Injection Moulding

INJECTION MOULDING

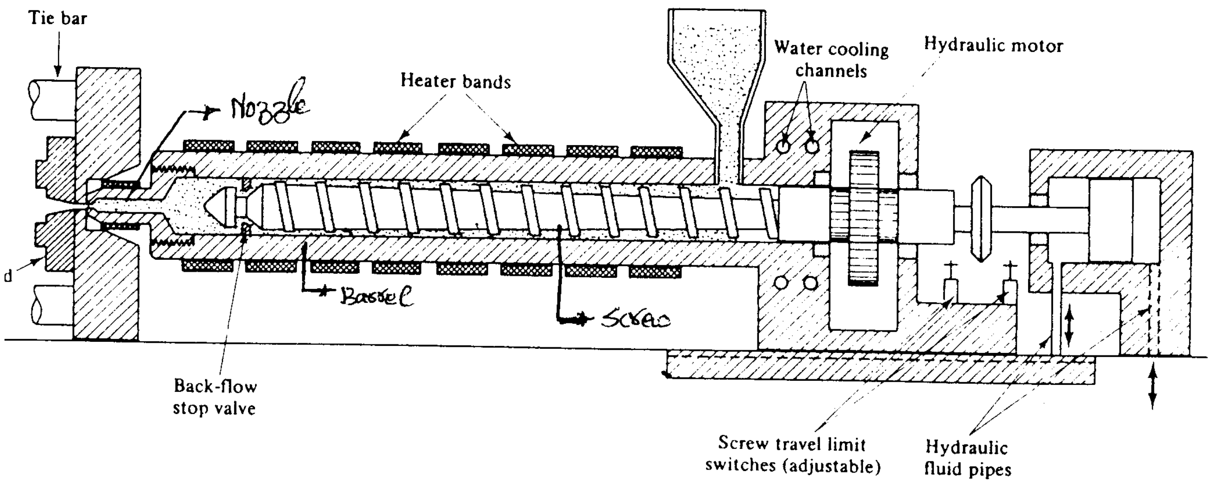
Injection moulding is a process of forming an article by forcing molten plastic material under pressure into a mould where it is cooled, solidified and subsequently released by opening the two halves of the mould.

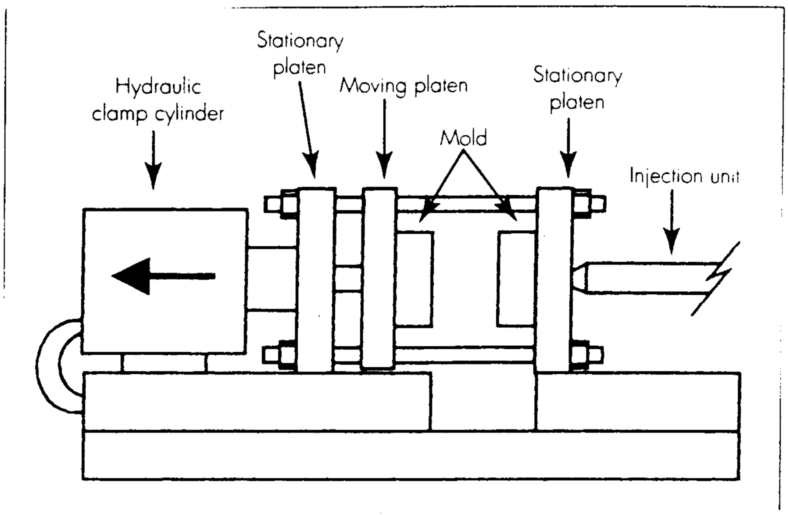
Injection moulding is used for the formation of intricate plastic parts with excellent dimensional accuracy. A large number of items associated with our daily life are produced by way of injection moulding. Typical product categories include housewares, toys, automotive parts, furniture, rigid packaging items, appliances and medical disposable syringes.

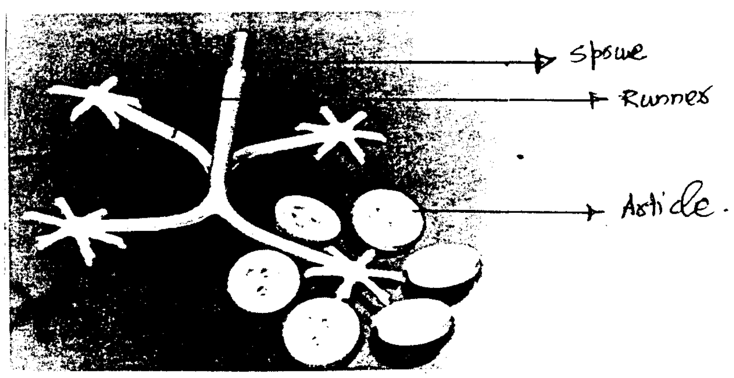
Advantages of Injection Moulding

- Accuracy in weight of articles
- Choice of desired surface finish and colours
- Choice of ultimate strength of articles
- Faster production and lower rejection rates
- Faster start-up and shut down procedures
- Minimum wastage
- Stability of processing parameters
- Versatality in processing different raw materials
- Option in article sizes by changing the mould.
- Minimum post moulding operations

INJECTION MOULDING MACHINE







Machine specifications:

To determine suitability of moulding machines for making a particular product, the following machine specifications need to be checked:

Maximum shot weight capacity of the machine should be more than the total weight of article/articles (in case of multicavity mould) plus the runner system.

Injection pressure should be sufficient to fill the cavities without any short shots.

Clamping tonnage required to hold the mould in locked condition should be adequate (otherwise there will be flashes)

Daylight opening of the machine should be higher than sum total of mould height, plus article neight, plus space required for removal of articles.

Injection moulding cycle

A typical sequence of operations from startup is as follows:

1. Starting with an empty cylinder, raw material from the feed hoper falls onto the rear flights of the screw which conveys material to the front of the cylinder. During its passage along the cylinder it is plasticised to a fluid state with the help of external heaters on the barrel. Some material may escape through the nozzle but the back pressure is generally sufficient to push the screw back in the cylinder and to provide a reservoir of fluid plastic in the front of the cylinder for injection.

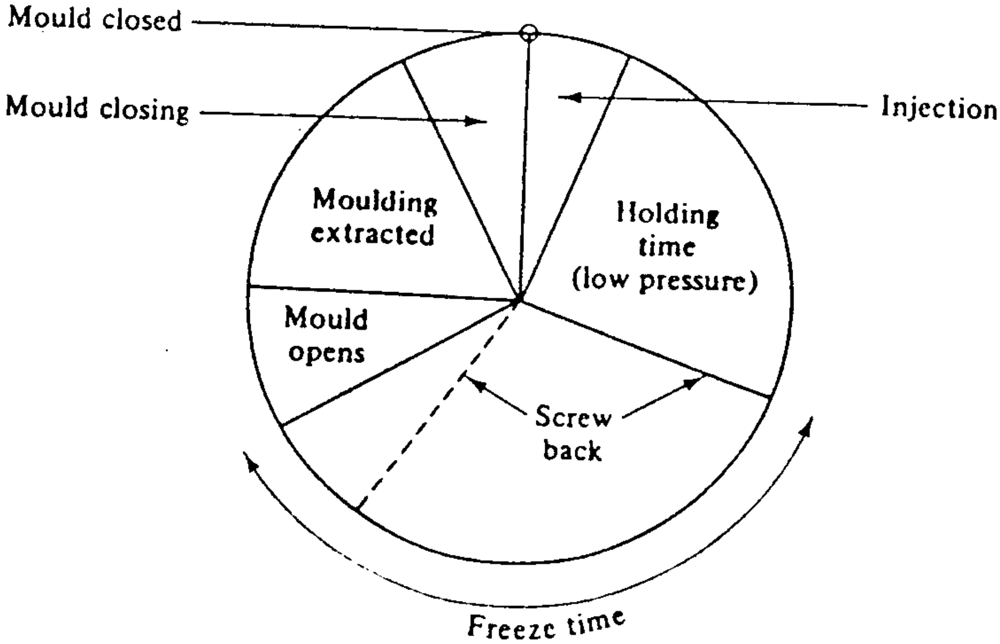
2. The mould closes and the cylinder moves forward units carriage until the nozzle is in contact with the entrance of the mould.

3. The screw is moved forward by the hydraulic cylinder at the rear of the machine and the injection takes place.

4. After a short interval (the holding time), the screw rotates, creating some pressure in the barrel, which offers it back against low pressure in the hydraulic cylinder, until the limit switch operates, stopping the rotation. This plasticises material ready for the next shot.

5. The mould opens, the article is ejected and the mould closes again ready for the next cycle.
6. Stages (2) to (5) repeat.

Cycle of operations



Mould release spray is sometimes used to remove the articles from the mould. Due to contours, ribs and undercuts, the article may get stuck up in the mould.

Key features of Polypropylene

- Strength and light weight
- Good heat resistances
- Good surface finish and gloss of moulded parts
- Excellent environmental stress crack resistance
- Ability to form an integral hinge with good life
- Good chemical and stain resistance
- Available in a wide range of flow rates and various impact levels
- Better dimensional stability

- Significance of MW. MWD and Xylene Solubles

Molecular Weight (melt flow)

- Polymers is processed as viscous fluids
- As polymer melt viscosity increases (or MFI decreases)
- Processing becomes more difficult
- End-use properties improve
- Therefore a balance of end-use properties with processability is highly desirable.

Molecular Weight Distribution (MWD)

Broad MWD

- Wider moulding window
- Higher stiffness
- Lower toughness
- Greater tendency for warpage

Broad MWD

- Wider moulding window
- Lower stiffness
- Higher toughness
- Less tendency for warpage
- Good surface finish

Xylene Solubles
Low molecular weight fraction containing certain amounts of static polypropylene
It is not detrimental to properties of Polypropylene and so, kept at a minimum level.

However, this low molecular weight fraction acts as lubricant and improves processability

Ideal melt temperatures for PP resins

Melt Flow Rate	**Melt Temperature (deg. C.)**
1.0-1.5	250
1.6-2.5	240
2.6-4.0	230
4.1-6.5	220
6.6-10.5	210
10.6-17.5	200
17.6>	190

Note: These are ideal temperatures to achieve best properties, however this needs to be modified on product to product basis.

Moulding thin sections

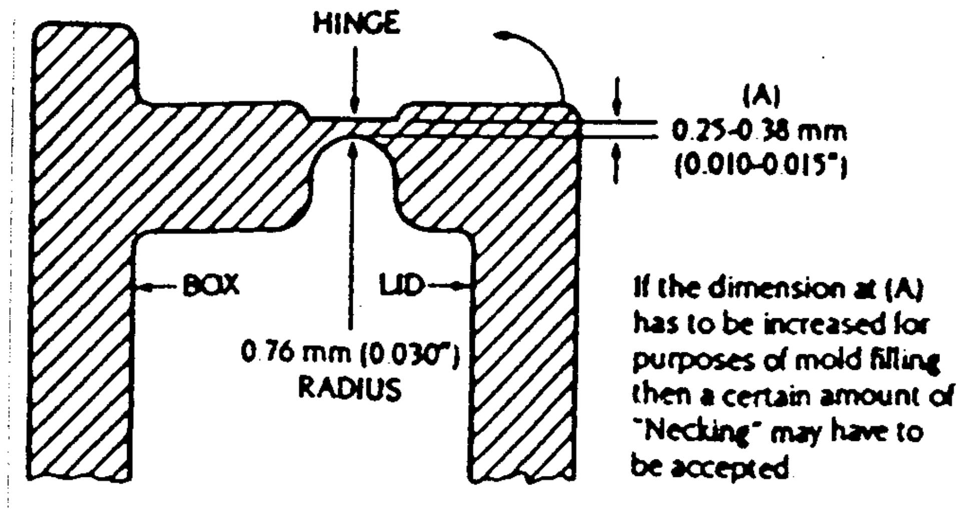
Hinge strength derived from moulded-in orientation and subsequent further orientation by flexing of the hinge soon after moulding.

When property formed, the hinge will have virtually unlimited flex life, even at low temperatures.

Factors affecting hinge strength

- Mould design
- Moulding conditions
- Melt flow
- Colourant

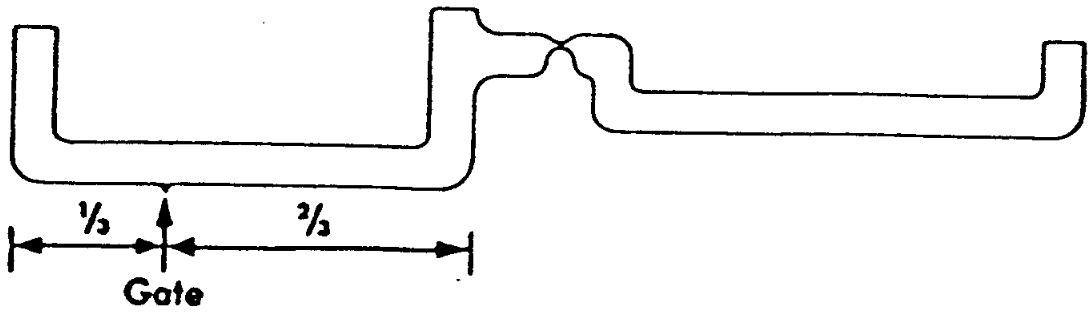
Hinge design



Gate position/Mould filling

Suitable gate away from hinge
Avoid"Stop and GO" flow through hinge by locating gate so that major cavity completely fills before flow starts through the hinge.

Correct gate location for shallow boxes



Mould cooling

Provide ample cooling over hinge area. High melt temperatures due to shear heating through gate can lead to delamination

Mould conditions

Flow of polymer melt through hinge should be rapid to promote orientation. Flow should be in a parallel stream through the hinge. "Stop and Go" flow will produce a layered hinge structure of limited flex life.
For optimum flex life, the hinge should be flexed through its full arc while still retaining moulding heat.

Melt flow

If properly moulded and flexed, virtually any injection moulding grade of PP will give acceptable flex life and strength.

Colourants

Hinge failures can occur due to improper dispersion and particle size of colourants/pigments.

Moulding with nucleated grades

Injection pressure and hold on pressure should be minimum to avoid overpacking and achieving better clarity.

Reduction in cycle time.

In many cases, increase of melt temperatures by 10 to 15 deg. c. helps in eliminating bubbles.

Processing clarified PP

For injection moulding, the following factors should be considered:

A.	Mould finish	♦ A highly polished mould for the best clarity ♦ Optical finish ♦ Draw finish(not recommended)
B.	Melt temperature	♦ Low melt temperature. Raise the melt temperature if bubbles are observed. Usually 190 to 210 deg. c. is a good starting point
♦ C.	♦ Mould temperature	♦ Mould temperature should be adjusted to avoid condensation. Raise mould temperature slightly in conjection with melt temperature to solve bubble problems.
♦ D.	♦ Injectionpressure/Speed	♦ Low pressure high speed mould filling is best for low haze. "Packing" can cause haze and some loss of impact properties.

Polypropylene grades:

It is obvious from the points discussed so far that the properties of end products are decided by various parameters, viz.,

- Temperature, pressure, speed and time set on the machine
- Moulds
- Resin properties

In order to derive the properties of similar resins, ASTM has devised standards, wherein they are injection moulded under identical conditions and tested.

The properties tested of various Repol homopolymer, random and co-polymer grades vis-à-vis some of the competitor grades are given in the following tables.

PROPERTIES OF POLYPROPYLENE GRADES

Homopolymers

Grade	MFI (g/10 min.)	Xylene Solubles (%)	TYS (MPa)	Elongation at Yield (%)	Flexural Modulus (MPa)	Izod Impact Strength (J/m)	HDT (deg. C.)	Spiral Flow (cms)
Repol H110MA	11.0	4.0	36.0	10	1650	27	104	37.0
Resin A	10.0	(2.7)	35.0	12	1400	30.0(24.2)	97	(35.0)
Resin B	10.0	(2.8)	35.0	12	1400	30.)(28.2)	97	(38.0)

Repol Ho33MG	3.3	4.0	34.5	11.5	1700	40.0	104	27.5
Resin C	3.0	(2.6)	33.0	12.0	1400	45.0	95	(28.0)

NOTE: Figures within brackets are values obtained at PARC.

Random Copolymers

Grade	MFI (g/10 min.)	Flexural Modulus (MPa)	Izod Imapct Strength (J/M)	HDT (deg. C)	DSC Melting Temp. (Deg. C)
Repol R120 MK	12.0	1300	60.0	90	150
Resin A	9.0	1380	74	90	153
Resin B	11.0	(1240)	(67)	(86)	151

Note: Figures within brackets are values obtained at PARC.

Impact Co-polymers:

Grade	MFI (g/10 min.)	TYS (MPa)	Elongation at Yield (%)	Flexural Modulus (Mpa)	Izod Impact Strength (j/m)	HDT (deg. C.)
Repol H030 MG	3.0	26.5	10.0	1500	110	95
Resin A	9.0	24.0	12.0	1100	113	88

Repol C015EG	1.5	26.5	10.0	1200	225	95
Resin B	1.5	23.0	12.0	1000	200	85

Repol C080MT	18.0	23.0	7.0	1000	110	85
Resin C	(10.2)	25.8	7.5	1240	88	92

Repol B120MA	12.0	24.0	10.0	1250	70	95
Resin D	13.0	26.0	12.0	1150	68	90

Repol B220MN	22.0	25.0	8.0	1300	80	95
Resin E	26.6	27.2	6.1	1830	76	120

NOTE: Figures within brackets are values obtained .

Application of Poly propylene

Homopolymer

Housewares *
Closures *
Industrial products
Furniture

Random Co-polymers

Housewares *
Disposable medical syringes
Thinwall containers *
Toothbrush handle

Imapct Co-polymer

Furniture
Luggage shells *
Industrial products *
Batteries
Automotive parts
Storage bins *
Thermoware
Large appliances

(*) Applications where Polyethylene is also used..

Comparison of different Polypropylenes

Rigidity	:	HP>RCP>PPCP
Clarity	:	RCP>HP>PPCP
Impact Strength	:	PPCP>RCP>HP

Applications

Houseware:

Homopolymer is used for hot fill applications. Generally preferred grade is Repol H110 MA. However, Homopolymer has lesser impact strength. Random Co-polymers are used where better gloss and clarity are desired. Air tight containers are made with tight fitting lids moulded out of LDPE/LLDPE.

high Density Polyethylene is also used to mould houseware items like kitchen containers, mugs and buckets. Buckets made out of HDPE have better impact strength than those made out of Random Copolymer.

Closures:

Homopolymer has excellent integral hinge properties. Impact Co-polymers are used where enhanced impact properties are required. Flip top lids are made out of Polypropylene because of its hinge properties. Grades used will depend upon the number of impressions in the mould. Multi-cavity moulds need grades of higher flow. Controlled rheology grades of PP are effective in giving warpage free mouldings. When stress- is applied, like flexing at the hinge, the stressed area, i.e. hinge becomes white, when impact Co-polymer is used. This phenomenon is known as stress whitening.

LDPE, LLDPE & HDPE are also used to mold closures. PP closures give good dimensional stability. LDPE/LLDPE is used if flexibility is required in lids.

Furniture:

Homopolymers form a major component of furniture mouldings. Homopolymers have high flexural modulus which help in imparting stiffness to furniture. This can further be enhanced with addition of mineral fillers like talc or calcium carbonate to the tune of 10 to 15%. To improve upon impact strength, Impact Copolymers are added. The blend ratio is determined keeping in view the end properties required for the furniture.

Design also plays a significant part in determining the blend. Preferred Homopolymer grade is H110MA and Copolymer is B030MG or B120 MA.

Disposable Syringes:

Two piece syringes are made with Polypropylene barrel, either Homopolymer or Random Copolymer and plunger with built-in head, moulded out of High Density Polyethylene. Three piece syringes are made with both barrel and plunger of Polypropylene with a latex rubber bunge infront of plunger.

H110MA & R120 MK are the respective Homopolymer ad Random Copolymer grades used, the moulds generally being multi-cavity. Both the grades are approved as per U.S Pharmacopea XXIII. The grades and additives incorporated in them also comply with FDA. Relene M60075 is used for plunger of two piece syringes.

The syringes have to undergo theylene oxide, carbon dioxide mix or gamma sterilisation. The surface of the barrels are flame treated to make them conducive for printing.

Thin wall containers:

The containers have a wall thickness below 1.0 mm. High flow grades are used to mould multi-cavity containers. Controlled rheology grades help in getting warpage free mouldings. Random Copolymer gives good clarity and gloss. Polypropylene is used for hot fill applications, because of high melting point and HDT.

High Density Polyethylene is used to mould thin wall containers, used for frozen food applciations, because of its better impact strength at low temperature. Brittleness temperature measured for HDPE is - 73 deg, Cent.

Toothbrush handles:

Three types of toothbrushes are generally manufactured:

1. Low cost, where PPHP handles are used
2. Medium cost, where RCP handles are used.
3. High cost, where SAN handles are used.
4. A new development is the spring back brushes where the handles are made of PP Impact Copolymers or a combination of PP impact and Homopolymers.

The following grades are used:

PPHP	:	H110 MA
RCP	:	R120MK
PPCP	:	C015EG

Luggage Shells:

Some of the manufacturers use HDPE of high stiffness and good impact strength for this application. Only after the introduction of samsonite luggage in India and the availability of PP. VIP has started moulding the luggage shells with PP.

This market is now mostly dominated by PP Impact Copolymer. The raw material properties required of this grade are as follows:

Medium to high imapct strength
Low blush (less stress whitening)
Good stiffness

Sometimes HDPe or LLDPE is added to PPCP to get low blush.

Repol B030MG or B120 MA is used. Samsonite uses DSM grade Stamylan 75MR10.

Generally preferred grade of HDPE is Ladene M 80064.

Batteries:

Polypropylene battery bodies with built-in separators and their covers with metal inserts are moulded with Impact Copolymer. Since the batteries are placed near the heat source, the Polypropylene grade used in this application is modified with a heat stabiliser additive.

The preferred Impact Copolymer grade is Samsung BJ 500. The equivalent Repol grade is C080MT.

Automotive Parts:

Generally, automotive parts are moulded with PP Impact Copolymers or compounded PP Homo or Imapct Copymers. The Impact Copolymers require a good impact/stifness balance. TO enhance impact strength, EPDM is added to PPCP and melt compounded. These are used in aprts like bumpers. Parts with long flow paths and varying thicknesses require high flow grades. Controlled Rheology can be used to mould these parts without warpage.

The following grades are used; depending on the properties desired:

C015EG
B030MG
B120 MA
B22MN

Storage Bins:

Bins are made with both HDPE and Impact Co-polymer. Perforated thin walled bins are moulded with PP Impact Copolymer of high flow grade. Polypropylene is preferred because of better ESCR properties.

Thermoware:

The inner container is made with PP Homopolymer and the outer with Homo or Impact Copolymer of 11.0 to 12.0 MFI. The top and bottom covers are made with Impact Copolymer of same grade.

Appliances:

Propylene Copolymers as such and compounded with additives are used extensively in appliances like washing machines, fans and refrigerators.

PP Impact Copolymers of various MFI are used depending on the size and thickness of the product.

Large products like twin-tub of washing machine require nucleated grades of PPCP, which have high stiffness and heat deflection temperature. Nucleation also shortens the moulding cycle time. Single tubs of automatic washing machines must have a beat stabilizer additive to withstand the heat given by hot water.

Repol B220 MN has been accepted by M/s. Whirlpool, M/s. Godrej and M/s. BPL to mould large products.

Industrial Products:

Paint containers and lids are moulded with both HDPE and PPCP. UV stabilized grade of HDPE, Relene L 60075 is used, as the containers are subjected to exposure to sunlight in shops. It is advisable to add UV additive in the form of masterbatch to containers made out of PPCP also. Thin walled paint containers called "Bocans" are made out of high flow nucleated PPCP to withstand post moulding forming operations and stackability.

Containers for packing grease are made out of PPCP because of better ESCR properties.

Industrial valves, where chemicals are used as also pump parts, are made out of PP Homo or Impact Copolymer, depending upon the impact strength requirements. H110MA and B120MA are the respective grades of Homo and Impact Copolymers used..

Moulding Problems and Suggested Remedies:

Problem	Possible Cause	Suggested remedy
Sink marks	Material too hot	Reduce cylinder temperature
	Insufficient material shot into cavity	Increase feed
	Insufficient dwell time	Increase cylinder heat
	Gate freezing off too early	Increase mould temperature
	Piece ejected too hot	Increase dwell time
	Insufficient effective pressure in cavity	Increase mould temperature
		Increase cooling time in mould
		Increase pressure
		Increase cylinder heating
		Increase mould temperature
Voids	Gas developed by too hot material	Reduce heating
	Condensation of moisture on granules	Pre-dry
	Shrinkage due to delayed solidification of the core with respect to the outside surface in thick sections	Increase pressure Increase mould temperature
Surface defects around gate	Cold mould Hot mould	Increase pressure Increase injection speed Increase mould temperature Cool mould near gate
Flash formation	Excessive injection pressure	Reduce pressure, Check sprue runners and gates
	Material too hot	Reduce heating
	Mould faces out of line	Realign mould faces
	Insufficient clamp pressure	Increase clamp pressure
	Foreign material of ace of mould	Clean mould faces
	Restriction to flow in one or	Find and remove restriction

	more cavities on multi-cavity mould	
Poor welds Flow marks Poor finish	Material too cold Injection pressure too low Inadequate venting Dirty cavity surface Mould temperature too low Excessive use of mould surface lubricant	Increase heating Increase injection pressure Give enough venting Clean Increase mould temperature Use of mould surface lubricant not recommended
Brittleness	Material cold	Increase heating
	Mould cold	Increase mould temperature
	Material degraded(Yellow specks) Contamination Excessive regrind	Decrease heating Check cylinder and hopper Reduce percentage of regrind
Warping	Moulded in stresses due to: (a) Material cold (b) (b) Overpacking in vicinity of gate	(a) Increase heating (b) (b) Check feed. Reduce injection pressure and heating. Reduce injection time.
	Part ejected too hot	Increase cooling time
Silver streaking	Material cold	Increase heating
	Mould cold	Increase mould temperature
	Condensation of moisture on mould Entrapped vapour	Dry and heat mould
		Pre-dry material
Polymer dripping from nozzle when mould is in the open position	Degradation due to overheating; polymer becomes too fluid and develops gas Nozzle too hot	Reduce temperatures Purge cylinder Reduce heat to nozzle
Burn marks	Improper venting	Clean vents

Gv: