the holding pressure phase than the injection phase. The change-over from injection phase to holding pressure phase is critical, as far as the hydraulic system is concerned. The ‘injection’ mode is characterized by high screw speeds and high pressure, while the ‘holding pressure’ mode is characterized by a very low screw speed and a relatively low hydraulic pressure. The transition from the former mode to the latter must be performed with extreme precision and within the shortest possible time. This demands high precision of the switching operations. The injection and holding pressure phases are followed by two other phases,

which proceed concurrently.

Cooling Phase

The material is now in the cavity of the mold. It has reached the cavity in a flowable state and must now solidify under the influence of the relatively low mold temperature. This will allow the finished molded part to be removed. The solidification of the molded part must occur under controlled conditions so that no undesirable stresses develop within the molded part. These stresses would warp the molded part.

Feed Phase

The sprue on the molded part has solidified, thus preventing any further injection of supplemental molding compound. The plasticating unit can thus fulfill its other tasks. New material can be prepared in readiness for the next cycle.

Cooling Phase

For the material within the mold cavity, the holding pressure phase is concluded as soon as the sprue solidifies-in other words, as soon as it is ‘sealed.’ From this point on, no more material can enter the cavity. During the injection and holding pressure phases, the material in the cavity has already begun to cool against the relatively cold mold wall. The outer layers have soldified very quickly. The cooling time therefore starts as early as injection. Cooling takes longer in the middle of the molded part. The surplus heat of melt remaining there must be dissipated through the outer layers to the mold wall. Now it becomes apparent that plastics are poor conductors of heat. The thermal conductivity of plastics is approximately 100 times poorer than that of steel. Heat transfer can be effectively defined with the help of mathematical equations. This makes it possible to perform advance calculations of the cooling time, during which the molded part must remain in the mold until it is sufficiently cooled. The cooling time also depends on for how long a period it is intended to cool the article within the mold. It is not necessary, to wait until the entire molding has cooled to mold temperature. It suffices, for the outer part of the molding to cool just enough, so that it can be removed from the mold in stable condition. It would also be ill-advised to allow the part to cool within the mold for longer than absolutely necessary. The reason is that the machine is essentially in a waiting mode during the cooling period and is therefore unproductive.

The choice of the proper cooling time is also especially important from the profitability aspect. Apart from the complicated equations for defining the cooling process - as applied in computer simulations of injection molding - there are also simple equations which make it possible to calculate cooling times with a pocket calculator or by hand.

Cooling Time Equation

The cooling time equation has been derived at as a simple approximation for defining heat-transfer within the molding during the cooling process in the injection molding tool:

$$t_c = \frac{s^2}{\pi^2 \times a_{eff}} \times \ln\left(\frac{4}{\pi} \times \frac{T_m - T_w}{T_E - T_w}\right)$$

t_c[s] = cooling time to be calculated

s[mm] = article thickness

T_m[K] = melt temperature at the start of the injection process

T_w [K] = mold temperature

T_E [K] = demolding temperature (assumed temperature at the molding’s center, at which it is to be removed)

a_{eff} [mm^2/s] = effective temperature conductivity (the molding compound’s physical characteristics, which can be found in Tables, subject to the mold wall temperature)

The following equation can be employed for a rough calculation of the cooling time:

$$t_c = 2s^2$$

t_c[s] = cooling time

s[mm] = the article’s wall thickness

The article’s largest wall thickness is decisive, as it determines the cycle time.

According to this formula, a CD with a wall thickness of 1.14 mm (0.045 in) requires a cooling time of approximately 2.6 seconds. (For wall thickness in inches, the formula for cooling time is CD = 2000 s^2.)

Mold and Clamping Unit

The status of mold and clamping unit during the holding pressure phase is identical with the one of the cooling phase.

Plasticating Unit

During the cooling period, material is prepared in the plasticating unit for the next shot. A detailed description of the events which take place in the plasticating unit during this phase is given in the section titled ‘feed phase.’

Control and Hydraulic Systems

Because the cooling phase represents a waiting phase for the machine, no actions need to be taken as far as hydraulics and controls are concerned during this phase. The events which take place during the concurrent feed phase are described in the ‘feed phase’ section.

Feed Phase

During the feed period- following the completion of the injection and holding pressure phases -material for a new shot must be prepared and provided in the proper quantity. The material is ‘fed’ or ‘metered.’

To this end, the material in the hopper above the plasticating unit is drawn in by the rotating screw and conveyed along the screw flights in the direction of the nozzle. As it moves toward the nozzle, the material is exposed to many different stresses. Heat is transmitted to the material from the cylinder wall of the plasticating unit. This transfer of heat is called thermal conduction.

The material is sheared by the rotation of the screw and further warmed by the resulting frictional heat. This effect is intensified by the fact that the height of the screw flights decreases in the direction of the nozzle. The material is thus being compressed increasingly. It is simultaneously mixed (homogenized) in a thorough manner. The pressure conditions in the space between the screw and the cylinder wall cause trapped air to be conveyed in the direction of the feed zone.

The intense compression and mixing of the material is desirable for ensuring that its properties are as uniform as possible. By the time it reaches the tip of the screw, the material has become molten. It accumulates in front of the screw in the ante-chamber. As the screw can be moved in an axial direction, it yields to the pressure of the accumulating material and moves backward. In order to improve homogenization, this movement is restricted by adjustable resistance, known as back-pressure.

In most cases, more energy is introduced into the material by friction than by the hot cylinder wall. Ultimately, this energy must be produced by the drive motor. Therefore, the amount of energy introduced is especially dependent on the screw speed and back pressure setting. The screw speed influences the time required to prepare the material.

When the settings for the process are selected, it is important to make sure, that the plasticating time does not exceed the cooling time. The reason is, that the plasticating time can vary as a result of variations in material characteristics. If the plasticating time were longer than the cooling time, these variations would directly affect the cycle time, possibly causing the quality of the molding to vary as well. The following rule therefore applies: The plasticating time must not be allowed to determine the cycle time.

Furthermore, an optimum cooling time offers the advantage of greater profitability, since it allows more moldings to be produced, due to time-saving.

The molding's cooling phase m s concurrently with the feed phase. As soon as the feed phase has ended, the material is available in the injection chamber for the next cycle. During the waiting period- while waiting for completion of the molding's cooling phase -a heat exchange occurs between the melt in the screw's ante-chamber and the cylinder wall. It is important to ensure, that during this waiting period the melt neither cools excessively nor absorbs too much heat and starts to decompose.

Mold and Clamping Unit

The mold and clamping unit are not involved in the plasticating operation.

Plasticating Unit

The preparation of new material begins immediately after the completion of the holding pressure phase. If a shut-off nozzle is used, it will close as soon as the holding pressure phase has timed-out. In this case the plasticating unit will be retracted from the mold to avoid excessive heat-transfer from the hot nozzle to the cooler mold.

If no shut-off nozzle is used, the plasticating unit cannot be retracted until the feed phase has ended. Otherwise, the molding compound would escape from the nozzle prematurely.

During the plasticating process, the screw is rotated by a hydraulic motor. The material descends from the hopper and enters the feed zone. The rotation of the screw then conveys the material toward the screw tip and through the open non-return valve. The screw is forced backward by the material accumulating in the injection chamber (ante-chamber) in front of the screw tip. As soon as the introduced melt has pushed the screw back to trigger the adjustable feed stroke limit switch, screw rotation is stopped.

Importance of using PPEs

PPE is equipment that will protect workers against health or safety risks on the job. The purpose is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

PPEs:

Name & Usage	Picture of PPE	Name & Usage	Picture of PPE
Safety goggles – used to protect eyes from flying particles (chips, sparks etc.)		Safety shoes – used to protect feet from spatters of welding and impact of other falling objects	
Face shield - used to protect face from welding sparks, radiations, arc and spatters		Face mask – used to protect from inhaling fumes, dangerous gases etc.	
Hard cap – used to protect the head from injury due to falling objects		Leather Apron – used to protect welder's body from welding spark and spatters	
Leather gloves – used to protect hands during welding		Cotton gloves – used to protect hands from sharp edges of sheets and plates	

Importance of housekeeping and safe storage of tools and equipment

The main function of housekeeping is to ensure cleanliness, comfort, convenience, privacy, health and hygiene in a safe environment. It includes keeping work areas neat and orderly. All the tools and equipment must be stored properly.

Importance of making a check list

It ensures you get your daily, weekly and monthly tasks done on time, helps you keep track of projects on deadline and ensures you're organized throughout the day.

Video links:

Plastic Injection Molding – University of Illinois: https://www.youtube.com/watch?v=RMjtmsr3CqA
Molding Machine Parts and Operation - Technology of Injection Molding: https://www.youtube.com/watch?v=DbaWBXe9-vQ
Instructional video: 80 Ton Arburg Injection Molder: https://www.youtube.com/watch?v=VxayepUk3r0

PLASTIC PROCESSOR

Module-7

Learner Guide

National Vocational Certificate Level 2

Version 1 - September, 2018

Module 7: 072200912 Produce Pipe Through Extrusion Moulding Machine

Objective of the module: The aim of this module to provide skills and knowledge to operate pipe extrusion machine in accordance with the manufacturer's manual

Duration: 150 hours **Theory:** 30 hours **Practical:** 120 hours

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1: Interpret Work Order	**The trainee will be able to:** Obtain Work order Verify production quantity available Ensure raw material as per work order Ensure machine setting as per production per data sheet provided	i) Basic literacy skills • Be able to read instructions about product, quantity and raw material • Be able to identify rolling required to produce different components as per work order ii) Reporting procedure • Understanding the work order contents • Knowledge of units (Kg, inches, etc.) iii) Work order process • Understand the top-down stream of task assignment • Knowledge of what the work order represents • Who generates the work order? • Where can it be obtained from? iv) Material handling and storing procedure • Understanding where to obtain raw material for the required production quantity • How to handle raw material? v) Set machine parameters as per data sheet provided vi) Be able to input machine parameters as	Extruder High speed mixer Pipe extrusion downstream line Extruded product samples Operation manual Basic Hand Tools

		mentioned in work order or datasheet	
LU2: Start production as per requirement	**The trainee will be able to:** Adjust pipe sizing as per job card Fix printer as per job card Manage production rate as per machine capacity to achieve standard component	i) Machine controls • Learn to input processing parameters in the machine and peripheral components ii) Machine operation in automatic mode • Be able to perform semi-auto operation • Up on successfully obtaining required product specification, switching the machine to auto mode iii) Peripheral equipments such as air compressors, chillers, vacuum pump, printer, dryer, etc. • Ensure working and operation of all affiliated equipment	Extruder High speed mixer Pipe extrusion downstream line Extruded product samples Operation manual Basic Hand Tools
LU3: Perform follow up procedure	**The trainee will be able to:** Verify pipe length as per order Verify pipe standard dimensions and visual inspection Generate parameters report according to set format	i) Knowledge of pipe standards (BS 3505, etc.) • Understand the difference in producing pipes as per multiple standards • Memorize dimensions of pipes as per commonly used standards ii) Maintaining product quality as per specifications • Be able to measure components for identification of dimensional defects • Usage of measurement tools is critical: Vernier caliper, micrometer gauge, scale, etc. iii) Raw material input in machine • Ensure consistent raw material feed into	Extruder High speed mixer Pipe extrusion downstream line Extruded product samples Operation manual Basic Hand Tools

		hopper/feeder • Be able to use overhead crane or moveable lifts/ladders • Understand the importance of cutting tools in opening raw material bags. • Concept of ‘clean slits’ using sharp tools to ensure particles of bag don’t get mixed in raw material iv) Lubrication requirements and procedure of machine • Understand the concept of lubricating moveable parts of machines • Be able to provide first-hand feedback to maintenance department for periodic machine maintenance v) Recognize different defects and their causes • Be able to visually identify commonly occurring defects, such as eccentricity, burn lines, blistering, etc. • Gain knowledge of rectification of commonly occurring defects.	
LU4: Submit production report	**The trainee will be able to:** More machine hours as per format Record production (kg/hr) as per format Record rejection (kg/no) on set format Record machine downtime (hours or	i) Production report writing • Understand the importance of reporting accurate production quantity • Be able to fill-in relevant production reports • Be able to identify waste generated along with identification of machine downtime with reasons	Reporting formats Job card Extruder High speed mixer Pipe extrusion downstream line Extruded product samples Operation manual

	minutes) Record machine output (productivity) on set format	ii) Data sharing with relevant departments • Understanding the concept of producing accurate data and benefits of the same on a larger scale • Submission of production reports to production planning department or the supervisor for timely actions.	Basic Hand Tools
LU5: Transport finished product	**The trainee will be able to:** Ensure finished goods are counted according to organization procedure Deliver relevant packaging documents to store personnel	i) Understand QC protocols • Understand and appreciate the importance of producing products as per specification • Be able to implement the first quality control protocol on machine to ensure elimination of defective products at sight ii) Inter-department co-ordination • Be able to co-ordinate with QC department with produced batches for relevant approvals iii) Be able to hand over final products to store • Familiarize with handing-over protocols and paperwork.	Reporting formats Job card Basic Hand Tools Medium of material transport

Examples and illustrations:

For further details, please refer to the book: Understanding Polymer Processing, by Hanser Publishers, Munich

Introduction:

During extrusion, a polymer melt is pumped through a shaping die and formed into a profile. This profile can be a plate, a film, a tube, or have any cross-sectional shape. Ramtype extruders were first built by J. Bramah in 1797 to extrude seamless lead pipes. The first ram-type extruders for rubber were built by Henry Bewley and Richard Brooman in 1845. In 1846, a patent for cable coating was filed for trans-gutta-percha and cis-hevea rubber and the first insulated wire was laid across the Hudson River for the Morse Telegraph Company in 1849. The first screw extruder was patented by Mathew Gray in 1879 for the purpose of wire coating. However, the screw pump can be attributed to

Archimedes, and the actual invention of the screw extruder in polymer processing by A.G. DeWolfe of the United States dates to the early 1860s. The first extrusion of thermoplastic polymers was done at the Paul Troester Maschinenfabrik in Hannover, Germany in 1935.

Pumping

Although ram and screw extruders are both used to pump highly viscous polymer melts through passages to generate specified profiles, they are based on different principles. The schematic in Fig. 4.1 shows the principles that rule the work of ram extruders, screw extruders, and other pumping systems. The ram extruder is a positive displacement pump based on the pressure gradient term of the equation of motion. Here, as the volume is reduced, the fluid is displaced from one point to the other, resulting in a pressure rise. The gear pump, widely used in the polymer processing industry, also works on this principle. On the other hand, a screw extruder is a viscosity pump that works based on the pressure gradient term and the deformation of the fluid, represented as the divergence of the deviatoric stress tensor in Fig. 4.1. Figure 4.2 represents the simplest form of a viscosity pump. Here, the inner cylinder turns and drags the highly viscous fluid in the counter-clockwise direction, until it is pushed out of the system. Various situations can be described with this type of pump:

- (Case 1) Open discharge,
- (Case 2) Closed discharge, and
- (Case 3) Flow resisting die.

The open discharge case is where the pump is open to the atmosphere and consequently does not encounter a flow resistance. Here, the maximum flow rate is generated, and no pressure is built up. In the closed discharge case, the exit of the pump is blocked, leading to no flow rate and a maximum pressure build-up. In the flow restricting die case the fluid exiting the pump encounters a resistance, such as a die, where it is forced to flow through a narrow gap. Here, the pressure generated by the shear deformation is consumed by the die.

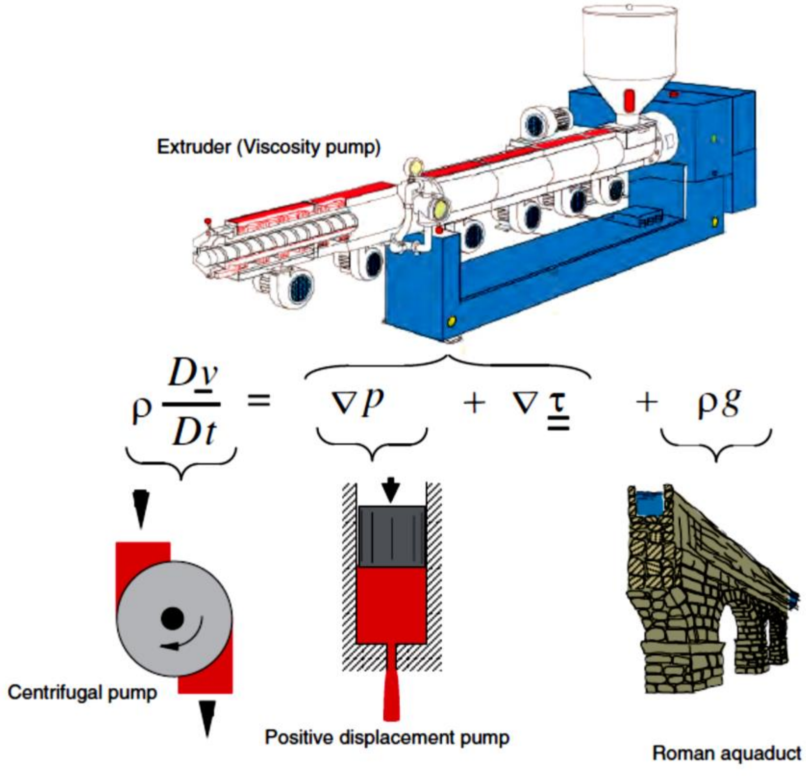


Figure 4.1 Schematic of pumping principles

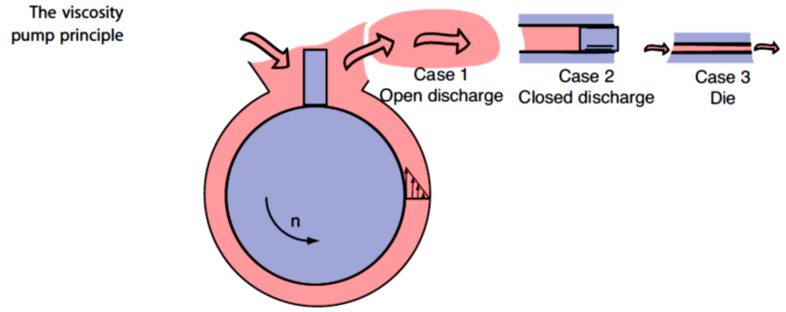


Figure 4.2 Schematic of a viscosity pump

The centrifugal pump, which works based on the fluid's inertia is also represented in the figure and is typical of low viscosity liquids. The Roman aqueduct, shown on the right of the figure, is driven by gravitational forces. In today's polymer industry, the most commonly used extruder is the single screw extruder, schematically depicted in Fig. 4.3. The single screw extruder can either have a smooth inside barrel surface, called a conventional single screw extruder, or a grooved feed zone, called a grooved feed extruder. In some cases, an extruder can have a degassing zone, required to extract moisture, volatiles, and other gases that form during the extrusion process.

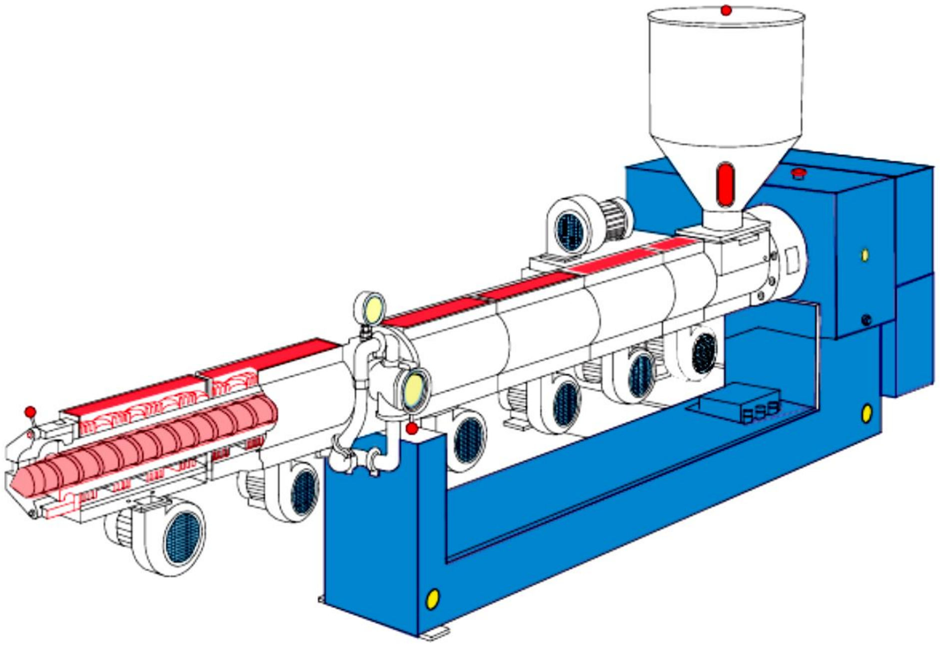


Figure 4.3 Schematic of a single screw extruder (Reifenhäuser)

Another important class of extruders are the twin-screw extruders, schematically depicted in Fig. 4.4. Twin screw extruders can have co-rotating or counter-rotating screws, and the screws can be intermeshing or non-intermeshing. Twin screw extruders are primarily employed as mixing and compounding devices, as well as polymerization reactors.

The Plasticating Extruder

The plasticating single screw extruder is the most common equipment in the polymer industry. It can be part of an injection molding unit and is found in numerous other extrusion processes, including blow molding, film blowing, and wire coating. A schematic of a plasticating, or three-zone, single screw extruder with its most important elements is shown in Fig. 4.5. Table 4.1 presents typical extruder dimensions and relationships common in single screw extruders.

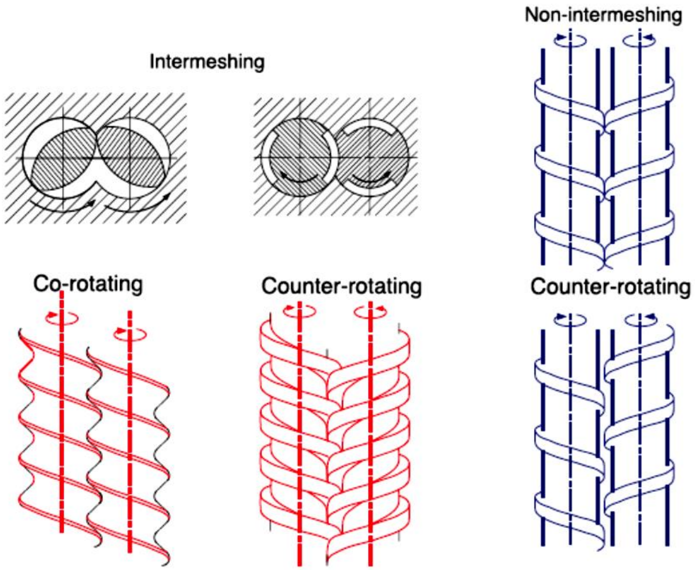


Figure 4.4 Schematic of different twin screw extruders

The three zone extruder — solids, melting and pumping zones

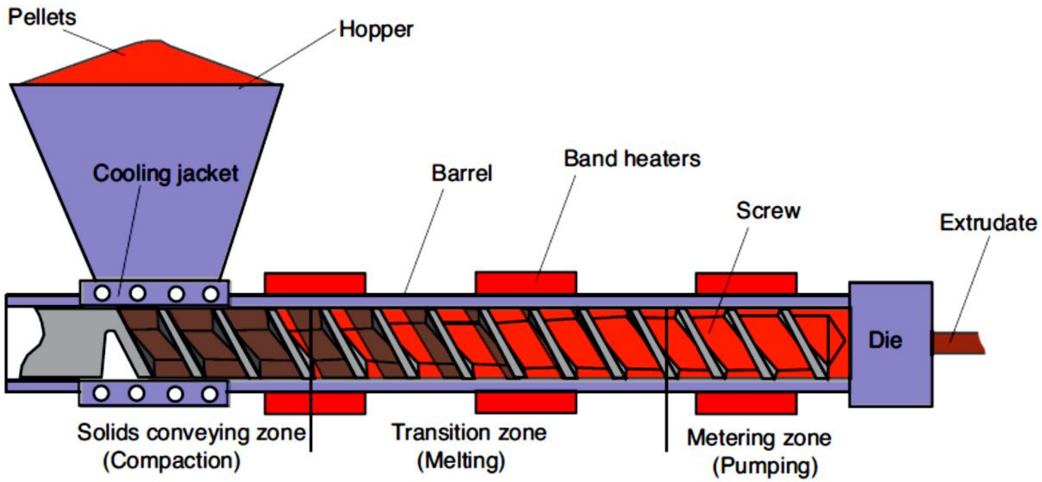


Figure 4.5 Schematic of a plasticating single screw extruder

Table 4.1 Typical extruder dimensions and relationships (the notation for Table 4.1 is defined in Fig. 4.6.)

L/D	Length to diameter ratio
	20 or less for feeding or melt extruders
	25 for blow molding, film blowing and injection molding
	30 or higher for vented extruders or high output extruders
D	Standard diameter
U.S. (in)	0.75, 1.0, 1.5, 2, 2.5, 3.5, 4.5, 6, 8, 10, 12, 14, 16, 18, 20, and 24
Europe (mm)	20, 25, 30, 35, 40, 50, 60, 90, 120, 150, 200, 250, 300, 350, 400, 450, 500, and 600
φ	Helix angle
	17.65° for a square pitch screw where $L_s = D$
	New trend: $0.8 < L_s/D < 1.2$
h	Channel depth in the metering section
	(0.05–0.07) D for $D < 30$ mm
	(0.02–0.05) D for $D > 30$ mm
β	Compression ratio: $h_{feed} = \beta h$
	2 to 4
δ	Clearance between the screw flight and the barrel
	0.1 mm for $D < 30$ mm
	0.15 mm for $D > 30$ mm
n	Screw speed
	1–2 rev/s (60–120 rpm) for large extruders
	1–5 rev/s (60–300 rpm) for small extruders
u_B	Barrel velocity (relative to screw speed) = $\pi D n$
	0.5 m/s for most polymers
	0.2 m/s for unplasticized PVC
	1.0 m/s for LDPE

Characteristic speed inside an extruder is 0.5 m/s for most polymers

The plasticating extruder can be divided into three main zones:

- the solids conveying zone
- the melting or transition zone
- the metering or pumping zone

The tasks of a plasticating extruder are to:

- transport the solid pellets or powder from the hopper to the screw channel
- compact the pellets and move them down the channel
- melt the pellets
- mix the polymer into a homogeneous melt
- pump the melt through the die

The pumping capability and characteristic of an extruder can be represented with sets of die and screw characteristic curves. Figure 4.7 presents such curves for a conventional (smooth barrel) single screw extruder. The die characteristic curves are labeled K1, K2, K3, and K4 in ascending order of die restriction. Here, K1 represents a low resistance die, such as for a thick plate, and K4 represents a restrictive die, such as is used for film. The different screw characteristic curves represent different screw rotational speeds. In a screw characteristic curve, the point of maximum throughput and no pressure build-up is called the point of open discharge. This occurs when there is no die. The point of maximum pressure build-up and no throughput is called the point of closed discharge. This occurs when the extruder is plugged. The lines also shown in Fig.4.7 represent critical aspects encountered during extrusion. The curve labeled T_{max} represents the conditions at which excessive temperatures are reached as a result of viscous heating. The feasibility line ($\dot{m}_{min}$) represents the throughput required to have an economically feasible system. The processing conditions to the right of the homogeneity line render a thermally and physically heterogeneous polymer melt.

The Solids Conveying Zone

The task of the solids conveying zone is to move the polymer pellets or powders from the hopper to the screw channel. Once the material is in the screw channel, it is compacted and transported down the channel. The process to compact the pellets and to move them can only be accomplished if the friction at the barrel surface exceeds the friction at the screw surface. This can be visualized if one assumes the material inside the screw channel to be a nut sitting on a screw. As we rotate the screw without applying outside friction, the nut (polymer pellets) rotates with the screw without moving in the axial direction. As we apply outside forces (barrel friction), the rotational speed of the nut is less than the speed of the screw, causing it to slide in the axial direction. Virtually, the solid polymer is then “unscrewed” from the screw.

The Melting Zone

The melting or transition zone is the portion of the extruder where the material melts. The length of this zone is a function of the material properties, screw geometry, and processing conditions. During melting, the size of the solid bed shrinks as a melt pool forms at its side, as depicted in Fig.4.13(a),which shows the polymer unwrapped from the screw channel. Figure 4.13b presents a cross section of the screw channel in the melting zone. The solid bed is pushed against the leading flight of the screw as freshly molten polymer is wiped from the melt film into the melt pool by the relative motion between the solids bed and the barrel surface. Knowing where the melt starts and ends is important when designing a screw for a specific application.

The solid bed profile in a single screw extruder

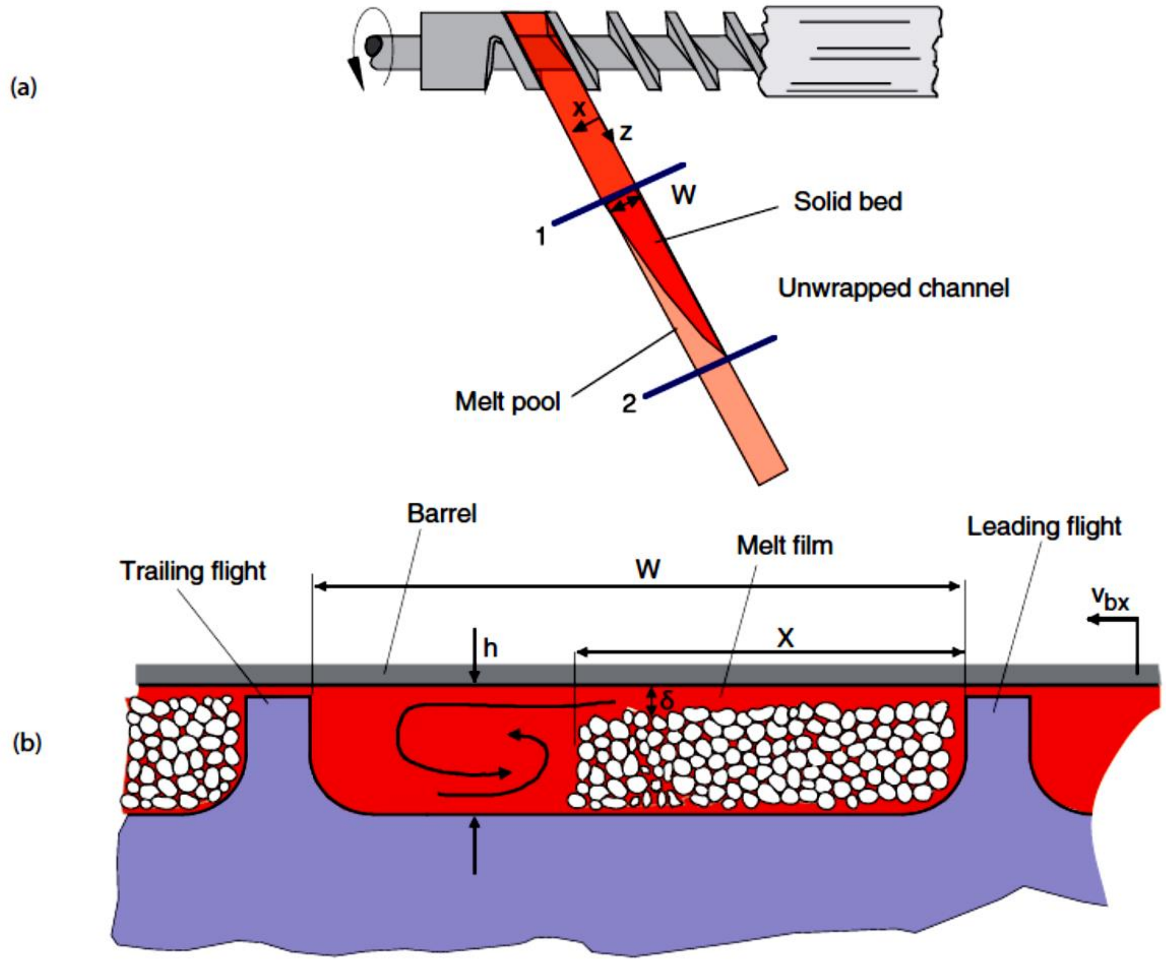


Figure 4.13 (a) Solids bed in an unwrapped screw channel and (b) screw channel cross section

The Metering Zone

The metering zone is the most important section in melt extruders and conventional single screw extruders that rely on it to generate pressures sufficient for pumping. The pumping capabilities in the metering section of a single screw extruder can be estimated by solving the equation of motion with appropriate constitutive laws. A restrictive extrusion die would clearly work best with a shallow channel screw, and a less restrictive die would render the highest productivity with a deep channel screw. In both the grooved barrel and the conventional extruder, the diameter of the screw determines the metering or pumping capacity of the extruder.

Extrusion Dies

The extrusion die shapes the polymer melt into its final profile. The extrusion die is located at the end of the extruder and it used to extrude:

- flat films and sheets
- pipes and tubular films for bags
- filaments and strands
- hollow profiles for window frames
- open profiles

As shown in Fig. 4.18, depending on the functional needs of the product, several rules of thumb can be followed when designing an extruded plastic profile. These are:

- Avoid thick sections. They add to the material cost and increase sink marks caused by shrinkage.
- Minimize the number of hollow sections. hollow sections add to die cost and make the die more difficult to clean.
- Generate profiles with constant wall thickness. Constant wall thickness in a profile makes it easier to control the thickness of the final profile and results in a more even crystallinity distribution in semi-crystalline profiles.

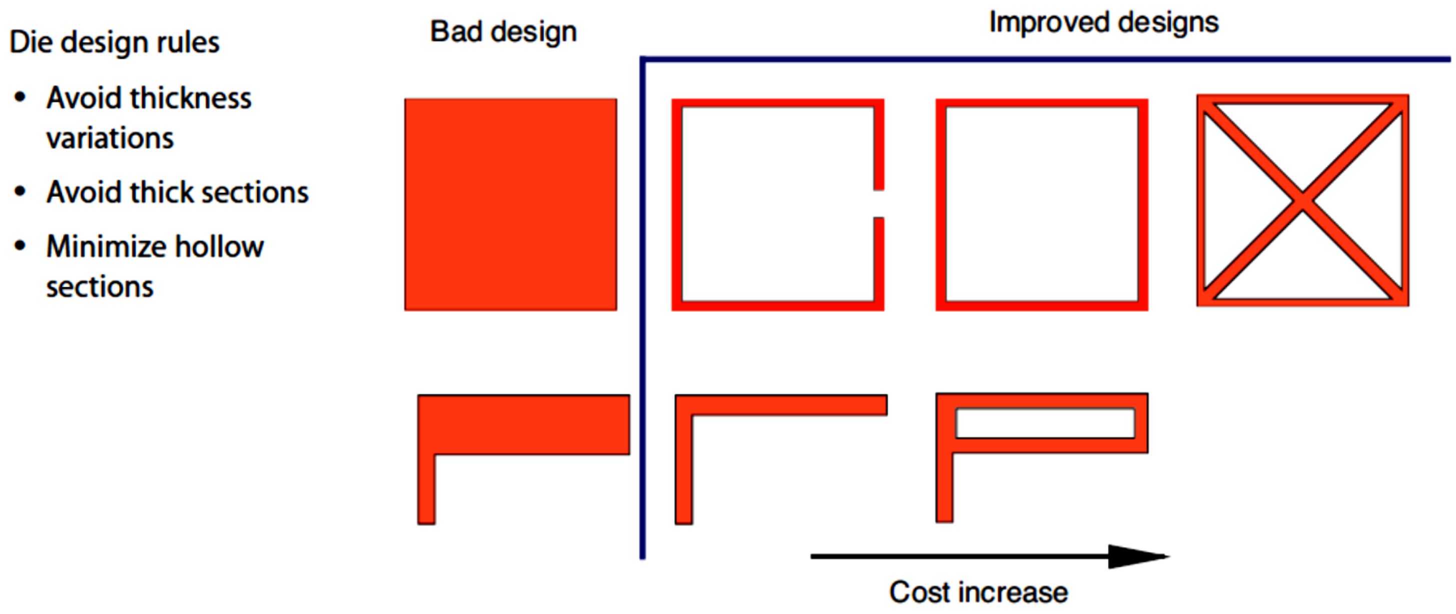


Figure 4.18 Extrusion profile designs

Sheeting Dies

One of the most widely used extrusion dies is the coat-hanger sheeting die. A sheeting die, such as depicted in Fig. 4.19, is formed by the following elements:

- Manifold: evenly distributes the melt to the approach or land region
- Approach or land: carries the melt from the manifold to the die lips
- Die lips: perform the final shaping of the melt
- Flex lips: for fine tuning when generating a uniform profile

To generate a uniform extrudate geometry at the die lips, the geometry of the manifold must be specified appropriately. Figure 4.20 presents the schematic of a coat-hanger die with a pressure distribution that corresponds to a die that renders a uniform extrudate.

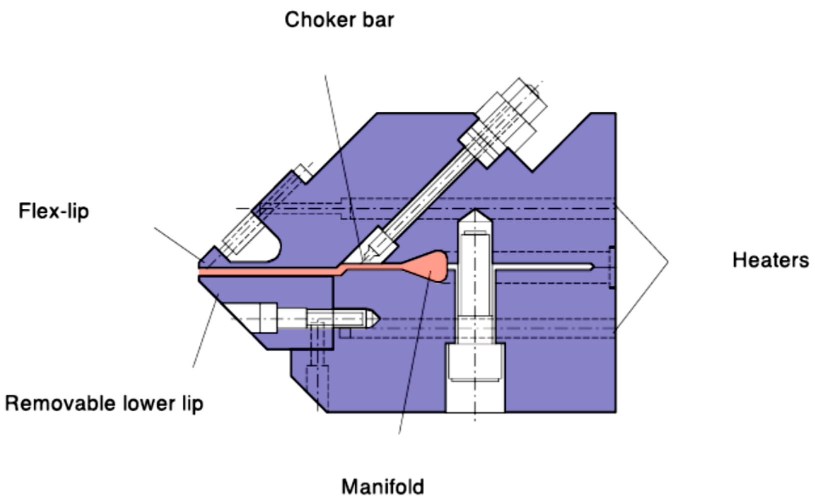


Figure 4.19 Cross section of a coat-hanger die

The goal in sheeting die design is to have a uniform product

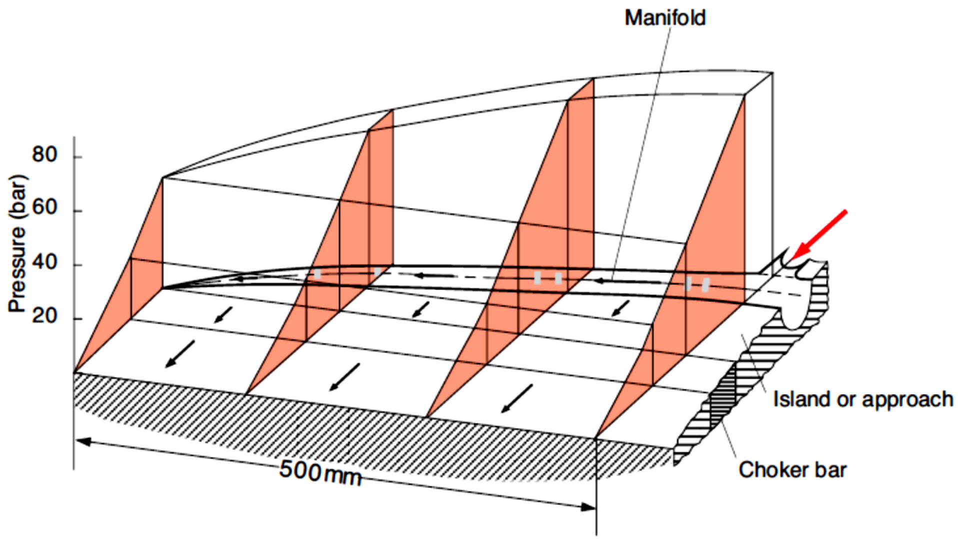


Figure 4.20 Pressure distribution in a coat-hanger die

It is important to mention that the flow through the manifold and the approach zone depend on the non-Newtonian properties of the polymer extruded. So the design of the die depends on the shear thinning behavior of the polymer. Hence, a die designed for one material does not necessarily work for another.

Tubular Dies

In a tubular die, the polymer melt exits through an annulus. These dies are used to extrude plastic pipes and tubular film. The simplest tubing die is the spider die, depicted in Fig. 4.21. Here, a symmetric mandrel is attached to the body of the die by several legs. The polymer must flow around the spider legs, causing weld lines along the pipe or film. These weld lines, visible streaks along the extruded tube, are weaker regions.

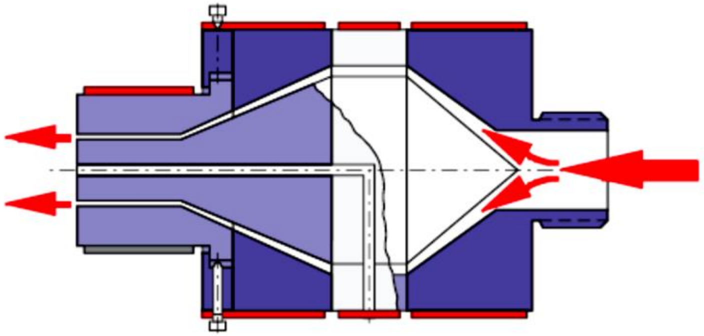


Figure 4.21 Schematic of a spider leg tubing die

To overcome weld line problems, the cross-head tubing die is often used. Here, the die design is similar to that of the coat-hanger die, but wrapped around a cylinder. This die is depicted in Fig. 4.22. Since the polymer melt must flow around the mandrel, the extruded tube exhibits one weld line. In addition, although the eccentricity of a mandrel can be controlled using adjustment screws, there is no flexibility to perform fine-tuning such as in the coat-hanger die. This can result in tubes with uneven thickness distributions.

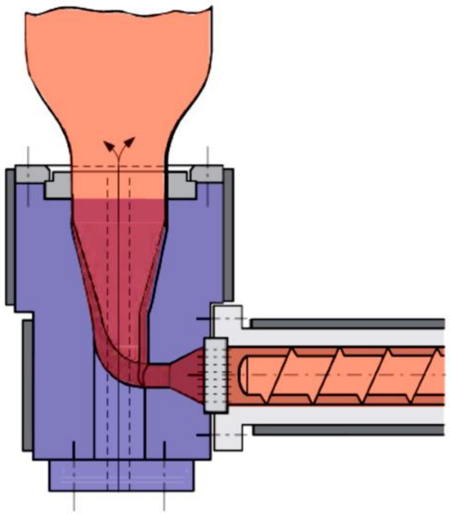


Figure 4.22 Schematic of a cross-head tubing die used in film blowing

The spiral die, commonly used to extrude tubular blown films, eliminates weld line effects and produces a thermally and geometrically homogeneous extrudate. The polymer melt in a spiral die flows through several feed ports into independent spiral channels wrapped around the circumference of the mandrel. This type of die is schematically depicted in Fig. 4.23.

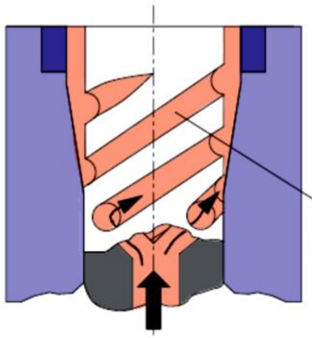


Figure 4.23 Schematic of a spiral die

Extruder Setpoints for Various Resin systems

Material	Feed Zone, °F (°C)	Transition Zone, °F (°C)	Metering Zone, °F (°C)	Die Zone, °F (°C)
ABS	400° (204°)	425° (219°)	440° (227°)	460° (238°)
Nylon 6	420° (216°)	460° (238°)	480° (249°)	500° (260°)
Nylon 6,6	530° (277°)	535° (280°)	545° (285°)	540° (282°)
LDPE	340° (171°)	355° (180°)	365° (185°)	375° (191°)
LLDPE	300° (149°)	325° (163°)	364° (185°)	410° (210°)
HDPE	340° (171°)	380° (193°)	400° (204°)	400° (204°)
PP	375° (190°)	410° (210°)	430° (221°)	430° (221°)
Polystyrene	350° (177°)	400° (204°)	440° (227°)	450° (232°)
HIPS	375° (191°)	420° (216°)	450° (232°)	450° (232°)
PMMA	360° (182°)	400° (204°)	430° (221°)	445° (230°)
Flexible PVC	265° (130°)	340° (171°)	355° (181°)	365° (181°)
Rigid PVC	300° (149°)	320° (160°)	340° (171°)	365° (181°)
PC	510° (266°)	530° (277°)	550° (288°)	560° (293°)
Noryl®	450° (232°)	480° (249°)	510° (266°)	510° (266°)
Ultem®	600° (316°)	640° (338°)	675° (357°)	675° (357°)
PET	520° (270°)	550° (290°)	510° (265°)	510° (265°)
PBT	470° (243°)	490° (121°)	500° (260°)	500° (260°)
Polysulfone	550° (288°)	600° (316°)	650° (343°)	650° (343°)
Acetal	400° (204°)	390° (199°)	400° (204°)	410° (210°)
Thermoplastic Polyurethane	330° (166°)	360° (182°)	380° (193°)	380° (193°)

For further details, please refer to: ***Extrusion: The Definitive Processing Guide and Handbook, William Andrew Publishing***

Hazards Associated with an Extruder

The three biggest potential safety hazards associated with extruders are burns, electrical shock, and falls. Without proper protective equipment, burns can be commonplace among employees working around extruders. Touching a hot die or handling extrudate without gloves normally causes burns. Long sleeves with properly approved thermal gloves should be worn when working around the die, changing the die, tightening die bolts, or other functions performed on the die. If insulation is placed around the die, make sure it is in good shape and properly installed. Hot extrudate from the extruder will stick to your skin. Since polymeric materials are great insulators, after sticking to the skin they cool very slowly, continuing to burn the skin affected.

Never stand in front of a die when a single screw extruder is starting up. Air in the extruder and possibly gas from degraded products (if the extruder has been sitting at extrusion temperature with material in the barrel for some time) is forced out of the extruder on start-up. If some polymer is left in the barrel, trapped air can be compressed,

blowing the hot polymer out of the die. Standing in front of the extruder creates an unsafe condition where molten polymer can be blown out of the die, land on you, and burn you. Polymer can stick to gloves, where it holds heat for a long time, and can burn you through the gloves if the proper type of glove is not used. When removing the die and/or screw from an extruder (they are normally hot), wear the proper protective equipment (heavy duty gloves and protective thermal sleeves) to prevent burns. Dies can be heavy; therefore, a back brace or other equipment to lift and hold the die can prevent back injuries.

Hazards Associated with Takeoff Equipment

The safety hazards associated with takeoff equipment depend on the extrusion process and takeoff equipment. Pinch points associated with nip rolls, pullers, and roll stacks are one potential safety hazard requiring careful operation. If two operators are running equipment containing nip rolls, they must communicate to verify all operators are clear when nip rolls are closed. Loose-fitting clothing that can be caught in nip rolls or pullers must be avoided. Some lines have rolling knives or knives for edge slitting. These should be guarded, and operators must use caution when working in those areas.

Noise above 80 dB requires that hearing protection be used by all people in the area. If the noise level is below 80 dB, employees may still want to wear hearing protection to prevent long-term hearing loss. Like the extruder, identify potential safety hazards associated with the takeoff equipment. Form a plan to avoid potential hazards. Know where all emergency stop buttons are and verify that they work. Don’t take the approach, **“It Won’t Happen to Me.”**

Material Safety

Understand the materials you are using by reviewing the Material Safety Data Sheets (MSDSs). Improper operating conditions or purging with the wrong materials can have serious consequences. Overheating polyvinyl chloride (PVC) generates hydrochloric acid (HCl), which attacks the lungs and rusts plant equipment. Never mix acetal with nylon, PVC, fluorinated polymers, or ionomer in an extruder, as they will react and give off formaldehyde. PVC has limited thermal stability and should not be left in a hot extruder. PVC degrades in an autocatalytic reaction, generating HCl. Proper purge material should be available to remove PVC from the barrel if the extruder is going to be down for an extended time. Operators who have the flexibility to change extruder temperature profiles need to understand the upper processing limits when extruding PVC or other temperature-sensitive polymers.

Importance of using PPEs

PPE is equipment that will protect workers against health or safety risks on the job. The purpose is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

PPEs:

Name & Usage	Picture of PPE	Name & Usage	Picture of PPE
Safety goggles – used to protect eyes from flying particles (chips, sparks etc.)		Safety shoes – used to protect feet from spatters of welding and impact of other falling objects	
Face shield - used to protect face from welding sparks, radiations, arc and spatters		Face mask – used to protect from inhaling fumes, dangerous gases etc.	
Hard cap – used to protect the head from injury due to falling objects		Leather Apron – used to protect welder's body from welding spark and spatters	

TVET SSP does not secure copyright of these pictures

Leather gloves – used to protect hands during welding		Cotton gloves – used to protect hands from sharp edges of sheets and plates	

Importance of housekeeping and safe storage of tools and equipment

The main function of housekeeping is to ensure cleanliness, comfort, convenience, privacy, health and hygiene in a safe environment. It includes keeping work areas neat and orderly. All the tools and equipment must be stored properly.

Importance of making a check list

It ensures you get your daily, weekly and monthly tasks done on time, helps you keep track of projects on deadline and ensures you're organized throughout the day.

Video Links:

Extrusion machine process (Hindi): https://www.youtube.com/watch?v=tbsApGggYGA
Plastic Extrusion - Safety, Pre-Start and Start-Up Procedures: https://www.youtube.com/watch?v=2rzhevw2Ong
Plastic Extrusion - Operation, Shutdown and Maintenance Procedures: https://www.youtube.com/watch?v=Rf5DQR5qXxU
CLEANING PROCESS FOR EXTRUDER MACHINE: https://www.youtube.com/watch?v=Pvn108_P46w

PLASTIC PROCESSOR

Module-8

Learner Guide

National Vocational Certificate Level 2

Version 1 - September, 2018

Module 8: 072200913 Produce Blow Moulded Plastic Parts

Objective of the module: The aim of this module to provide skills and knowledge to operate blow moulding machine in accordance with the manufacturer's manual

Duration: 150 hours **Theory:** 30 hours **Practical:** 120 hours

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1: Interpret Work Order	**The trainee will be able to:** Obtain work order Verify production quantity available Ensure raw material available as per work order Ensure machine setting for production as per data sheet provided	i) Basic literacy skills • Be able to read instructions about product, quantity and raw material • Be able to identify rolling required to produce different components as per work order ii) Reporting procedure • Understanding the work order contents • Knowledge of units (Kg, inches, etc.) iii) Work order process • Understand the top-down stream of task assignment • Knowledge of what the work order represents • Who generates the work order? • Where can it be obtained from? iv) Material handling and storing procedure • Understanding where to obtain raw material for the required production quantity • How to handle raw material? v) Set machine parameters as per data sheet provided • Be able to input machine parameters as	Blow moulding machine Machine mould Air compressor Vacuum machine De-humidifier Chiller for cold water Utility documentation Service manual Operation manual Basic hand tools

		mentioned in work order or datasheet	
LU2: Perform production	**The trainee will be able to:** Set machine on auto-cycle mode as per SOP Perform periodic quality checks as per requirement	i) Machine operation in automatic mode • Be able to perform dry-run • Be able to perform semi-auto operation • Up on successfully obtaining required product, switching the machine to auto mode ii) Maintaining product quality as per specifications • Be able to measure components for identification of dimensional defects • Usage of measurement tools is critical: Vernier caliper, micrometer gauge, scale, etc. iii) Recognize different defects and their causes • Be able to visually identify commonly occurring defects, such as flashing, orange-peel, drooling, etc. • Gain knowledge of rectification of commonly occurring defects.	Blow moulding machine Machine mould Air compressor Vacuum machine De-humidifier Chiller for cold water Utility documentation Service manual Operation manual Basic hand tools
LU3: Perform follow up procedure for machine production	**The trainee will be able to:** Ensure product packed in assigned packaging Check feed level in hopper/bin, etc. Ensure machine lubrication as per requirement	i) Knowledge of product packaging • Understand different types of packaging, e.g.; flexible packaging, packing in cartons, etc. • How to pack final product? ii) Raw material input in moulding machine • Ensure consistent raw material feed into hopper/feeder	Blow moulding machine Machine mould Air compressor Vacuum machine De-humidifier Chiller for cold water Utility documentation

		• Be able to use overhead crane or moveable lifts/ladders • Understand the importance of cutting tools in opening raw material bags. • Concept of ‘clean slits’ using sharp tools to ensure particles of bag don’t get mixed in raw material iii) Lubrication requirements and procedure of machine • Understand the concept of lubricating moveable parts of machines • Carefully use mould lubricant sprays • Ensure spray cans are stored in a secure location after pre-shot application • Be able to identify different mould release agents as per raw material • Be able to provide first-hand feedback to maintenance department for periodic machine maintenance	Service manual Operation manual Basic hand tools
LU4: Submit production report	**The trainee will be able to:** Record production report as per given format (kg/nos, hours) Submit report to concerned department	i) Production report writing • Understand the importance of reporting accurate production quantity • Be able to fill-in relevant production reports • Be able to identify waste generated along with identification of machine downtime with reasons ii) Data sharing with relevant departments • Understanding the concept of producing accurate data and benefits of the same	Job card Production report format

		on a larger scale • Submission of production reports to production planning department or the supervisor for timely actions.	
LU5: Transport finished product to concerned department	**The trainee will be able to:** Place finished product in designated area Take approval of finished product from Quality Control Deliver relevant packaging documents to store personnel	i) Understand QC protocols • Understand and appreciate the importance of producing products as per specification • Be able to implement the first quality control protocol on machine to ensure elimination of defective products at sight ii) Inter-department co-ordination • Be able to co-ordinate with QC department with produced batches for relevant approvals iii) Be able to hand over final products to store • Familiarize with handing-over protocols and paperwork.	Reporting formats Job card Basic Hand Tools Medium of material transport

Examples and illustrations:

For further details, please look at: **Practical Guide to Blow Moulding Technology, Rapra Technology Ltd.**

Introduction

The basic process is common to all variations of the blow moulding method, which consists of three stages:

1. Melting and Plasticising – This is accomplished with either extrusion and/or injection moulding machine to produce the melt.

2. Plastic Formation – Through head and die or in an injection mould.

3. Blowing and Moulding – An auxiliary compressor provides air pressure and a clamp unit, which closes over a split mould that is operated with a hydraulic system.

The first step involves the production of a hot tube, known as a parison, a term derived from the glass industry. This may be produced, as indicated, by one of two methods, extrusion or injection. In the injection case it is referred to as preform. The heated parison or preform is placed between two halves of the blowing mould, which closes and clamps around it. The heated tube is blown against the cavity wall and the molten plastic or resin takes the shape of the mould while being cooled. This is illustrated in Figure 1.2. After the cooling stage the part is ejected from the mould. In the case of an extruded part it is necessary to remove the fl ash (excess plastic around the part) for further finishing.

Drilling, labelling or printing may be required in both methods. Moulding for high volume production parts often uses robots.

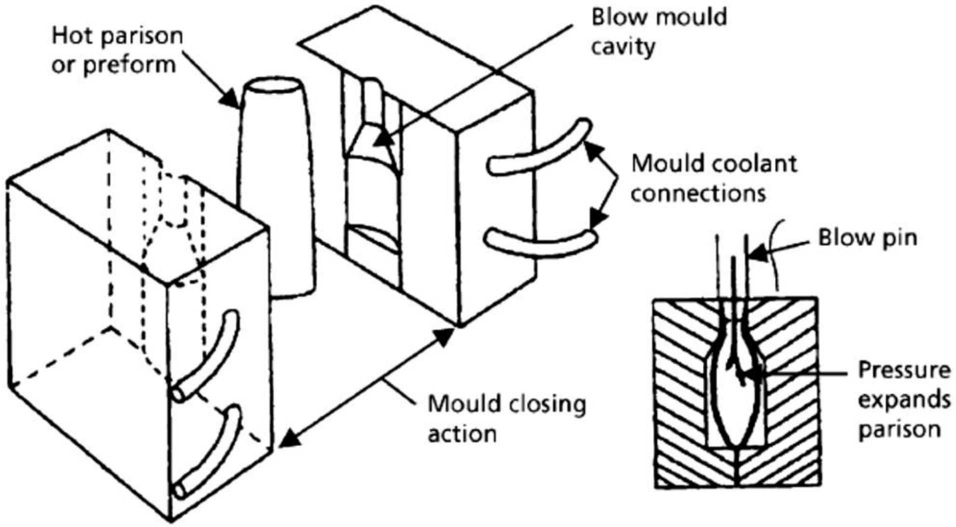
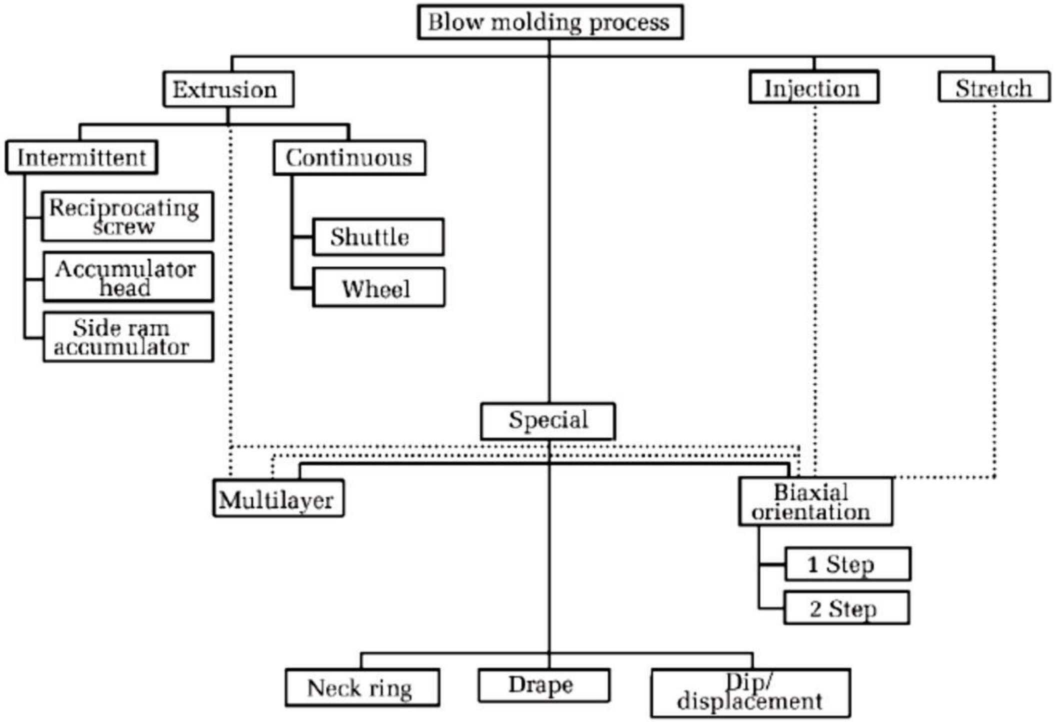


Figure 1.2 Basic blow moulding process

As indicated earlier blow moulding may use either extrusion or injection methods for processing. Figure below shows the breakdown of the subsidiary methods in each case and where they crossover in application.



Injection Blow Moulding

Injection blow moulding produces a parison with bottle neck and threads already formed to final dimensions. This process is used primarily for small pharmaceutical and personal product containers. The economics for such containers dictate multiple (up to ten) cavities - one set each for injection moulding and blow moulding. When tolerances in the neck and closure thread area are critical, injection blow moulding is applicable

to larger bottles. An example is pressurized carbonated beverage containers up to 2 liters. Another application is aerosol spray bottles, in which neck tolerances must provide sufficient thickness and taper to meet top load stresses from pressurized filling line equipment, and the closure thread (or lip) must conform to the twist cap (or valve seal). There is essentially no plastic waste or trim generated with the latest injection blow moulding machines, only improperly formed containers from start-up and occasional 'off-spec' parts from production are candidates for regrind.

Injection Blow Moulding Process

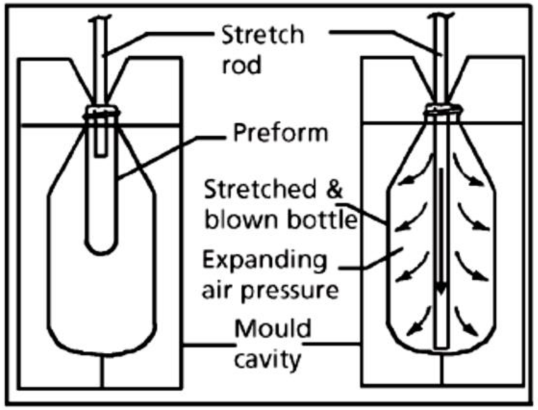
The injection moulding process produces a moulded parison called a preform. This method is preferred over extrusion blow moulding for making small parts that require high production volumes and closer quality dimensions. Injection blow moulding consists of injecting a thermoplastic material into a cavity and around a core rod producing a hollow test tube like shape (preform). The moulded preform still on the core rod is transferred to the blow mould. The mould is clamped around the preform and air is blown to shape of the cavity. The preform is injected onto a support pin or core, which forms a neck with threads to their required dimensions. The preform is then blown against the cavity wall to its final shape.

Advantages of injection blow moulding are:
- No scrap or flash to trim and reclaim
- High quality neck finish and details
- No process weight variation
- Offers lowest part cost for high-volume bottles 37 grams (12 oz) or less.

Disadvantages of injection blow moulding are:
- Tooling costs are higher than extrusion blow moulding
- Bottle sizes and shapes are limited to an ovality ratio of 2:1 and a blow-up ratio of no greater than 3:1
- Offset necks are possible but not handles.

Stretch Blow Moulding

Stretch blow moulding became known in the blow moulding industry with the introduction of the soft drink bottle. Bi-axial stretch blow moulding applies to the method of producing a plastic container from a preform that is stretched in the hoop direction and the axial direction when the preform is blown into its final shape. Stretch blow moulding consists of conditioning (heating) a moulded and cooled preform to a specific temperature. The preform is closed in the blowing mould and is stretched in length and diameter (See figure below).



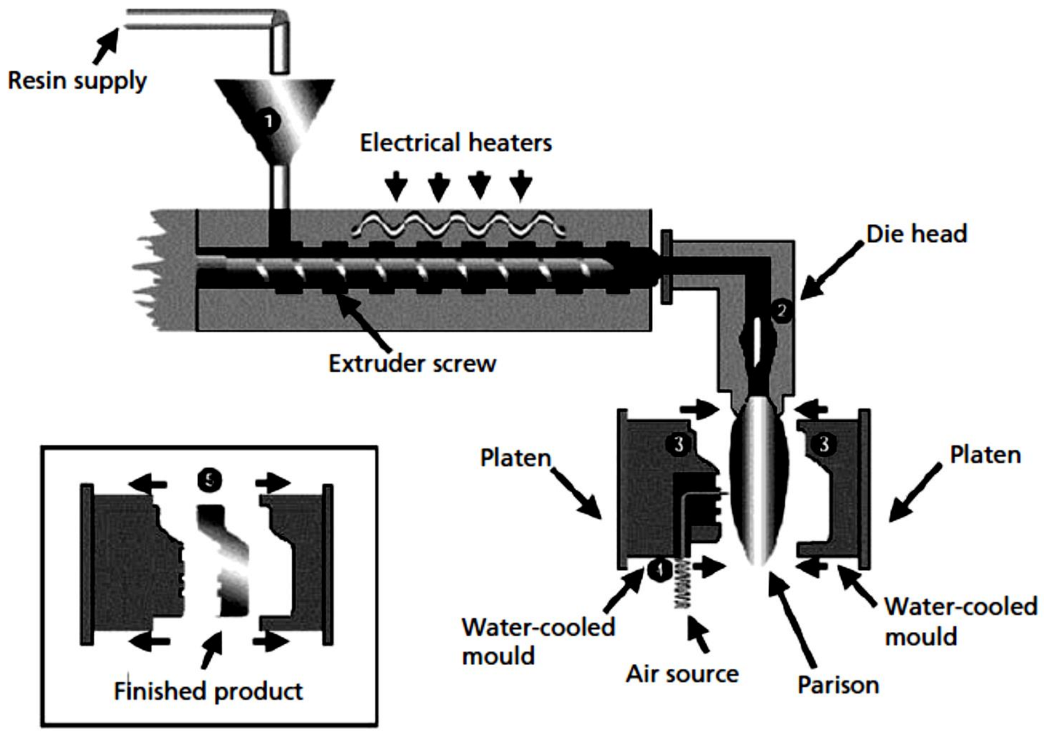
A temperature conditioned preform is inserted into the blowmould cavity, then is rapidly stretched. Often a rod is used to stretch the preform in the axial direction with air pressure to stretch the preform in the radial direction.

Extrusion Blow Moulding

In contrast to injection blow moulding, all areas of the extruded (free) parison, with the exception of the pinch off, undergo forming during the blowing step. This includes the closure threads on bottles and, in some cases, handles and support lugs. Containers produced by extrusion blow

moulding must meet minimum stiffness requirements to undergo filling on automated lines and to avoid, or limit, unsightly bulging under weight of their contents, both alone or when stacked. They must also withstand normal impacts of handling, transport and accidental dropping. Such

impact must be absorbed by container walls, weld lines (pinch-off and handle areas), and screw cap closure threads, often under extremes of temperature. HDPE provides most of the requirements noted previously at low cost and is also chemically inert to many fluids used in personal products, food products, and household and industrial chemicals.



Extrusion Blow Moulding Process

Extrusion is the process of applying heat and pressure to melt the resin and force it through an accurately dimensioned die to produce the desired shape. For blowing purposes this is a shape from which the parison is cut. There are several main parts to an extrusion blow moulding machine,

which are: screw, barrel, hopper, feed section, compression section, metering section, screen pack, breaker plates, adapter, die head, core, mandrel, and die tip.

Co-Extrusion Blow Moulding

This term refers to products made with several layers in their wall structure and to the method of making them. These layers may be different materials, coloured or not coloured, recycled or virgin. This process makes it possible to combine materials of various properties to create a final product to meet the requirements of a particular application.

Advantages of extrusion blow moulding are:
- Natural process for containers and hollow parts
- Preferred process for high volume containers

Disadvantages of extrusion blow moulding are:
- Uneven wall thicknesses
- Close dimensional tolerances are difficult to achieve
- Relatively low accuracy of surface finishing details.

Start-Up Preparations

An understanding of the settings is needed before starting up a blow moulding machine. Obtain advice from someone who is very familiar with the equipment, or better yet, consult the written procedures. A general procedure is:
- Turn on the main power switches and then select or set the temperatures.
- Ensure that the cooling water is on and check to see that it is flowing through the feed throat.
- Preheat the hydraulic oil to its correct operating temperature.

This may be done either by pumping the oil back into the tank or by using a preheater fitted for this purpose. Once the machine has reached the required temperature, it should be allowed to settle down before any material is introduced into the barrel. The settling-in (equilibration) time, sometimes called 'soak' time, is the time needed for the barrel, screw, breaker plate, and die or mould temperatures to stabilize close to the temperature set points. The equilibration or soak time will depend on the size and type of machine. It may take 20 minutes for a small machine and it may take several hours for a larger machine. This time should be used to prepare for the production run.

Other start-up steps include:
- Check the nozzle/die and moulds to see if they are clean and operational.
- Review the production order for colour, quantity, and other requirements.
- Check for necessary tools and equipment, and be sure they are in place and working properly.
- Make sure that all auxiliary equipment is clean and operational, to include hopper loaders, conveyors, grinders, vacuum pumps, and leak testers.

Melt Temperature

Two methods are commonly used to measure melt temperature in a blow moulding machine:

- Extrusion or injection of the material onto a suitable surface, then measuring the temperature of the plastic mass with a thermocouple probe.
- Direct reading by a thermocouple that is placed in the barrel and is in direct contact with the melt.

When the temperature of the melt is measured with a probe, care should be taken during the measurement to ensure that the purging of hot plastic does not cause an accident. As has been mentioned previously, molten material will cause serious burns because it is very hot and it adheres to the skin and is very difficult to remove. Burns are a common injury in moulding operations, so long sleeves, gloves and face shields should be worn when handling hot material or where there is danger of being splashed with hot plastic melt, particularly during start-up or purging. As with other situations requiring personal protective equipment, the plant's requirements must be followed.

Warming up an Empty Machine

The machine's warm-up cycle should be programmed so that thermal overshoot does not occur, and heating times are kept reasonably short. Once the machine is at the set temperature, it should be allowed to equilibrate ('heat soak') before material is introduced into the barrel. It is advisable to keep this time as short as possible so that any resin left in the barrel after purging does not degrade. Check the machine for correct temperatures by briefly rotating (jogging or 'inching') the screw. If the screw requires excessively high motor currents or will not rotate, then allow the machine to equilibrate further. The set-up sheets should show the normal heat soak time. Before starting the machine, be sure that the set conditions are satisfactory by purging a few pounds of resin out of the die (or nozzle) at slow screw speeds. Check the melt temperature with a melt probe and also check the general appearance of the melt. It should be smooth and free of dark specks, streaks, bubbles, or other signs of degradation. If no material is delivered when the screw is turned, check to see that plastic feed is available to the screw, check for faulty heater bands, and find out if the feed has 'bridged' (stuck together) in the hopper. Checking for bridging or material blockage in the machine feed throat requires caution and the immediate attention and expertise of trained personnel wearing the appropriate safety equipment. This is because of the potential for serious personal injury from the hot gases, and degraded and overheated plastic that may spray violently back through the hopper.

Warming up a Full Machine

When material is in the barrel or die head, the machine is said to be full. A full, cold machine might result when there is a power failure or when the machine is deliberately shut down because of deterioration of the material by oxidation or depolymerisation. The machine must be heated in a safe way because decomposition produces gases under pressure and can cause serious accidents. To warm a cold machine, set all temperatures just below the melting temperatures of the material, for example, at 135 ºC for low-density polyethylene (LDPE). Allow the machine to reach and equilibrate at these temperatures, and then raise the temperature of the die (nozzle) to the process set point. To reduce the potential for dangerous pressure build-up in the barrel, wait for a period of time to allow the plastic in the die or nozzle to melt, and then raise the other barrel temperatures to the set point. Allow the machine to equilibrate to these temperatures before beginning to purge.

Initial Operation and Purging

When the machine is fully up to temperature, put a small amount of material in the hopper, make sure the hopper lid is in position and the hopper gate is open, and start the screw at 10-15 rpm. Do not allow the screw to turn in an empty machine, because this can damage the barrel and screw. Check to see that the set process conditions are correct by running for a minute or so on an extruder or by running a few purge cycles on an injection machine. A machine with a grooved barrel may require careful hand feeding of material by trained personnel, because it is easy to over-feed the machine.

After a short period of operation, check the melt temperature with a melt probe, and also the general appearance of the melt. Dispose of the hot, sticky plastic melt in a safe way once being satisfied that the material is feeding well, and the melt looks satisfactory. On an extruder, also check the drive motor current. It should be with the normal start-up range. If it is too high, there is probably unmelted material in the barrel. If it is too low, there may be feeding problems. On an injection moulding machine, material should fl ow freely from the nozzle. If it doesn't, the nozzle may be blocked by unmelted plastic. Do not attempt to clear a blockage by turning the screw or injecting under high pressure. If all is well, fill the hopper to the normal level for running. Check to see that the monitoring equipment is working, and in extrusion blow moulding, when material starts to extrude from the die, turn on the screw cooling if it is required.

Commencing Moulding – Manual Operation

When purging is complete and satisfactory melt is being produced, moulding may begin. The moulding process usually begins with manual operation, in which the operator initiates each part of the moulding cycle by pushing buttons according to the operation sequence. When the mould is closed, clamping pressure should be checked. To begin extrusion blow moulding, produce a parison and check its temperature and appearance. The parison must be long enough to reach the bottom of the mould for pinch-off. Start moulding, and adjust conditions and settings as needed to obtain a satisfactory part. Increase screw rpm gradually until it reaches the normal operating speed, while constantly checking the parts. A periodic check should be made to ensure that the hopper has enough material and that the melt is not leaking or weeping from around the nozzle/die/adaptor areas. Product quality should be closely watched to see that parts are free from froth or unmelted resin particles, and when the cycle is stable and the parts are good, production can begin. Note: If for some reason a different material was used for purging, it must be removed from the barrel according to procedures required by the material manufacturer, before moulding begins.

Commencing Moulding – Automatic Operation

Automatic operation is only started after satisfactory melt is made, after the purging procedure, and after the machine settings have been established based on experience or process records, or as determined from the manual operating conditions if this is a new product. Commence moulding on an automatic, or semi-automatic cycle (in which the operator opens and closes the safety gate to start the cycle) using pre-determined cycle times. These may be calculated, based on experience, or determined from the manual operating conditions. Gradually adjust conditions until product of the required quality is obtained at an optimum rate. After each adjustment, allow the machine to settle down for a reasonable time (approximately six cycles) before making further adjustments. With intermittent extrusion machines, adjust the cooling time until the moulding can be ejected without distortion. Screw start delays and screw speed (rpm) can be adjusted to fill this time.

Changing Conditions and Dimension Verification

Any changes must be well thought out in advance and should be made gradually. As an example, any increase in screw rpm may cause not only an increase in output but also an increase in temperature. Changes must be made one at a time. The machine must be allowed to settle down and the effect of the change noted, otherwise no one would know what is going on. Frequent or incorrect changes in the process can cause time to be lost and large amounts of scrap to be made.

Recording Production Conditions

The object of moulding is to make mouldings (parts) to the required specification (quality) and at the quoted cost. To do this, it is essential to keep accurate records. On many machines, data are recorded by computer. This data should be preserved. Critical parts, such as those for medical applications, have bar codes and the data are stored. When this is not possible, an appropriate record sheet should be completed initially and then periodically updated throughout the run. It is also good practice to keep sample mouldings. Logs of key events - the reasons, and observations are also useful.

Safety in Normal Machine Operation

Once the machine has settled in, controls and heaters should operate between an upper and a lower limit. This allows parts to be successfully made to specification. Most machines have process controls that warn when a condition is moving outside of a limit. The operator should advise the process technician so that the cause can be found quickly, and the problem corrected both to minimize the production of bad parts and to reduce the likelihood of hazardous overheating or excessive melt pressure.

Safety Considerations

Machines that are set to run automatically usually eject the parts onto a conveyor for finishing operations, so that the operator does not have to reach into the press. For some large industrial parts, an automated picker or robot picks the part from the press and delivers it to the finishing operations. Many times, particularly on small runs and when using a semi-automatic press cycle, the operator removes the parts by reaching into the press and removing the part from the mould. Redundant safety switches and devices must be in place and working to prevent the press from inadvertently closing on the operator. In all cases, the operator must wear gloves ('cooled' plastic parts are extremely hot to the touch when ejected), safety glasses, and usually earplugs. In plants with several different types of equipment running, the noise generated could damage hearing if protection is not worn. Entrances into plant areas that require sight, hearing, and sometimes helmet protection are usually marked with signs at the entrance indicating the type of safety protection required before entering the area.

Table 7.1 Safety standards for extrusion blow moulding machines	
Clause	Safety Caution
Operator's Gate	Operator's gate, window and mounting hardware to keep the operator away from hazards associated with moving parts and hot parison(s) including electric, hydraulic and pneumatic interlocks.
Power Operated Gates	A. Leading edges mounted with pressure sensitive switches to stop or open the gate. B. Closure of the gate shall not initiate cycle start.
Operator's Gate Electrical Interlock with Monitoring	To prevent all clamp, carriage, calibration or take-out motions when the gate is open.
Operator's Gate Hydraulic and Pneumatic Interlock with Monitoring	To prevent hydraulic or pneumatic powered motions when the gate is open including monitoring and alarm.
Emergency Stop Button	At least one emergency button to be provided near the point of operation.
Reset	Resetting a safety interlock shall not directly initiate a cycle.
Rear Guard	A fixed guard for the moulding area opposite the point of operation.
Top Guard	A fixed guard to prevent reaching over another gate or guard.
Additional Safety Requirement for Large Machines only	Presence sensing device; mechanical latch; double acknowledge system.
Emergency Stop	At least one emergency stop button in a walk-in mould area.
Blow Air Release	Monitoring of blow air to prevent mould opening under full blow pressure.
Part Discharge Opening	Guarding required near conveyor openings.
Windows to Moulding Area	All windows to conform to ANSI Z97.1 [2].
Guards	Fixed guards (or movable guards with interlocks) at all other hazardous points.
Guarded Feed Throat Opening	Guarding where access to the rotating feed screw is a hazard.
Extruder Barrel Covers	Cover or barrier to prevent inadvertent contact with high voltage or high temperature.
Window	All windows to conform ANSI Z97.1 [2].
Safety Signs	Safety sign kit to current standard.

Table 7.2 Health and Safety Executive (HSE)	
Hazard	**Safeguard**
Dangerous moving parts in the mould area	Guards interlocking with the drive(s) (pneumatic, hydraulic or electrical) for the dangerous parts and sufficient fixed guards to complete the enclosure. The interlocking system should be dual channel and both channels should be monitored to prevent any further dangerous movement if a fault is detected.
Other dangerous moving parts	If not protected by the guard systems specified for the mould area, use: □ Fixed guards; or □ Distance guards positioned to take account of safety distances to prevent the operator reaching the danger zone; or □ Single-channel interlocked guards, monitored to prevent any further dangerous movement if a fault is detected. And for large machines a monitored, person sensing safety device should be installed, for example: □ A pressure-sensitive mat which extends between the mould; or □ An electro-sensitive device; or □ A mechanical latch which prevents involuntary guard closure and which can only be released from outside the mould area. Having triggered such a device, it should be necessary to do one of the following before initiating another cycle: □ Reset the safety devices □ Close the guards; and □ Actuate an enabling device to confirm the danger area is clear. Reset and enabling device actuation positions should provide a clear view of the danger areas. It should not be possible to actuate the enabling device from the danger area. Accessible emergency stops should be fitted on both sides of the mould. On large rotary machines they should be placed at intervals of 2 m or less inside the danger area.
Dangerous moving parts which can be reached through the delivery aperture	If not protected by the guarding systems specified for the mould area, use □ Fixed guards; or □ Distance guards positioned to take account of safety distances to prevent the operator reaching the danger zone; or □ Interlocked product delivery systems, monitored to prevent any further dangerous movement if a fault is detected. Such product delivery systems would include: – Single-channel interlocked guards, consisting of outward opening doors which are activated to let articles out but otherwise act as an interlocked guard; or – Two electro-sensitive sensing units arranged so they let articles out but prevent access; or – Other equally effective means, for example, pressure-sensitive mats built into the delivery system or scanning devices.
Power-operated guards	Either: □ Sensitive edges (fitted on both sides of the guard) which arrests or reverses guard closure; or □ A reduced-pressure closing system.

Shutting Down

A great deal of money can be saved by using the proper shutdown procedures. For example, if the material could be prevented from degrading or burning, a large amount of purging could be eliminated. Additional money would be saved if a complete machine shut down and cleanout were

unnecessary, and start-up would certainly be easier.

Temporary Stops

It is a good idea during a temporary stop to periodically purge the cylinder or barrel by passing material through the machine and/or making air shots. If the plastic material starts to look a bit discoloured, increase the frequency of purging. When a minor machine repair is required,

set the heaters on the plasticising cylinder to low values (about 150 °C) to minimise thermal degradation.

Overnight Stops

For overnight stops with thermally stable plastics such as polyethylene (PE) at blow moulding temperatures, close the gate at the base of the feed hopper and turn off the barrel heaters. With the nozzle/die heat on, purge the barrel clean by pumping the screw dry. As soon as nothing more comes from the die/nozzle, stop the screw drive and set the barrel cooling (if equipped) to maximum. When the machine is cool, shut everything off.

High Temperature Work

When extrusion blow moulding at very high temperatures (with a material that does not melt until 265 °C) oxidation and material removal can be a problem. Depending on the material type, it may be purged with a 'wet' high-density polyethylene (HDPE) (approximately 2% of water is added to the HDPE before use). The water reduces the viscosity. In condensation polymers such as polyamide and polycarbonate (PC), the water further reduces the viscosity because it causes depolymerisation. Water also acts as a lubricant with polyamide. To purge, shut the gate at the base of the feed hopper and run the machine until it is free of high temperature material. With an accumulator extrusion blow moulding machine, open the die gap and keep the machine and cylinder temperatures at a high value (270 °C); run 'wet' HDPE through the system and fi ll the accumulator. The melt will foam and there will be crackling and spitting noises. Keep purging, reduce temperatures to 215 °C, and open the die gap fully. Introduce dry HDPE and then purge the barrel clean by pumping the screw dry. Turn off the heaters when no more material comes through the die, set barrel cooling to the maximum, and then when machine is cool, turn everything off. Note: a 7 kg accumulator machine may require 90 kg of 'wet' HDPE and 45 kg of dry HDPE to properly purge out a high temperature resin.

Heat-Sensitive Materials

A major problem with heat-sensitive materials is decomposition ('burning') of the plastic in the machine. The results may be discoloration and rejection of the moulded part. When decomposition occurs, a complete shutdown is usually necessary, although it may be possible to purge the heat sensitive material with another, more heat stable material to clean the machine of contaminated resin.

Purge Materials

Purge compounds are materials used to clean the cylinder (barrel), and may be purchased for this purpose. Instead of a commercial purge compound, a resin such as LDPE may also be introduced into the barrel to push out a thermally unstable material such as polyvinylchloride (PVC). Many purge materials do not melt or flow as ordinary resins do, so to prevent blockage it is advisable to remove the die assembly before purging. The die should be thoroughly cleaned. Once the purge compound has come through, the shutdown procedure should be followed.

When PE is used as a purge, it may be stored in a small hopper alongside the main hopper, from which it can be introduced rapidly into the machine by a power-operated valve. When PVC degrades, the rapid introduction of purge material is often necessary. With a stoppage of more than 0.5 of an hour when running PVC, the barrel should be purged with PE. Stripping, cleaning and purging should be done when re-starting a PVC run after a power failure or some other unplanned shutdown.

Shutting Down an Injection Blow Moulding Machine

For injection blow moulding machines, retract the barrel away from the parison meld's sprue bushing. Run the screw dry by allowing the screw to turn just until no more melt exits the nozzle. Do not allow the screw to continue turning, because it may cause unnecessary and possibly damaging wear to the screw and barrel. Follow with a small amount of purge material, the type of which will depend on the type of material that had just been run. In the case of PE, purging is not usually necessary. It is generally safe to simply leave the screw in the forward position and turn off the barrel heats. Other materials may require different purging materials and procedures. For glycol-modified polyethylene terephthalate (PETG) (a material used to make soda bottles and many other types of beverage bottles), polystyrene (PS), low melt index HDPE, or cast acrylic are the typical purging materials. PC are generally purged with a low melt index HDPE or a cast acrylic resin. Polyetherimide resins, which are moulded at very high temperatures (in the 370-400 °C range), are purged in either a one-step or a two-step process. In the one-step process, extrusion grade HDPE (with a low melt index, in the range of 0.3 to 0.35 g/10 min) is run through the machine after as much of the resin as possible has been pumped out. The barrel temperatures are reset to the normal melt processing range for HDPE once the HDPE begins to exit the barrel. HPDE is run through the machine until the purge exiting the nozzle is clear and clean. The screw is left in its forward position inside the barrel, the heaters are turned off, and the machine is shut down. In the two-step process, a material that is intermediate in melt temperature between the high temperature material and the lower melt temperature purge material is used. For example, a PC, which normally processes in the 293 to 310 °C range may serve as an intermediate temperature material that is used for an initial purge. Once the PC begins to exit the nozzle, the barrel temperatures can be reduced to that for moulding PC. The next step is to purge the PC; either with a low melt index HDPE or a cast acrylic resin. Acrylics and PS should not be used as purge materials for resins that are processed at high temperatures, that is, at temperatures above 310 °C. Chemical purging compounds which are designed to work with certain families of materials are often used, usually in conjunction with a plastic purge material. Always check with your supervisor or team leader for the material manufacturer's recommendations regarding purging materials and the safe procedures for their use. Note: When purging materials from the injection barrel, always wear a full face safety purge shield, always move the barrel (injection carriage) to a rearward position, never inject or purge through an open mould, and always make sure the purge safety guard is functioning and closed to avoid a serious burn accident.

Tables 8.1, 8.2 and 8.3 show some causes and effects of problems with finished containers, forming, and parisons.

Table 8.1 Finished container

Observation	Action: Machine ***Running***	Action: Machine ***Stopped***
1. Rough surface	Check for moisture or condensation in the mould, blast with air hose and raise coolant temperature.	Additional mould venting.
2. Excessive shrinkage	Increase blow cycle. Lower melt temperature.	Check die-mandrel concentricity.
3. Warpage	Check mould cooling. Increase blow cycle. Lower melt temperature.	Same as 2
4. Weld-line breaks	Same as 3	Same as 2 Increase pinch-off areas.
5. Thin wall at parting line	Increase mould clamp pressure.	Inspect mould alignment. Inspect mould venting.

Table 8.2 Forming

Observation	Action: Machine ***Running***	Action: Machine ***Stopped***
1. Parison blow out	Lower melt temperature. Reduce blow pressure.	Check mould for 'hot spots'. Check parison alignment. Check for contamination inside tooling.
2. Container sticking	Lower melt temperature. Lower mould coolant temperature.	Check mould design.

Table 8.3 Parison

Observation	Action: Machine ***Running***	Action: Machine ***Stopped***
1. Excessive stretch	Lower melt temperature. Lower die temperature. Increase extrusion rate.	
2. Rough surface	Reduce extrusion rate. Raise temperature.	Clean die tip. Clean tooling. Change tooling.
3. Uneven parison	Reduce extrusion rate.	Align die and mandrel. Inspect for contamination. Inspect for heater band outage.
4. Fisheyes (bubbles)	Lower melt temperature. Lower feed section temperature.	Check resin for moisture and for contamination.
5. Streaks	Raise extrusion back pressure.	Inspect tooling for contamination or damage. Check tooling design.
6. Curl	Increase extrusion rate.	Check tooling temperature profile. Check tooling alignment.
7. Wrinkles	Lower melt temperature.	Check tooling temperature profile. Check tooling alignment.

Importance of using PPEs

PPE is equipment that will protect workers against health or safety risks on the job. The purpose is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

PPEs:

Name & Usage	Picture of PPE	Name & Usage	Picture of PPE
Safety goggles – used to protect eyes from flying particles (chips, sparks etc.)		Safety shoes – used to protect feet from spatters of welding and impact of other falling objects	
Face shield - used to protect face from welding sparks, radiations, arc and spatters		Face mask – used to protect from inhaling fumes, dangerous gases etc.	
Hard cap – used to protect the head from injury due to falling objects		Leather Apron – used to protect welder's body from welding spark and spatters	
Leather gloves – used to protect hands during welding		Cotton gloves – used to protect hands from sharp edges of sheets and plates	

Importance of housekeeping and safe storage of tools and equipment

The main function of housekeeping is to ensure cleanliness, comfort, convenience, privacy, health and hygiene in a safe environment. It includes keeping work areas neat and orderly. All the tools and equipment must be stored properly.

Importance of making a check list

It ensures you get your daily, weekly and monthly tasks done on time, helps you keep track of projects on deadline and ensures you're organized throughout the day.

Video Links:

What Is blow molding process?? Applications, Types, Advantages & Disadvantages: https://www.youtube.com/watch?v=H04DIgWN3kQ

Extrusion Blow Molding - Lesson 3 - Extrusion Blow Molding Operating Controls: https://www.youtube.com/watch?v=YWzaZYHXS9s

Blow molding – IIT Roorkee: https://www.youtube.com/watch?v=LHquzUSOX0E

Module 9: 072200914 Produce Compression Moulded Plastic Parts

Objective of the module: The aim of this module is to provide skills and knowledge to operate compression moulding machine in accordance with the manufacturer's manual

Duration: 150 hours **Theory:** 30 hours **Practical:** 120 hours

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1: Interpret Work Order	**The trainee will be able to:** Obtain work order Verify production quantity available Ensure raw material available as per work order Ensure machine setting for	i) Basic literacy skills • Be able to read instructions about product, quantity and raw material • Be able to identify rolling required to produce different components as per work order ii) Reporting procedure	Compression mounding machine & mould Weighing scale Plastic raw material Product samples Machine manual

	production as per data sheet provided	• Understanding the work order contents • Knowledge of units (Kg, inches, etc.) iii) Work order process • Understand the top-down stream of task assignment • Knowledge of what the work order represents • Who generates the work order? • Where can it be obtained from? iv) Material handling and storing procedure • Understanding where to obtain raw material for the required production quantity • How to handle raw material? v) Set machine parameters as per data sheet provided • Be able to input machine parameters as mentioned in work order or datasheet	Job card
LU2: Perform production	**The trainee will be able to:** Start machine on auto-cycle mode as per operation manual Perform periodic quality check as per requirement	i) Machine operation in automatic mode • Be able to perform dry-run • Be able to perform semi-auto operation • Up on successfully obtaining required product, switching the machine to auto mode ii) Maintaining product quality as per specifications • Be able to measure components for identification of dimensional defects • Usage of measurement tools is critical: Vernier caliper, micrometer gauge, scale, etc.	Compression mounding machine & mould Weighing scale Plastic raw material Product samples Machine manual Job card

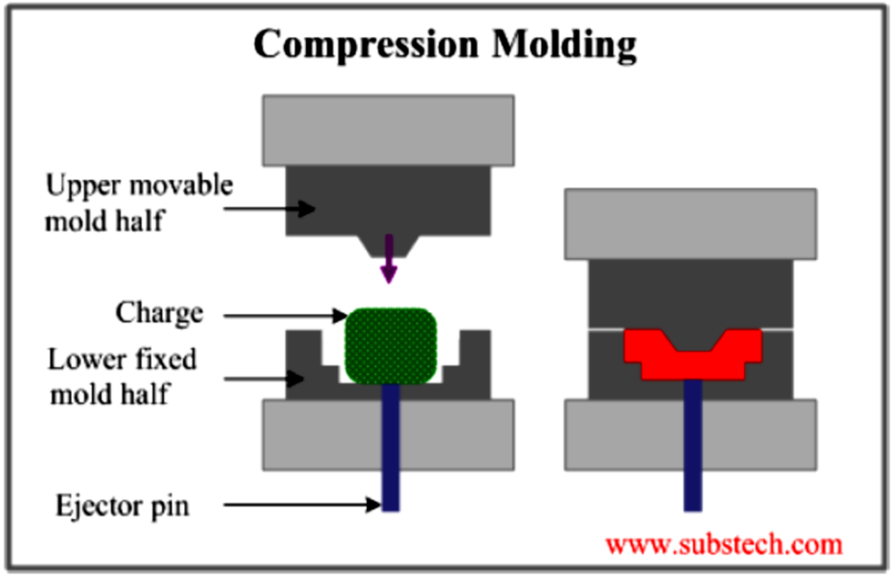
		iii) Recognize different defects and their causes • Be able to visually identify commonly occurring defects, such as flashing, pin-holes, short-shots, etc. • Gain knowledge of rectification of commonly occurring defects.	
LU3: Perform follow-up procedure for machine production	**The trainee will be able to:** Ensure product packed in assigned packaging Check feed level in hopper/bin as per requirement Ensure machine lubrication as per requirement	i) Knowledge of product packaging • Understand different types of packaging, e.g.; flexible packaging, packing in cartons, etc. • How to pack final product? ii) Raw material input in moulding machine • Ensure consistent raw material feed into hopper/feeder • Be able to use overhead crane or moveable lifts/ladders • Understand the importance of cutting tools in opening raw material bags. • Concept of 'clean slits' using sharp tools to ensure particles of bag don't get mixed in raw material iii) Lubrication requirements and procedure of machine • Understand the concept of lubricating moveable parts of machines • Carefully use mould lubricant sprays • Ensure spray cans are stored in a secure location after pre-shot application	Compression mounding machine & mould Weighing scale Plastic raw material Product samples Machine manual Job card

		• Be able to identify different mould release agents as per raw material • Be able to provide first-hand feedback to maintenance department for periodic machine maintenance	
LU4: Submit production report	**The trainee will be able to:** Record production report as per given format (kg/nos, hours) Submit report to concerned department	i) Production report writing • Understand the importance of reporting accurate production quantity • Be able to fill-in relevant production reports • Be able to identify waste generated along with identification of machine downtime with reasons ii) Data sharing with relevant departments • Understanding the concept of producing accurate data and benefits of the same on a larger scale • Submission of production reports to production planning department or the supervisor for timely actions.	Job card Production report format
LU5: Transport finish product to concerned department	**The trainee will be able to:** Place finished product in designated area Take approval of finished product from Quality Control Deliver relevant packaging documents to store personnel	i) Understand QC protocols • Understand and appreciate the importance of producing products as per specification • Be able to implement the first quality control protocol on machine to ensure elimination of defective products at sight ii) Inter-department co-ordination • Be able to co-ordinate with QC	Reporting formats Job card Basic Hand Tools Medium of material transport

		department with produced batches for relevant approvals iii) Be able to hand over final products to store • Familiarize with handing-over protocols and paperwork.	

Examples and illustrations:

Introduction:



Compression molding is widely used in the automotive industry to produce parts that are large, thin, lightweight, strong, and stiff. It is also used in the household goods and electrical industries. Compression molded parts are formed by squeezing a glass fiber reinforced charge inside a mold cavity, as depicted in Fig. 7.25. The matrix can be either a thermoset or thermoplastic. The most common matrix used to manufacture compression molded articles is unsaturated polyester sheet reinforced with glass fibers, known as sheet molding compound (SMC). The 25 mm long reinforcing fibers are randomly oriented in the plane of the sheet and make up for 20−30% of the molding compound's volume fraction. A schematic diagram of an SMC production line is depicted in Fig. 7.26. When producing SMC, the chopped glass fibers are sandwiched between two carrier films previously coated with unsaturated polyester-filler matrix. A fiber reinforced thermoplastic charge is often called a glass mat reinforced thermoplastic (GMT) charge. The most common GMT matrix is polypropylene. During processing of thermoset charges, the SMC blank is cut from a preformed roll and is placed between heated cavity surfaces. Generally, the mold is charged with 1 to 4 layers of SMC, each layer about 3 mm thick, which initially cover about half the mold cavity's surface. During molding, the initially randomly oriented glass fibers orient, leading to anisotropic properties in the finished product. When processing GMT charges, the preforms are cut and heated between radiative heaters. Once heated, they are placed inside a cooled mold that rapidly closes and squeezes the charges before they cool and solidify.

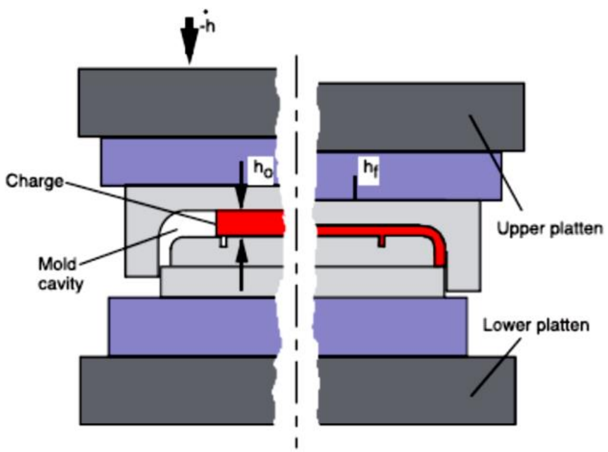


Figure 7.25 Compression molding process (h_0 = charge thickness, h_f = part thickness and $\dot{h}$ = closing speed)

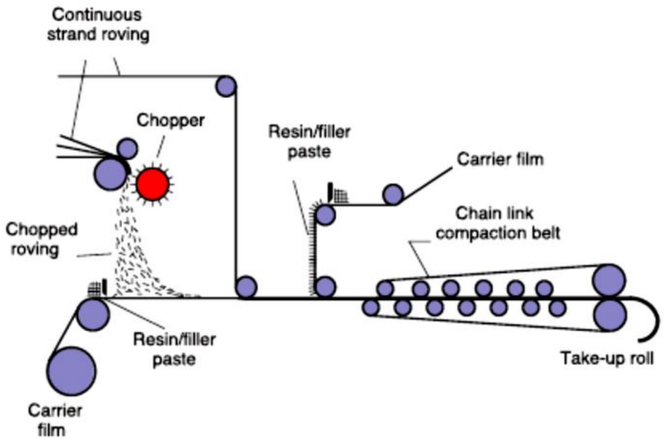


Figure 7.26 SMC production line

One of the main advantages of the compression molding process is the low fiber attrition during processing.Here, relatively long fibers can flow in themelt without the fiber damage commonly seen during plastication and cavity filling in injection molding. An alternate process is injection-compression molding. Here, a charge is injected through a large gate followed by a compression cycle. The material used in the injection compression molding process is called bulk molding compound (BMC), which is reinforced with shorter fibers, generally 10 mm long, with an unsaturated polyester matrix. The main benefit of injection compression molding over compression molding is automation. The combination of injection and compression molding leads to a lower degrees of fiber orientation and fiber attrition compared to injection molding. As in any polymer process, in compression molding there is a direct relationship between deformation and final orientation in the part. Figure 7.27 depicts the fiber orientation distribution within a plate where the initial charge coverage was 33%. Such distribution functions are very common in compression or transfer molding and lead to high degrees of anisotropy throughout a product. To illustrate the effect of fiber orientation on material properties of the final part, Fig. 7.28 shows how the deformation and resulting orientation from 33, 50, 66 and 100% mold coverage affects the stiffness of the plate. Similar to injection molding, there are commercially available codes that can be used to predict mold filling, fiber orientation, and warpage of compression molded parts. To predict fiber orientation in realistic parts, the Folgar–Tucker model has been implemented into commercially available compression mold filling simulation programs. The predicted fiber orientation distribution field for a compression molded automotive fender is shown in Fig. 7.29. To calculate the residual stress development during the manufacturing process and shrinkage and warpage of the finished product, commercially available programs use models where the heat transfer equation is coupled to the stress–strain analysis through constitutive equations. Figure 7.30 compares the mold geometry with the part geometry for the truck fender shown in Fig. 7.29 after mold removal and cooling, computed using numerical models.

High degrees of fiber orientation are common in compression molded parts

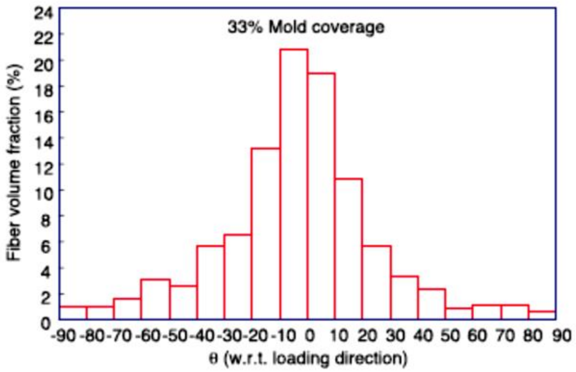


Figure 7.27 Measured fiber orientation distribution histogram in a plate with 33 % initial mold coverage and extensional flow during mold filling

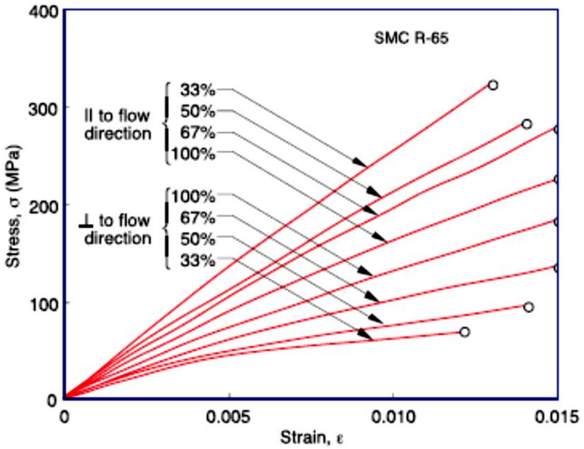


Figure 7.28 Stress–strain curves of 65 % glass by volume SMC for various degrees of deformation

Fiber orientation results in parts with large variations in thermomechanical properties

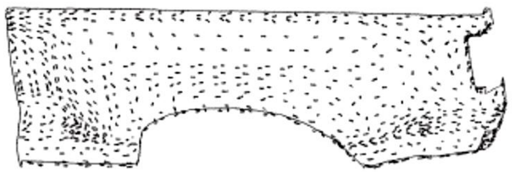
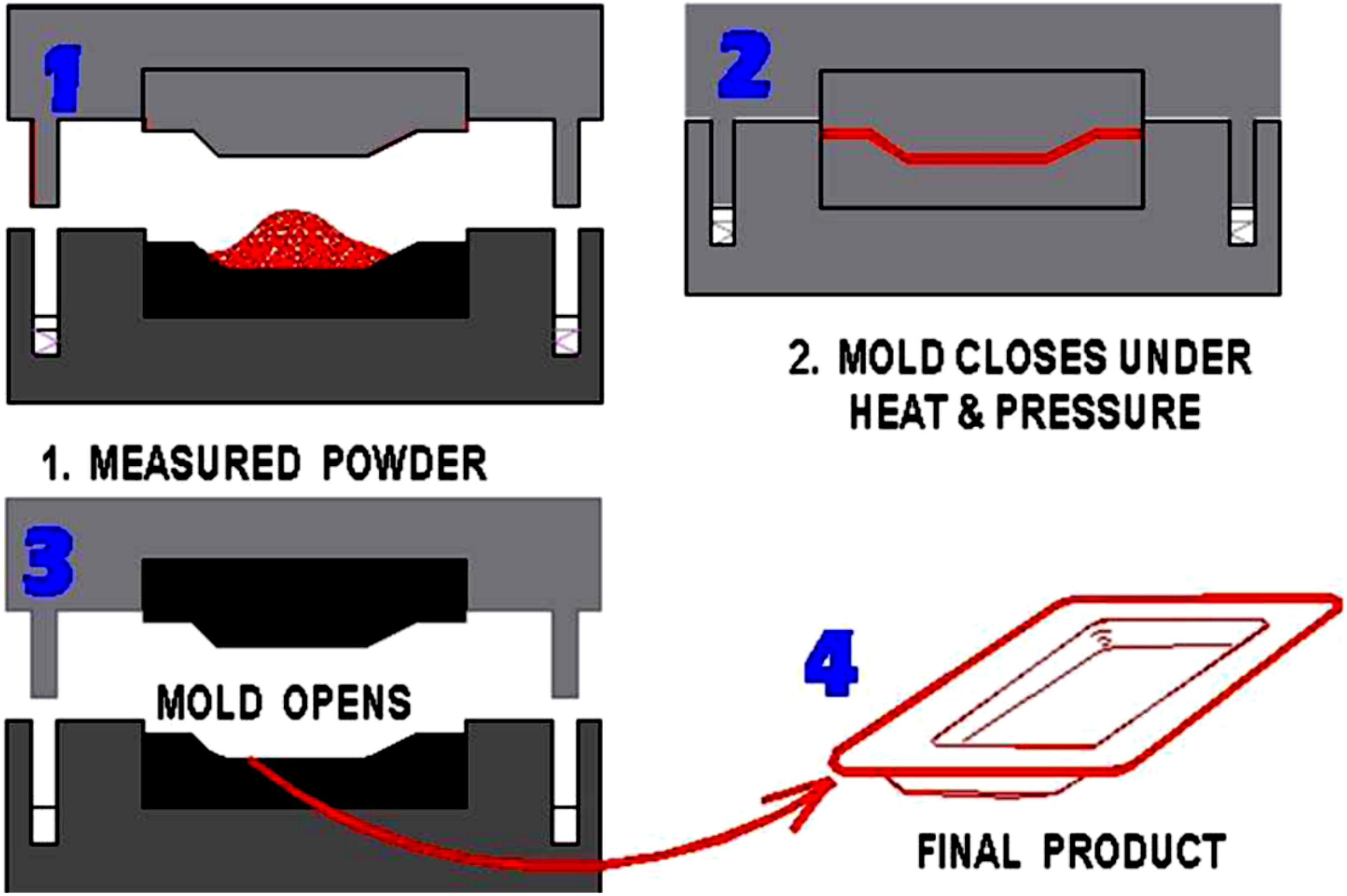


Figure 7.29 Fiber orientation distribution in a compression molded automotive fender

Process Description



Parameters

1. The quantity of charge(molding material)put into the mold

2. Pressure of the molding process:

   • Range of pressure 2000-3000 psi(13.8-20.7 MPa)

3. Mold temperature:

   • Temperature range 300ºF to 375ºF (149ºC- 191ºC).

4. Cure time variables:

   • The period required to harden thermosetting material to partial and complete polymerization is called cure time.

Advantages

- Lowest cost
- More uniform density
- Uniform shrinkage due to uniform flow
- Improved impact strength due to no degradation of fibers during flow
- Dimensional accuracy
- Internal stress and warping are minimized

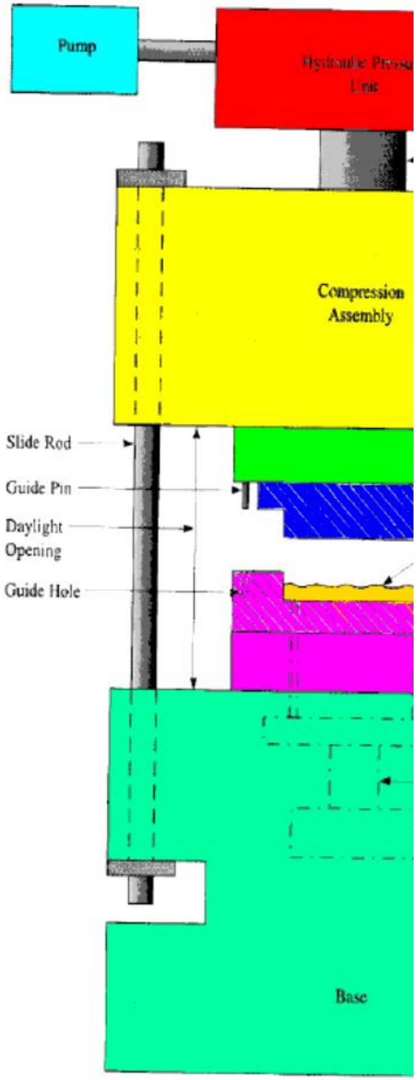


Illustration of a Press Mechanism used for Compression Moulding

(Image courtesy http://course1.winona.edu)

Disadvantages

- Curing time large
- Uneven parting lines present
- Scrap cannot be reprocessed.

Applications & products

- Dinnerware
- Buttons
- Knobs
- Appliance Housings
- Radio Cases
- Automotive exterior panels especially for commercial vehicles
- Ash trays & electrical parts

Materials used in this process

- Thermosetting polymers:
- Fiber reinforced composite
- Thermoplastic:
    - Ultra-High Molecular Weight Polyethylene (UHMWPE)
    - Long Fiber Reinforced Thermoplastics, etc.

For further details, please refer to: Compression Moulding Presentation by Chandra Shekhar Thakur, 2008, AMD 2927

Materials

Each monomer used for compression molding has its own special cure chemistry. Successful materials enhance properties such as heat resistance, impact, tensile strength, etc. In compression molding the selected polymer resin and the glass fibers are premixed with other additives. The premix or prepreg is made initially before compression molding the desired shape. Thermoset and thermoplastic materials have very different processing methods.

Thermoplastics and Compression Molding

Glass fiber matrix thermoplastic (GMT) processing was invented twenty years after sheet molding compound (SMC) was established. Long fiber thermoplastic composites were developed in the 1990s. The main process difference is that these compounds are melted in a heating station or extruder and put in the "cold7' mold (60-80°C). Due to the withdrawal of heat in the mold the material starts to freeze right after deposition and during the flow in the mold. Thus, the material properties are influenced by the thermal process parameters and the local pressure/velocity gradients, analogous to thermoset materials. Hence, the compression molding manufacturer has a great responsibility to find the optimal process parameters. In compression molding thermoplastic laminates, blanks smaller in area than the part size, are heated in a continuous belt drive oven above the melting temperature. The blanks are manually or robotically transferred to the compression molding tool where pressure is applied to fill the tool. During the compression process, the material begins to solidify since the tool temperature is controlled with water or oil to a temperature well below the resin matrix solidification point. The compression speed and tool temperature effect how the polymeric material flows during processing [10-11]. Continuous Fiber Reinforced Thermoplastics (CFRT) can replace other materials, such as thermoset composites, in many commercial engineering applications. Their principal advantages are:

- excellent toughness
- durability and damping properties
- easier storage
- possibility of continuous processing
- reshaping
- reparability
- and more favorable recycling and processing routes that do not involve chemical reactions.

However, the high cost of continuous fiber thermoplastic composite impregnation, arising from melting the polymer or using solvents, still restricts their use in commercial applications. Hence, cost reduction largely depends on developing more efficient fiber impregnating methods with high-viscosity thermoplastics and processing final composite parts. A recently developed technology for coating continuous fibers with polymer powders at low cost [12-14] can allow the efficient production of thermoplastic towpregs which are prepregs fabricated from powder coated tow which can be converted to woven and braided fabric. The consolidation is a critical phase of the towpreg processing into a final composite part by compression molding. Using thermoplastic resins to toughen thermosets is a relatively new technology. Polyethersulfones, polyimides, polyetherimides, and nylons are often used. These toughen thermosets have a morphology with ductile particles that are able to create microcracks and bridge the crack surface. The toughness increase is much more modest than their counterparts for lightly crosslinked thermosets but such increases allow these highly crosslinked thermosets to be successfully applied to high performance composites.

Thermosets and Compression Molding

Compression molding fiber reinforced thermosets is well established. There are two main compound types such as prepregs (SMC) that were established in the early 1960s. For thermoset resins compression molding is the critical and productivity controlling step. The thermoset cure process cross-links the linear macromolecules with complications. Closed mold techniques are used to make complex parts from bulk molding compounds (BMC). During processing of thermoset charges, the SMC blank is cut from a preformed roll and is placed between heated cavity surfaces. Generally, the mold is charged with 1^4 layers of SMC, each layer about 3 mm thick, which initially cover about half the mold cavity's surface. During molding, the initially randomly oriented glass fibers orient, leading to anisotropic properties in the finished product. When processing glass mat reinforced thermoplastic (GMT) charges, the preforms are cut and heated between radiant heaters. Once heated, they are placed inside a cooled mold that rapidly closes and squeezes the charges before they cool and solidify. One advantage of the compression molding process is the low fiber attrition during processing. Here, relatively long fibers can flow in the melt without the fiber damage common during plastication and cavity filling during injection molding. An alternate process is injection-compression molding. Here, a charge is injected through a large gate followed by a compression cycle. The material used in the injection compression molding process is called bulk molding compound (BMC), which is reinforced with shorter fibers, generally 10 mm long, with an unsaturated polyester matrix. The main benefit of injection compression molding over compression molding is automation. The combination of injection and compression molding leads to lower fiber orientation and fiber attrition compared to injection molding.

Premix or Prepreg Preparation

Open tool processing is often employed to process fiber-reinforced parts. The simplest open mold process is called hand lay-up, which involves manual placing impregnated fibers mats with thermosetting resin on an open mold. Room temperature and elevated cure temperature resins can be used. A spray-up method is used for faster production rates but it is limited to chopped fibers. The combination of viscous resins and high fiber loads requires a vacuum bag technique to eliminate voids and increase compaction. In extreme circumstances, laminates enclosed in a vacuum bag can be place in an autoclave to cure under high pressure and temperature.

Fiber Alignment

The alignment of fibers can be made in different types and typical premix systems include:

- Sheet molding compound commonly known as SMC is resin and chopped fibers placed randomly on the sheet plane with appropriate uniform thickness to fabricate the articles. SMC process is similar to thermoforming process.

- Dough molding compound commonly known as DMC is a resin and chopped fiber mixture that looks like dough. It is used for molding three dimensional articles. The fibers are randomly placed throughout the article.
- Tape uses continuous fibers impregnated with resin and the fibers may be placed uniaxially or woven. The woven fabric provides biaxial direction strength.

Pre-form

Pre-forming is accomplished with a mechanical or hydraulic press into which a hardened steel die set is mounted. The die has a cavity section and an upper and lower punch. The press compresses a compound fed from a hopper and transforms the loose powder into densely packed shape in a very rapid cycle. Pre-form weights are accurately controlled. It can be done with single or multi-cavity die. Pre-form process is dusty and it requires a separate area to reduce contamination.

Prepreg

Traditionally prepreg has been used to fabricate high performance composites for aerospace components, high performance yachts, racing cars, sports equipments and so on. A prepreg is a semi-finished, machine made product in which a reinforcement material has been impregnated with a pre-catalyzed resin. Prepreg quality will greatly influence the molded product properties. During prepreg manufacture, the resin content, the soluble resin content and the volatile content are the key factors to ensure quality.

Sheet Molding Compound – Production

SMC is frequently used material composed of reinforcing chopped glass fibers combined with a very complex specialty resin, formulated in an almost infinite number of ways. In SMC, the long reinforcing fibers are randomly oriented in the sheet plane and make up 20-30 percent of the molding compound's volume fraction. The product size to be molded is limited by available equipment size and tonnage. Figure 18.1 illustrates a SMC production line. Chopped strands have low formability, low wetability, and low cost. So, the mats made from them are used for making medium strength objects with uniform cross-sections by compression molding and hand lay-up. Fabrics are made from yarns which are produced from twisted fine strands. Woven fabrics can easily handle strength orientations, and increase mechanical properties. They exhibit high biaxial strength, and good formability. They are used in wet lay-up and compression molding processes. Fillers must be clean and free of oily materials, dirt, dust and especially moisture. Moisture complicates problems in compression-molding. When processing thermoset charges, the SMC blank is cut from a preformed roll and is placed between heated cavity surfaces. During molding, the initially randomly oriented glass fibers orient, leading to anisotropic properties in the finished product. When processing GMT charges, the preforms are cut and heated between radiative heaters. Once heated, they are placed inside a cooled mold that rapidly closes and squeezes the charges before they cool and solidify.

The SMC sheets can be formed in a belt press. Such sheets are allowed to mature for several days before they are cut into appropriate pieces that are stacked to form a charge that is put in an open heated mold. The mold is then closed to form a charge that is put in an open heated mold. The mold is then closed with certain force to fill SMC in the formed cavity. During the filling there is an extensive built-up in the SMC due to its initially high viscosity. As the SMC is heated up by the tooling its velocity naturally decreases at the same time as the thermosetting starts. The latter is usually a slower process that only affects the resin viscosity after the mold is closed. It is also possible to design the processing tools and conditions so that a high pressure remains on the SMC after the mold has been closed. The curing takes place and when the mold is opened; the final SMC product can be removed. The procedure is well known and has been used effectively a number of decades. When producing SMC, the chopped glass fibers are sandwiched between two carrier films previously coated with unsaturated polyester-filler matrix. A fiber reinforced thermoplastic charge is often called a glass mat reinforced thermoplastic (GMT) charge. The most common GMT matrix is polypropylene. More recently, long fiber reinforced thermoplastics (LFT) have become common. Here, one squeezes sausage-shaped charges deposited on the mold by an extruder.

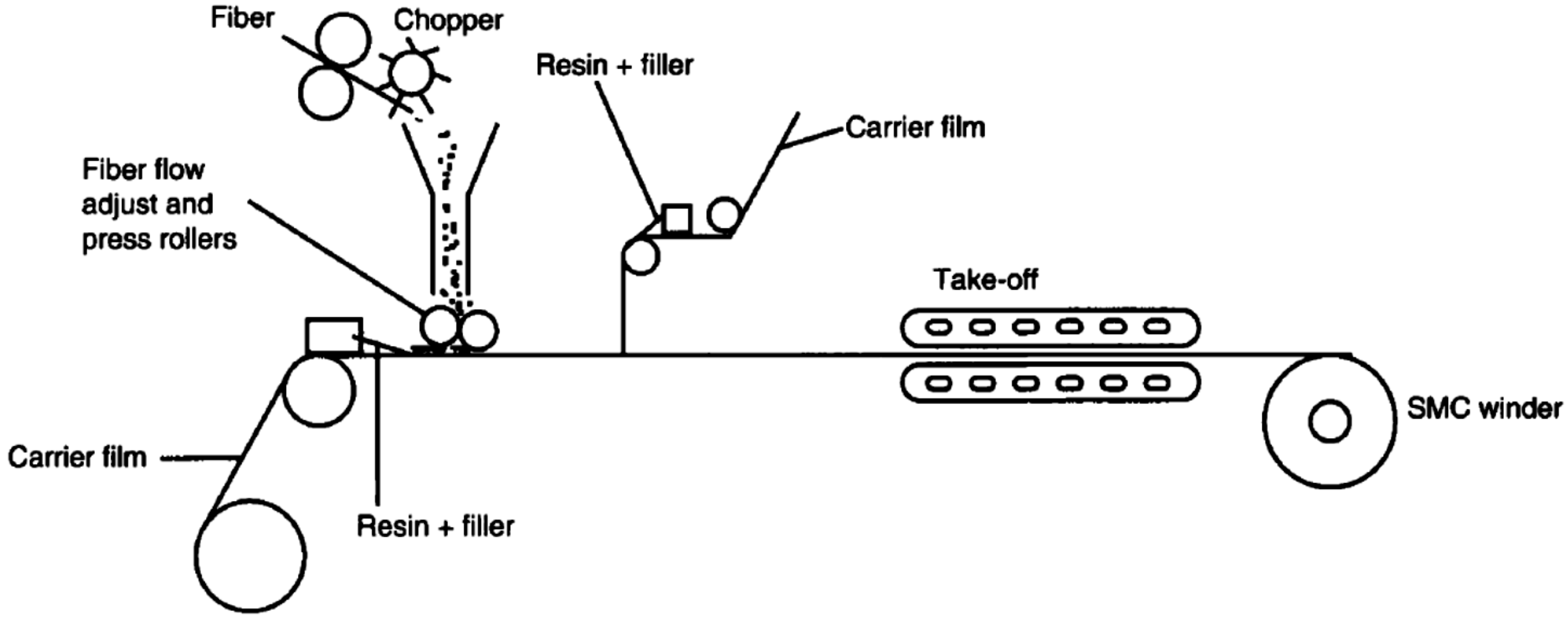


Figure 18.1 Sheet molding compound production process.

Mold

Several different mold designs can be used in compression molding. However all designs utilize the same molding press. Compression molding uses stiff to medium flow compounds because it involves the best flow during its process. A properly designed compression mold will produce molded parts of excellent overall mechanical properties.

Technology - Compression Molding

In the compression molding process it is very importance that the void content is low on the surface and in the bulk. Sheet molding compound is a fiber reinforced polymer material consisting of thermosetting resin, chopped fibers, fillers, and additives. An appropriate amount of compound in the form of premix or prepreg to be molded is placed into the cavity which is the lower half of the heated mold. During compression molding cycle, the mold halves are then brought together to squeeze the material and fill the mold. Compression molding starts with an appropriate prepreg shape. The mold is heated at its curing temperature and brought together under pressure. During processing, the compound softens by heat and transforms to the cavity shape. The softened melt hardens further under heat and pressure. After sufficient hardening the part can be removed without distortion when the mold is opened. The heated mold in the compression molding process, initiates the curing process for the resin. In compression molding, the desired molded article shape is defined by the two-piece mold. The pressure is maintained while the material cures. The charge temperature is about room temperature, the mold temperature ranges from 120-150°C. The compound temperature rises during the flow due to heat transferred from the cavity surfaces. Due to this the viscosity declines before the cross-linking reaction starts. Much attention is given to improve compression molding costs by reducing the cycle time required to produce acceptable parts in steady production. In compression molding, the cure time is the longest part of the cycle time. However filling time play an important role. With shorter filling times, a more reactive material can be used and thus a shorter the cure time. In particular one important area for compression molding is being able to predict the pressing force needed to close the mold at a given speed. Figure 18.2 illustrates the molding cycle in compression molding. Local pressure gradients in the mold cause different local velocities and fiber orientations during flow. These orientations affect the part anisotropy. Besides the thermal process parameters, it is the flow that has a major influence on the part properties. Compression molding cycle starts with:

- Opening of the mold.
- Insert(s), if any, to be placed in the cavity.
- Molding compound loaded in the cavity in the form of powder or pre-form or pre-heated.
- Closing of hot mold, breathe if needed. Heating to be continued until complete cure of the thermoset material under pressure.
- Ejection of molded part and the part to be placed in shrink or cooling fixtures if needed or whenever necessary to maintain close dimensional tolerances.
- Removal of foreign matter and flash usually by air blast from the mold.

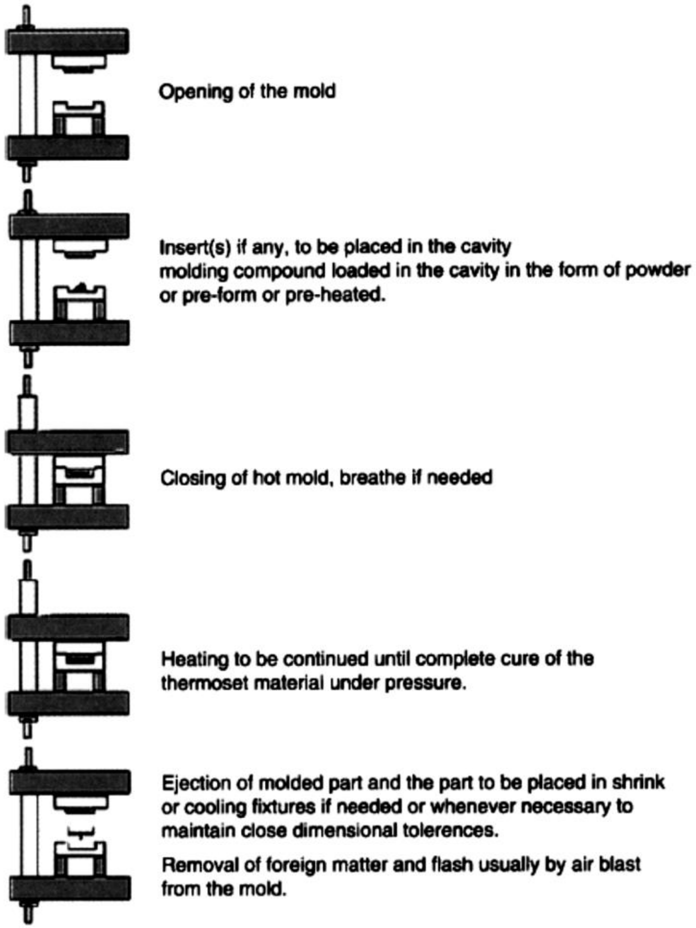


Figure 18.2 Compression molding cycle.

Important Variables during Processing

In compression molding, thermoset materials determine the pressure required to produce molding with minimum cycle time. Important variables such as

- Product design in terms of:
  - projected area and depth
  - wall thickness
  - obstructions such as sharp corners, pins, etc.
- Press speed, slow versus fast
- Self-contained versus hydraulic system
- Ability to maintain holding pressure during molding
- Material plasticity being processed:
  - pre-heating conditions
  - compound density (pre-form or powder)
  - material position placed in die.
  - compound flow properties under pressure
  - filler material and concentration.
- Overall mold temperature and its uniformity
- Mold surface condition
- Mold pressure.

Troubleshooting

Today process parameters are often found by trial and error rather than by process simulation because simulation software is often considered suitable for industrial applications. Compression molding is facing many challenges to meet a rapidly changing and diversifying market environment. There are many problems encountered in the process with associated inherent complexities in terms of:

• Kinetics
• Mechanisms
• Physical changes
• Transport effects such as:
  o viscosity increase
  o particle formation
  o inter-facial mass and heat transfer limitations.

The end-use applications are often represented by non-molecular parameters such as:
• Tensile strength
• Impact strength
• Color
• Crack resistance
• Thermal stability
• Density, etc.

These must be somehow related to fundamental polymer properties such as:
• Composition
• Branching
• Cross-linking
• Stereo-regularity, etc.

Unfortunately, process variables affect properties and the relationship between the process variables and end-use properties is generally very difficult and not well established. In situ real-time monitoring of compression molding is of crucial importance to polymer scientists and engineers engaged in efforts to optimize processes and products. Moreover, many process variables that affect product quality namely non-ideal mixing and conveying, and strong process non-linearity related to limited cycles and multiple steady states. Two big expenses for any processing are:

• Failure to quickly and accurately troubleshoot process upsets and equipment problems
• Failure to realize the operating potential of its process through optimization
• Minor upsets and equipment problems which are not identified and resolved quickly can progress into much larger problems potentially resulting in:

  o lost production
  o off-spec product
  o equipment loss
  o catastrophic accidents.

Additionally, operating a process at suboptimal performance results in elevated operating costs due to:

• Increased energy costs

- Equipment reliability costs
- Lower yields
- Longer startups, etc.

Therefore, the ability to troubleshoot and optimize process operations are two of the most valuable skills operation personnel can possess. Troubleshooting requires a comprehensive analysis of:

- The process
- Mold design
- Material

Compression molding tends to focus on process modifications to solve problems. There may be longer cycle times, secondary rework operations or formulation modifications that negatively impact profits. Thorough and systematic analysis can pinpoint the exact problem cause and identify the most cost and time-effective solution.

Problems and Solution(s)

Compression molding is widely used in the automotive industry for producing exterior body panels. For the last two decades, and in spite of many cosmetic problems, compression molded parts usage has increased for exterior body panels such as hoods, deck lids, and door panels. The cosmetic problems most commonly observed in compression molded parts are sink marks over ribs and bosses, long term waviness, and surface porosity. Painting or coating the molded part can be very effective in providing a cosmetic surface free from substrate porosity. A low profile agent such as thermoplastic material mixed with the resin just prior to compounding has been found to reduce the polymerization shrinkage as it cures in the mold and in turn reduces sink marks and long term waves observed on the part surface. Using coatings and low profile additives has reduced sink marks. However sink marks can still exist in the molded parts. To solve the sink mark problem one must style and design surface contours so that sink marks are concealed. Jutte et al. studied the role of polymerization and thermal shrinkage, and concluded that the polymerization shrinkage can be minimized by using low profile agents. Thermosets are inherently brittle, organic additives can be used to improve the fracture toughness of these materials. For thermosets, that are lightly cross-linked, reactive oligomers that phase separate during cure help and for highly cross-linked thermosets, thermoplastic toughening agents can be used. During pressing the temperature and the pressure are substantially increased. This means that even large voids can be dissolved in a very short time. If the pressure is large enough within the resin most enclosed gas should dissolve and SMC products ought to be completely free from voids. It is well known that these items can have a relatively high void content. There are several reasons for this. Still some issues are unresolved such as fiber reorientation during processing, which strongly affects the final SMC strength and residual void formation which can cause large surface defects after painting and lower the electrical insulation capacity of the part manufactured.

The voids located in the SMC during pressing may have entered the SMC via:

- the constituents when they are mixed to form the SMC

• being enclosed during the lay-up procedure
• or formed as the charge flows in the mold during pressing.
It may also happen that during the curing process the pressure becomes too low and SMC constituents such as styrene start to boil. Regardless of how the voids form, their final size and location are strongly affected by the fluid pressure in the SMC during compression. Specifically, it has been observed that the formation, movement, and amount of voids are strongly related to the temporal and spatial distribution of the pressure and the pressure gradients, where high pressures, and pressure gradients, generally gives a low residual void content since it enables the voids to move forward through fiber networks or dissolve into the resin. The SMC consists of fibers, caulk, and some additives that may considerably slow down the dissolution of gas. Low-pressure zones are formed during pressing. This may be due to uneven filling or, complex shaped molds or uneven solidification. A substantial amount of gas is dissolved during the compression which saturates the resin much faster than predicted in the model. This could be a reasonable explanation if air is trapped between the sheets during charge lay-up. Molding cycles are longer with the need to remove flash from the parting line and holes. Difficulties in molding side holes or sections, and problems with molding in flash free metal inserts have all contributed to reduced use of compression molding.

Summary

In summary following are the fundamentals, advantages and disadvantages of compression molding:

Fundamentals

• The simplest closed mold method is casting which involves pouring the liquid into a mold. For more viscous systems, compression molding is used to squeeze the material into two halves of a heated mold.
• Cold powder or pre-form can be loaded in compression molding
• Mold is open when the material is loaded.
• Material positioned for optimum flow.
• Least shrinkage observed in compression molding.
• In compression molding, inserts might be displaced during the compression molding cycle.
• With compression molding parting line flash generally prevents metal – metal closing of the mold halves. It makes dimensions perpendicular to the parting line greater by the flash thickness.
• Transfer molding is similar to compression molding except the plunger pushes the reactive resin through a mixing nozzle to mix the reactants before injecting them into a closed cavity.

Advantages

• Sprue, runners, and transfer-culls can be avoided without any gate erosion problems.
• Minimize stress by short and multidirectional flow in the mold.

• With reinforcing fibers, high impact strength is gained due to more randomly positioned fibers.
• Multiple cavities can be used without a sprue and runner system.
• Possible to automatically load material and remove molded articles.
• Thin wall parts without warpage or dimensional change.
• Molds for compression molding are less expensive.
• Can mold heavily reinforced materials
• Best method for moldings with large surface area related to thickness
• Greatest uniformity in molded properties
• Most versatile process with relation to quantities and component complexity
• Relatively simple to understand and control.

Disadvantages

• Thermosets have poor fracture resistance.
• Thermoset materials are brittle, hence recommended minimum part wall thickness are necessary.
• Relatively labor intensive, with more material handling involved.
• Material losses due to the flash allowances and general waste.
• Secondary operations for flash removal are generally required.
• Poor part thickness and weight control.
• Cannot mold around delicate inserts or pins.

For further details, please refer to the book: Handbook of Troubleshooting Plastic Processes: A Practical Guide, Chapter 18.

Importance of using PPEs

PPE is equipment that will protect workers against health or safety risks on the job. The purpose is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

PPEs:

Name & Usage	Picture of PPE	Name & Usage	Picture of PPE
Safety goggles – used to protect eyes from flying particles (chips, sparks etc.)		Safety shoes – used to protect feet from spatters of welding and impact of other falling objects	
Face shield - used to protect face from welding sparks, radiations, arc and spatters		Face mask – used to protect from inhaling fumes, dangerous gases etc.	
Hard cap – used to protect the head from injury due to falling objects		Leather Apron – used to protect welder's body from welding spark and spatters	
Leather gloves – used to protect hands during welding		Cotton gloves – used to protect hands from sharp edges of sheets and plates	

Importance of housekeeping and safe storage of tools and equipment

The main function of housekeeping is to ensure cleanliness, comfort, convenience, privacy, health and hygiene in a safe environment. It includes keeping work areas neat and orderly. All the tools and equipment must be stored properly.

Importance of making a check list

It ensures you get your daily, weekly and monthly tasks done on time, helps you keep track of projects on deadline and ensures you're organized throughout the day.

Video links:

Processing of Plastics- Compression and Transfer Moulding: https://www.youtube.com/watch?v=A1XKGUH7wRQ
What is Compression moulding process in hindi: https://www.youtube.com/watch?v=NlJqDPlnDXY
Compression Moulding Process: https://www.youtube.com/watch?v=sus8arkJOeA

Module summary

Module Title and Aim	Learning Units	Timeframe of modules
Module 1: Comply Personal Health and Safety Guidelines **Aim:** This Competency Standard identifies the competencies required to protect/apply occupational Safety, Health and Environment at workplace according to the industry's approved guidelines, procedures and interpret environmental rules/regulations. Trainee will be expected to identify and use Personal Protective Equipment (PPE) according to the workplace requirements. The underpinning knowledge regarding Observe Occupational Safety and Health (OSH) will be sufficient to provide the basis for the job at workplace.	**LU1:** Identify Hazard at workplace **LU2:** Apply personal protective and safety equipment (PPE). **LU3:** Observe occupational safety and health (OSH) **LU4:** Dispose of hazardous waste/materials	30
Module 2: Communicate the Workplace Policy and Procedure **Aim:** This unit describes the performance outcomes, skills and knowledge required to develop communication skills in the workplace. It covers gathering, conveying and receiving information, along with completing assigned written information under direct supervision.	**LU1.** Identify workplace communication procedures **LU2.** Communicate at workplace **LU3.** Draft Written Information **LU4.** Review Documents	20

Module Title and Aim	Learning Units	Timeframe of modules
Module 3: Perform Basic Communication (Specific) **Aim:** This unit describes the skills and knowledge required to assist in the development of communication competence by providing information regarding different forms of communication and their appropriate use.	**LU1.** Communicate in a team to achieve intended outcomes **LU2.** Follow Supervisor's instructions as per organizational SOPs **LU3.** Develop Generic communication skills at workplace	30
Module 4: Perform Basic Computer Application (Specific) **Aim:** This unit describes the skills and knowledge required to use spreadsheet to prepare a page of document, develops familiarity with Word, Excel, email, and computer graphics basics.	**LU1.** Create Word Documents **LU2.** Create Excel Documents **LU3.** Use internet for Browsing	40
Module 5: Arrange Raw Material for Processing **Aim:** This competency standard is designed to gain basic knowledge and skills required to arrangement of raw material for processing of manufacturing products and sample.	**LU1:** Obtain Work Order **LU2:** Identify Components & Attachments **LU3:** Apply pre-processing procedure	80

Module Title and Aim	Learning Units	Timeframe of modules
Module 6: Produce Injection Moulded Plastic Parts **Aim:** The aim of this module to provide skills and knowledge to operate injection moulding machine in accordance with the manufacturer's manual	**LU1:** Interpret Work Order **LU2:** Perform Production **LU3:** Perform follow up procedure for machine production **LU4:** Submit production report **LU5:** Transport finish product to Concerned department	150
Module 7: Produce Pipe through extrusion moulding machine **Aim:** The aim of this module to provide skills and knowledge to operate pipe extrusion machine in accordance with the manufacturer's manual	**LU1:** Interpret Work Order **LU2:** Start Production as Per Requirement **LU3:** Perform Follow up Procedure **LU4:** Submit Production Report **LU5:** Transport Finished Product	150
Module 8: Produce Blow moulded plastic parts **Aim:** The aim of this module to provide skills and knowledge to operate compression moulding machine in accordance with the manufacturer's manual	**LU1:** Interpret Work Order **LU2:** Perform Production **LU3:** Perform Follow up Procedure for Machine Production **LU4:** Submit Production Report **LU5:** Transport Finish Product to Concerned Department	150
Module 9: Produce Compression moulded plastic parts **Aim:** The aim of this module to provide skills and knowledge to operate compression moulding machine in accordance with the manufacturer's manual	**LU1:** Interpret Work Order **LU2:** Perform Production **LU3:** Perform Follow up Procedure for Machine Production **LU4:** Submit Production Report **LU5:** Transport Finish Product to Concerned Department	150

Short Questions/Answers

Q1. Which plastics are used in injection molding?	Thermoplastics
Q2. What types of polymeric materials (plastics and elastomers) are there?	Amorphous and Semi-crystalline
Q3. What is the difference between parallel and conical twin screw extruders?	Conical twin screws are used for better throughput and parallel twin screws are used for better mixing.
Q4. Complex shape of parts or components cannot be formed by the injection moulding process.	False
Q5. Components from injection moulding process are made very expensive due to the application of very costly equipment.	False
Q6. The moulding directions in injection moulding can affect the cost of equipments used in the process.	True
Q7. The flow of plastic in the mould cavity is more proper and smooth if the thickness of the component made is very small.	False
Q8. Shrinkage of the plastic parts in mould cavity can results in generation of sink holes in the plastic.	True
Q9. A heavy surface finishing is always required for components made in injection moulding machine.	False
Q10. In injection moulding process, ribs are generally provided for the reinforcement to avoid sink marks from the component.	True
Q11. The barrel is used for opening and closing of	False

the mold.	
Q12. There is a varied pressure provided in the solidification unit of injection molding process.	False
Q13. Calendering is mostly suited for making PVC	True
Q14. Tubes having U shape cannot be manufactured by polymer extrusion process.	False
Q15. Extrusion is a process which uses an electric system for processing various polymers.	False
Q16. Thermosetting polymers can be processed by extrusion process by forming cross-linking in the extruder.	True
Q17. In processing polymers, injection moulding process is almost similar to extrusion process except for the screw operation.	True
Q18. Extruder is a device used for the finishing of processed polymer products in the extrusion process.	False
Q19. Continuous type of extruder is generally equipped with rotating parts in the extrusion process.	True
Q20. Multiple screw extruders are mostly preferred than the single screw extruders in the extrusion process.	False
Q21. In the extrusion process, a cast type barrel is mainly used for the heating of polymer material.	False
Q22. Extruder die is a machine part that gives final shape to the polymer material used in the extrusion	True

process.	
Q23. In the extrusion process, a water-cooling system is used which automatically controlled by a sensor.	True
Q24. Speed of production in transfer molding is higher than that of compression molding?	True
Q25. Thermosetting materials are the polymeric materials which get soften on heating with or without pressure.	False
Q26. Thermosetting plastics are generally used for making products of high strength and rigidness.	True
Q27. Polyurethanes plastics can be made in flexible foams even after belonging to thermosetting polymers.	True
Q28. Polyethylene, polypropylene and polyvinyl chloride (PVC) are the main example of thermosetting polymers.	False
Q29. Thermosetting plastics like epoxies can be used for filament wound rocket motor casings in missiles by combining with glass fibers.	True
Q30. Polyurethane plastics are highly reactive to chemical compounds due to lack of elasticity in this plastics.	False
Q31. Phenolic plastics can also be used as binder for holding plies of wood in making of plywood.	True
Q32. Thermosetting plastics can be used for manufacturing of windshield for airplane.	False

Q33. Mechanical properties of any plastics are mainly dependent on the temperature, force and time of load applied.	True
Q34. The heater in vacuum forming process is heated up to 90°C.	True
Q35. The initial cost in blow molding is low.	True
Q36. Blow moulding is a very slow process, however economical for producing products with better quality.	False
Q37. In extrusion blow moulding process, it is very difficult to trim away excess of plastics	True
Q38. Single stage stretch blow moulding is always preferred than two stage stretch blow moulding for increase in production rate.	False
Q39. Single stage stretch blow moulding process is mostly used for small level production.	True
Q40. Thermoforming process involves injecting of molten plastic into a mould cavity by application of compressed air.	False
Q41. In thermoforming process, it is very difficult to control thickness of moulded parts or sheets.	True
Q42. In thermoforming, it is very easy to mould the plastic materials which are of crystalline nature.	False
Q43. Thermoforming is basically a cheap process as compared to injection and blow moulding process.	True
Q44. Which material is mostly used for making of thermoforming moulds?	Aluminum

Test Yourself (Multiple Choice Questions)

MODULE	**6**			
Question	**1**	Three overall classes of plastics are distinguished from one another. They include thermosets, thermoplastics and ________________	A	Monomers
			B	Synthesis
			C	Elastomers
			D	Fibers
Question	**2**	Thermoplastics are soluble and ________	A	Densely cross-linked
			B	Fusible
			C	Non-fusible
			D	Crystalline

Question **3** Amorphous thermoplastics are ________ when they are not combined with fillers or similar additives.

A Transparent

B Milky opaque

C Translucent

D Black

Question **4** Polycarbonate (PC), from which Compact Disks are molded, is a(n) _________ thermoplastic.

A Amorphous

B Semi-crystalline

C Liquid Crystal

D Immiscible

Question **5** ___________ cannot be fused or dissolved but can be swelled.

A Thermoplastics

B Elastomers

C Thermosets

D Composites

Question **6** Thermosets are non-fusible and ____________

A Soft

B Densely cross-linked

C Dense

D Irregular shaped

Question **7** The intermolecular forces which operate in the crystalline state are considerably ___________ than those in the amorphous state.

A Weaker

B Stronger

C Complex

D Diverse

Question	**8**	The abbreviation for polyamide, as specified by IS0 1043, is ___________________	A PS B PA C PC D PVA
Question	**9**	Processing temperatures are _________ for thermoplastics than for metals.	A Higher B Lower C Left D Right
Question	**10**	Viscosity is a measure of the __________ of a melt.	A Hardness B Flow properies C Density D Visco-elasticity

Question	**11**	As temperature decreases, the viscosity of the melt ________________	A	Increases
			B	Decreases
			C	Varies
			D	Eliminates
MODULE	**7**			
Question	**12**	Which of the following material is not used in extrusion?	A	Wax
			B	Granules
			C	Powder
			D	Pellets
Question	**13**	In extrusion process, extra shearing occurs in which part of the system?	A	Feed section
			B	Pumping section
			C	Collapse section
			D	Transition section

Question 14 Melting section is another name for which section?

A Feed Section

B Transition section

C Transition section

D Collapse section

Question 14 How are extruded materials cooled?

A Water

B Contact with chilled surface

C Air

D Oil

Question 15 Which of the following is not an important factor of cooling in extrusion?

A Reduction in shrinkage

B Reduction in distortion

C Ease of adding colors

D Rate of cooling

Question	**16**	Which of the following is not an application of polymer extrusion?	A	Door insulation
			B	Chewing gums
			C	Cables
			D	Circuit boards
Question	**17**	Film extrusion process, best involves film having thickness below what length?	A	0.2mm
			B	0.3mm
			C	0.4mm
			D	0.5mm

Question 18 In cable extrusion process, what is the speed of product winding?

A 40m/s

B 50m/s

C 60m/s

D 70m/s

Question 19 Which of the following equipment is used for controlling the temperature of polymer material in the extrusion process?

A Thermoresister

B Thermometer

C Thermocouple

D Glasstube

MODULE	8			
Question	21	In blow molding, to inflate soft plastic, which medium is used?	A	Air
			B	Water
			C	Oil
			D	Alcohol
Question	22	Which of the following plastics is not used in blow molding?	A	Terephthalate
			B	Polypropylene
			C	Polyethylene
			D	PVC
Question	23	What is the minimum air pressure required in blow molding process?	A	350KPa

			B	400KPa
			C	450KPa
			D	500KPa
Question	**24**	What can be the maximum pressure to be given to a plastic for blow molding process?	A	700KPa
			B	750KPa
			C	800KPa
			D	850KPa
Question	**25**	Which of the following is not a type of blow molding process?	A	Injection blow moulding
			B	Extrusion blow moulding
			C	Multi-smaller blow moulding
			D	Multi-larger blow moulding

Question	**26**	Which of the following is not an application of blow molding process?	A	Toy bodies
			B	Door liners
			C	Bottles
			D	Pipes
Question	**27**	What is the maximum thickness that can be allowed for a plastics sheet in vacuum forming process?	A	3mm
			B	3.1mm
			C	3.2mm
			D	3.3mm

Question	**28**	What is the minimum thickness required by the plastic for vacuum forming?	A	0.125mm
			B	0.25mm
			C	0.375mm
			D	0.5mm
MODULE	**9**			
Question	**29**	What is the minimum pressure required in a compression molding process?	A	0.5MPa
			B	1MPa
			C	1.5MPa
			D	2MPa

Question	**30**	What is the minimum temperature required in a compression molding process?	A	120°C
			B	125°C
			C	130°C
			D	135°C

Question	**31**	What is the maximum pressure required in a compression molding process?	A	35MPa
			B	40MPa
			C	45MPa
			D	50MPa

Question 32 What is the maximum temperature required in a compression molding process?

A 240°C

B 245°C

C 250°C

D 255°C

Question 33 In compression molding, the curing time does not depend on which of the following factors?

A Material

B Curing temperature

C Geometry

D Thickness

Multiple Choice Questions Answer scheme

Module 6:

Q1: C
Q2: B
Q3: B
Q4: B
Q5: C
Q6: B
Q7: B
Q8: B
Q9: B
Q10: B
Q11: A

Module 7:

Q12: A
Q13: B
Q14: B
Q15: B
Q16: C
Q17: B
Q18: D
Q19: B
Q20: C

Module 8

Q21: A
Q22: A
Q23: B
Q24: C
Q25: C
Q26: D
Q27: C
Q28: A

Module 9

Q29: A
Q30: B
Q31: D
Q32: C
Q33: B

National Vocational and Technical Training Commission (NAVTTC)

Plot 38, Kirthar Road, Sector H-9/4, Islamabad, Pakistan
+92 51 9044 322
+92 51 9044 322
info@navttc.org
www.navttc.org