7.1.9 Other Chemicals that May Attack Plastics

Oils

Fatty acids

Alcohols

Detergents

Acids

Environmental stress cracking (ESC) is a major cause of failures in plastics, especially amorphous plastics.

Exposure of polymers to chemicals tends to accelerate the process of cracking or crazing. This process begins with stress much lower than that needed to produce cracks simply in contact with air. The mere effect of both conditions separately, stress or contact with an aggressive chemical, need not necessarily result in ESC. This phenomenon usually occurs when a combined action of both effects occurs.

ESC depends on multiple factors such as crystallinity, surface roughness, residual stress, presence of chemical agents, temperature, and strain level or molecular stretching.

The ESC effect can be minimized by lower residual stress and molecular stretching during the injection process. The use of cold molds should be avoided, as they cause residual stresses that will accelerate the ESC. Polymers of higher molecular weight should be used, because they are more resistant to ESC.
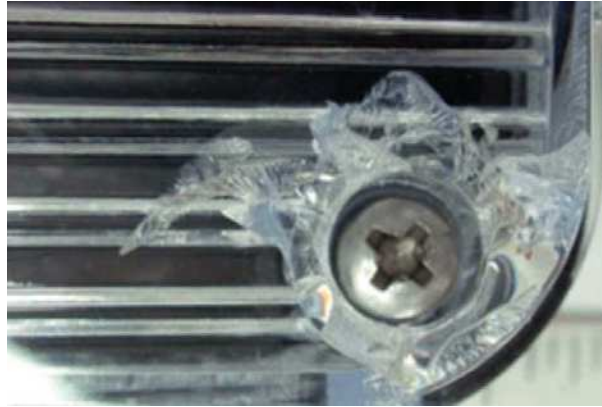
Chemical resistances

🟧	LIMITED RESISTANCE, MINOR OR MODERATE ATTACK. USE BRIEFLY
🟦	GOOD RESISTANCE, MINOR ATTACK
🟩	EXCELLENT RESISTANCE, WITHOUT ATTACK
🟥	LOW RESISTANCE. NOT RECOMMENDED

	LDPE	HDPE	PP	PP C	PS	PC
DILUTED ACIDS	🟩	🟩	🟩	🟩	🟩	🟩
CONCENTRATED ACIDS	🟩	🟩	🟩	🟩	🟧	🟥
ALCOHOLS	🟩	🟩	🟩	🟩	🟩	🟦
ALDEHYDES	🟦	🟦	🟦	🟦	🟥	🟧
BASES	🟩	🟩	🟩	🟩	🟩	🟥
ESTERS	🟩	🟦	🟦	🟦	🟩	🟥
ALIPHATIC HYDROCARBONS	🟧	🟦	🟦	🟦	🟥	🟥
AROMATIC HYDROCARBONS	🟧	🟦	🟧	🟧	🟥	🟥
HALOGENATED HYDROCARBONS	🟥	🟧	🟧	🟧	🟥	🟥
KETONES	🟦	🟦	🟦	🟦	🟥	🟥
MINERAL OIL	🟧	🟦	🟩	🟩	🟩	🟩
VEGETAL OIL	🟦	🟦	🟦	🟦	🟦	🟦
MAX TEMPERATURE °C	80	120	135	121	70	130
MIN TEMPERATURE °C	-50	-100	0	-40	0	-135
AUTOCLAVE STERILIZATION	🟥	🟥	🟩	🟩	🟥	🟩
MICROWAVES	🟩	🟥	🟩	🟩	🟥	🟩
GAS STERILIZATION	🟩	🟩	🟩	🟩	🟩	🟩
DRY HEAT STERILIZATION	🟥	🟥	🟥	🟥	🟥	🟥
GAMMA RAY STERILIZATION	🟩	🟩	🟥	🟥	🟩	🟩
CHEMICAL STERILIZATION	🟩	🟩	🟩	🟩	🟥	🟩
NITROGEN PERMEABILITY	20	3	4.4	4.2	3	
CO2 PERMEABILITY	280	45	92	65	75	
OXYGEN PERMEABILITY	60	10	25	24	15	

Chemical resistances

	LDPE		HDPE		PP		PC		PS		SAN		ABS	
TEMPERATURE	20	50	20	50	20	50	20	50	20	50	20	50	20	50
ACETALDEHYDE														
ACETIC ACID														
ACETONE														
AMMONIUM HYDROXIDE														
AQUA REGIA														
BENZENE														
WATER BROMINE														
BUTYL ACETATE														
BUTYL ALCOHOL														
CHLORINE WATER														
CHLOROFORM														
CYCLOHEXANE														
ETHYL ACETATE														
ETHYL ALCOHOL														
ETHYL OXIDE														
FORMALDEHYDE														
FORMIC ACID														
FUEL OIL														
METHYL ALCOHOL														
METHYL ETHYL KETONE (MEK)														
MINERAL OIL														
SODIUM OXIDE 50 %														
SODIUM CHLORITE 20 %														
SULFURIC ACID 10 %														
SULFURIC ACID 98 %														
TOLUENE														
VEGETAL OIL														

Legend:
- EXCELLENT RESISTANCE, WITHOUT ATTACK
- LIMITED RESISTANCE, MODERATE ATTACK
- GOOD RESISTANCE, MINOR ATTACK
- POOR RESISTANCE (ATTACKED OR DISSOLVED), NOT RECOMMENDED
- NO DATA

Chemical resistances

NOT RESISTANT   NOT RECOMMENDED   RESISTANT

	ABS	EVA	HDPE	LDPE	PA 6	ZYTEL PA 66	PA 12	PC	PMMA	DELRIN POM	PP	X TEL RYTON	PS	SAN
WEAK ACIDS														
STRONG ACIDS														
OXIDANT ACIDS														
WEAK ALKALIS														
STRONG ALKALIS														
SALTS (SOLUTIONS)														
HALOGENS														
ALIPHATIC HYDROCARBONS														
CHLORINATED HYDROCARBONS														
ALCOHOLS														
ESTERS														
KETONES														
ETHERS														
ALDEHYDES														
AMINES														
ORGANIC ACIDS														
AROMATIC HYDROCARBONS														
OIL AND DERIVATIVES														
MINERAL OILS														
FATS AND OILS														
UNSATURATED CHLORINATED HYDROCARBONS														

9.1.2 Flexural Test ISO 178
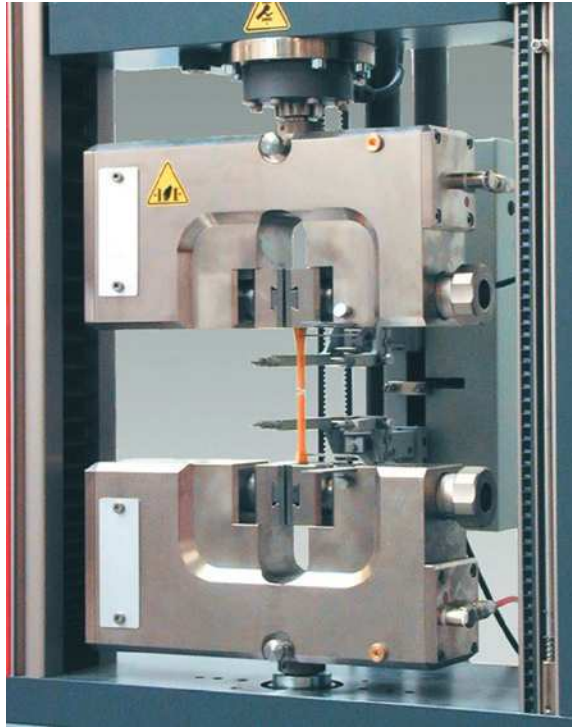
Figure 9.1 Universal testing machine; source: Zwick-Roell

This flexural test measures the extent of bending resistance of a material and its stiffness. To carry it out, a specimen is placed so that it rests on two points. Then, pressure is applied at its midpoint.

Test speed: 2 mm per minute.

To calculate the flexural modulus, the load/deflection curve is drawn. The flexural modulus is determined by the slope of the line tangent to the stress-strain curve in the region where the plastic has not yet been permanently deformed or where elastic strain occurs.
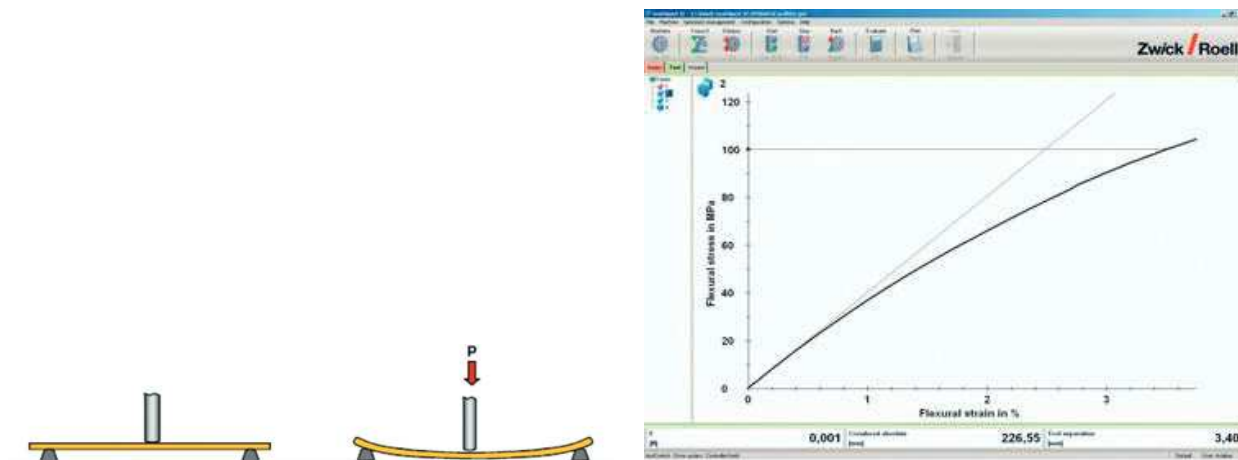
Figure 9.2 Graph of flexural stress; source: Zwick-Roell

9.1.3 Wear Resistance Test TABER ASTM D1044

Figure 9.3 TABER machine; source: Neurtek

This wear resistance test measures the amount of material loss by abrasion or wear.

The sample is mounted on a turntable which rotates at 60 rpm. Loads are applied as weights that push the abrasive wheels against the sample. After a certain number of cycles the test is stopped.

The mass lost by abrasion is indicated in mg/1000 cycles.

9.1.4 Hardness Tests

9.1.4.1 Ball Pressure Hardness Test ISO 2039-1

A 5 mm diameter ball of hardened and polished steel is pressed at 358 N on a sample surface with a minimum thickness of 4 mm. 30 seconds after, the depth of impression is measured.

Hardness pressure is calculated by dividing the load applied by the mark area (N/mm^2).

9.1.4.2 Rockwell Hardness Test ISO 2039-2

The diameter of the ball depends on the Rockwell scale used. The indenter is made of hardened and ground steel. The sample is subjected to a lighter load. A heavier load is then applied and, finally, the lighter load is applied again.

The measurement is based on the total penetration depth achieved. The values are always between 50 and 115 (in Rockwell units).

The scale increases in severity R to M through L.

Table 9.1 Rockwell Hardness Test

Rockwell hardness scale	Lower load (N)	Higher load (N)	Ball diameter (mm)
R	98.07	588.4	12.7
L	98.07	588.4	6.35
M	90	980.7	6.35
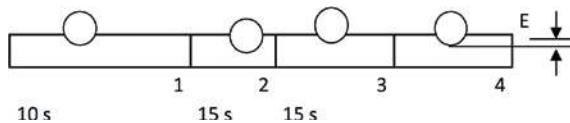
Figure 9.4 Rockwell hardness conditions and sequence

Figure 9.5 Rockwell hardness test machine; source: Zwick-Roell

Rockwell hardness calculation = $130 - E$ (see Figure 9.4).

Units: 0.002 mm (one unit per each 0.002 mm of the mark depth).

9.1.4.3 Shore A and Shore D Hardness Test ISO 868

The Shore A test is intended for soft materials. The Shore D test is intended for harder materials.

Pressure is applied on the sample for 15 seconds. Hardness is read on the durometer scale. Values range from 0 (total penetration: 2.5 mm) to 100 (no penetration).

Shore A hardness ranges from 10 to 90. Shore D hardness ranges from 20 to 90.

Shore A values over 90 require switching to the Shore D scale. Shore D values under 20 require switching to the Shore A scale.
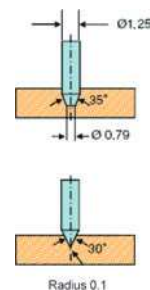
Figure 9.6 Shore A durometer; source: Zwick-Roell

9.1.5 Impact Charpy Test ISO 179 IZOD, ISO 180

The sample specimens are different between ISO and ASTM. See Table 9.2.

Table 9.2 Sample Dimensions for Charpy Impact Test

	Thickness	Length
ISO sample	4 mm	80 mm
ASTM sample	3 mm	60 mm

The impact Charpy test is used to estimate the degree of weakness or strength of material samples subjected to impact. We can thus compare the toughness of different materials.

The sample is placed in the specimen holder. Then, a pendulum hammer (with a hardened steel tip of a certain radius) is dropped from a certain height. The impact causes shearing of the sample material due to the sudden load.

The height difference between the baseline and the residual height reached by the hammer represents the energy absorbed by the sample.

This test can be performed at different temperatures. It can also be performed with or without notches in the sample.

9.1.5.1 Izod Test ISO 180

The result of this test is obtained by dividing the energy required to break the sample by the initial area. The result is expressed in kilojoules per square meter, kJ/m^2.

The Injection Molding Machine

Figure 13.1 Injection molding machine; source: Wittmann-Battenfeld

The characteristics and instructions included in catalogs and technical documentation brochures provided by injection machine manufacturers allow us to determine if a machine can be technically optimal for producing a particular project or part made by an injection molding process.

The injection machine can be divided into two main units: the clamping unit and the injection unit.

The clamping unit comprises, among others, the clamping force, the moving plate stroke, the tie bar free spacing, the mold minimum and maximum thicknesses, clamping and opening mold speed, etc.

The injection unit incorporates several characteristics, like the screw diameter, maximal pressure, L/D ratio, compression ratio, plasticizing capacity, maximal injection volume, heating power, maximal injection speed, etc.

13.1 Clamping Unit

Figure 13.2 Clamping unit

Clamping unit determines:	Clamping force	Mold maximum and minimum thicknesses
	Moving plate stroke	Plate thickness
	Tie bar free spacing	Ejection stroke

13.1.1 Clamping Force

Function and characteristics

- Keeping the mold closed so it does not open due to the injection pressure thrust during the cavity filling and packing.

- When the product obtained by multiplying the projected part area in the mold by the injection pressure needed exceeds the closing force, the tie bars are overstressed and elongate even more. They can exceed the steel elastic tensile limit and break or deflect the clamping plates.

- The mechanical clamping systems are stiffer than hydraulic clamping systems.

- The hydraulic clamping system exerts pressure close to the center of the plate.

- The latest generation of mechanic toggle clamping systems also concentrate strength close to the center of the movable plate.

Movable platen stroke

A longer stroke will make the machine more versatile. In the hydraulic clamping systems, the total stroke of the piston is equal to the sum of the mold thickness and the maximum opening mold stroke.

Tie bars distance

The distance should be the widest possible, provided that the plate bending will be respected.

Stationary and movable platen

They should be parallel. The weight of the movable platen and mold must rest on the base of the bed and not on the tie bars.

Mold size regarding the platen size

According to the rule of thumb, the molds whose base area regarding the movable platen is less than ¼ of the area of the platen should not be placed.

The projected area of the molds used should not be **less than a quarter of the area delimited by the tie bars in the clapping platen. If the mold area were smaller, the plates could be flexed more than recommended.**

13.1.2 Clamping Unit Systems

According to their design, we can distinguish the following sealing systems:

- Mechanic toggle clamping system
- Hydraulic clamping system
- Hydraulic two-stage piston system
- Tie-barless system
- Electrical system
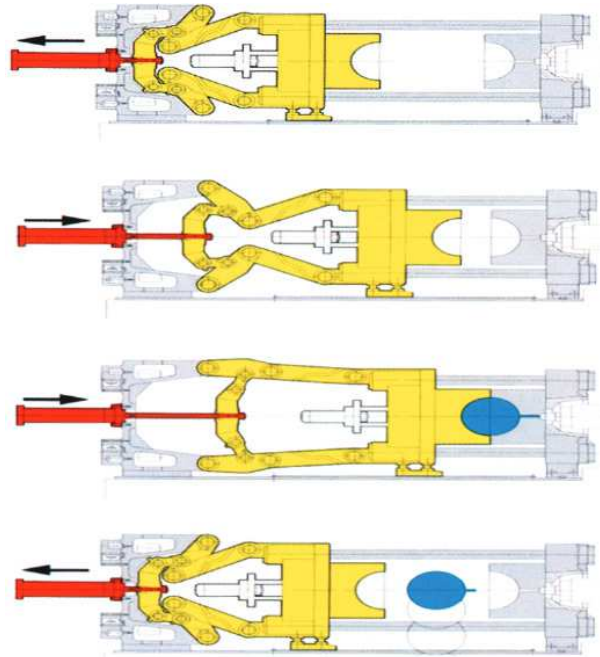
Figure 13.3 Toggle clamping system schema; source: Ascamm

13.1.2.1 Mechanical Toggle Clamping System

Figure 13.4 Tie–barless clamping unit detail; source: Helmut Roegele

13.1.2.2 Hydraulic Piston Clamping System

Figure 13.5 Hydraulic clamping system; source: Ascamm

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There are several kinds of two-stage clamping systems that may be included within the hydraulic clamping systems. The most common system is a mechanical lock in the machine made by two very s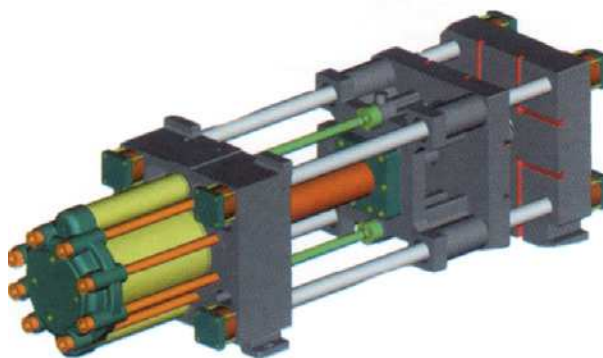mall hydraulic cylinders, driving two locking parts which act over the central axis. Once the central axis is locked, the high pressure enters through a larger cylinder (pressure cylinder), moving it only a few millimeters, to provide the necessary and programmed clamping force.

13.1.2.3 Hydraulic Closure System for Large Tonnages
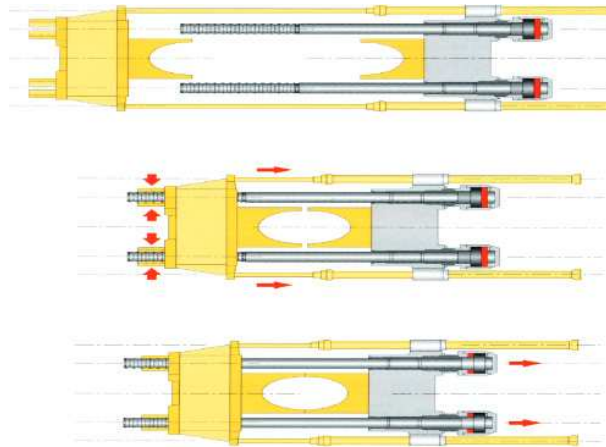
Figure 13.6 Hydraulic clamping system scheme; source: Ascamm

There are as many hydraulic clamping systems as there are machine manufacturers. All of them have tried to develop more versatile, fast, accurate, and low-maintenance systems.

In general, these devices have a system of small-section and low-volume piston to effect a fast closing movement. Thus, this movement requires little volume of oil and, therefore, has a low energy cost and is performed very rapidly. The system is complemented with a large piston. This piston performs the final locking of clamping force by a short stroke.

13.1.2.4 Servoelectric Clamping: Movements Made by Servomotors, Bearings, and High-Precision Screws
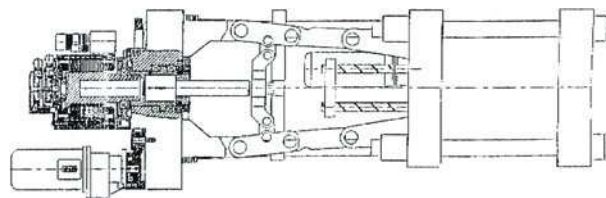
Figure 13.7 Servoelectric motor clamping

Generic Recommendations for Injection Molding Conditions

Attention: follow carefully the recommendations in this chapter. The author assumes no responsibility for incidents, accidents, damage to equipment or people, or adverse outcomes that may occur.

MATERIAL	NAME	MOLD TEMP	MELT TEMP	MELT TEMP	MELT TEMP	MAX MELT TEMP	RESIDENCE TIME
FEP	FLUORINATED ETHYLENE POLYPROPYLENE	200-240ºC	345-370ºC	330-350ºC	335-350ºC	390ºC	5 min

DRYING	
TEMPERATURE	TIME
150°C	2-4 hours

| PERIPH SPEED m/s |
|---|
| 0.5 |

BACK PRESSURE bar
< 60

INJECTION PRESSURE bar
1050

HOLD PRESSURE bar
600

VENTING
DEEP

GATES

SHRINKAGE

COMMENTS
FILTERS, CAPS, AND GASKETS

MATERIAL	NAME	MOLD TEMP	MELT TEMP	MELT TEMP	MELT TEMP	MAX MELT TEMP	RESIDENCE TIME
PEI	POLYETHERIMIDE	175°C	325-410ºC	320-400ºC	310-375ºC	415°C	5 min

DRYING	
TEMPERATURE	TIME
150°C	4 hours

PERIPH SPEED m/s
0.5

BACK PRESSURE bar
< 5

INJECTION PRESSURE bar
2000

HOLD PRESSURE bar
1800

VENTING
DEEP

GATES

SHRINKAGE

COMMENTS
ELECTRICAL COMPONENTS
INTEGRATED CIRCUITS' HOLDERS
f/e 150:1

MATERIAL	NAME	MOLD TEMP	MELT TEMP	MELT TEMP	MELT TEMP	MAX MELT TEMP	RESIDENCE TIME
PEEK	POLYETHER ETHER KETONE	150-160 °C	370-380 °C	350-370 °C	340-350 °C		
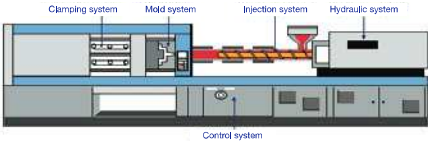
DRYING	
TEMPERATURE	TIME
150°C	4 hours

PERIPH SPEED m/s

BACK PRESSURE bar
< 5

INJECTION PRESSURE bar
1500

HOLD PRESSURE bar
1000

VENTING	
DEEP	

GATES		SHRINKAGE

COMMENTS
CLUTCH PLATES
GEARS
RTI 260
TF 343
f/e 200:1

MATERIAL	NAME	MOLD TEMP	MELT TEMP	MELT TEMP	MELT TEMP	MAX MELT TEMP	RESIDENCE TIME
PSU/PPSU/PESU	POLYSULFONES	150°C	315-380°C	310-370°C	295-365°C	380°C	30 min
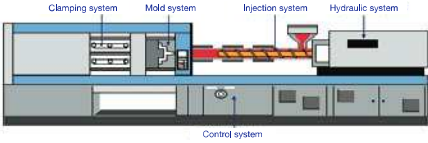
DRYING	
TEMPERATURE	TIME
150°C	3 hours

PERIPH SPEED m/s
0,6

BACK PRESSURE bar
< 1

INJECTION PRESSURE bar
2000

HOLD PRESSURE bar
1200

VENTING	
DEEP	

GATES		SHRINKAGE

COMMENTS
MEDICAL PRODUCTS
AIRCRAFT INDOORS
f/e 60-120:1

MATERIAL	NAME	MOLD TEMP	MELT TEMP	MELT TEMP	MELT TEMP	MAX MELT TEMP	RESIDENCE TIME
PC	POLYCARBONATE	80-120°C	295-315°C	285-315°C	275-300°C	320 °C	7 min
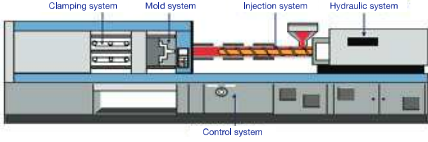
DRYING	
TEMPERATURE	TIME
120°C	4 hours

PERIPH SPEED m/s
0,5

BACK PRESSURE bar
< 10

INJECTION PRESSURE bar
2000

HOLD PRESSURE bar
1200

VENTING	
DEEP	
0.05mm	

GATES		SHRINKAGE
60-70 % thickness		0,6-0,8%

COMMENTS
STRENGTHS   WEAKNESSES
HIGH TRANSMITTANCE   UV RESISTANCE
IMPACT RESISTANCE UNTIL -150°C   HOT WATER, HYDROLYSIS
DIMENSIONAL STABILITY   LOW RESISTANCE TO OILS AND FATS
f/e 30-70:1

MATERIAL	NAME	MOLD TEMP	MELT TEMP	MELT TEMP	MELT TEMP	MAX MELT TEMP	RESIDENCE TIME
PBT	POLYBUTYLENE TEREPHTHALATE	80-100 °C	235-250 °C	225-240 °C	215-230 °C	270°C	2 min

DRYING	
TEMPERATURE	TIME
120°C	2-5 hours

VENTING
DEEP

GATES

SHRINKAGE
1.4-2%

PERIPH SPEED m/s
0.35

BACK PRESSURE bar
< 7

INJECTION PRESSURE bar
1300

HOLD PRESSURE bar
750

COMMENTS

STRENGTHS WEAKNESSES

DIMENSIONAL STABILITY IMPACT RESISTANCE
OUTDOORS STRICT DRYING, HYDROLYSIS
CHEMICAL RESISTANCE TO OILS LOW RESISTANCE TO GASOLINES AND KETONES

f/e 160-200:1

MATERIAL	NAME	MOLD TEMP	MELT TEMP	MELT TEMP	MELT TEMP	MAX MELT TEMP	RESIDENCE TIME
PET	POLYETHYLENE TEREPHTHALATE	130-140 °C	270-285 °C	270-285 °C	270-280 °C	290 °C	4 min

DRYING	
TEMPERATURE	TIME
130°C	5 hours

VENTING
DEEP

GATES

SHRINKAGE
1.2-2%

PERIPH SPEED m/s
0.3

BACK PRESSURE bar
< 10

INJECTION PRESSURE bar
1600

HOLD PRESSURE bar
1000

COMMENTS

STRENGTHS WEAKNESSES

UV RESISTANCE STRICT DRYING
ACIDS RESISTANCE PERMEABILITY TO CO_2
STIFFNESS

f/e 350:1

MATERIAL	NAME	MOLD TEMP	MELT TEMP	MELT TEMP	MELT TEMP	MAX MELT TEMP	RESIDENCE TIME
PPO	POLYBUTYLENE OXY MODIFIED	60-110 °C	250-290 °C	220-270 °C	219-250 °C	290 °C	

DRYING	
TEMPERATURE	TIME
100°C	2 hours

VENTING
DEEP

GATES

SHRINKAGE
0.5-0.7%

PERIPH SPEED m/s
0.4

BACK PRESSURE bar
< 10

INJECTION PRESSURE bar
1800

HOLD PRESSURE bar
1400

COMMENTS

STRENGTHS WEAKNESSES

DIMENSIONAL STABILITY IMPACT RESISTANCE
IMPACT RESISTANCE RESISTANCE TO GASOLINES AND KETONES

f/e 100-200:1

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25.1.2 Streaks

25.1.2.1 Streaks Caused by Burns

This thermal degradation is caused by excessive temperatures and/or residence times; gases are generated by the decomposition of the polymer or additive pack. Brown or silver streaks can be seen in the workpiece surface.

When the molecular structure is thermally degraded, the molecular chain can decrease, and silver streaks appear. The change in the macromolecules causes a brownish discoloration.

The heat required for thermal degradation of the material may come from the injection unit setting, from an excessive shear during dosing (back pressure) by a high peripheral speed (rpm), from an excessive shear on sharp edges, from sudden changes of direction, etc.

Verifications—To Check:

- Check if the melt temperature is near the upper limit recommended or even above.
- See if the streak appears behind narrow sections of passage of material.
- Check if the defect can be reduced by decreasing the injection speed.
- Check if the reduction in the melt temperature has a positive effect on the defect.
- Check if the degradation streak is affected by a high residence time caused by interruptions, excessive cycle, or inadequate machine size.
- Check for a considerable amount of regrind material or dust from the regrind process.
- Check there are no retentions inside the hot runners.
- Check that the nozzle is working properly and there are no retentions. Pay attention to shut-off hydraulic nozzles.
- Check that time and temperature of pre-drying material are not excessively high.
- Check that the shear originated during the dosing by screw rotation is not excessive (keep within the recommended limits for the material).

25.1.2.2 Streaks Caused by Moisture

They appear on the part surface with the shape of comet trails. The surface surrounding the silver streaks is porous and rough. This can be seen under a microscope.
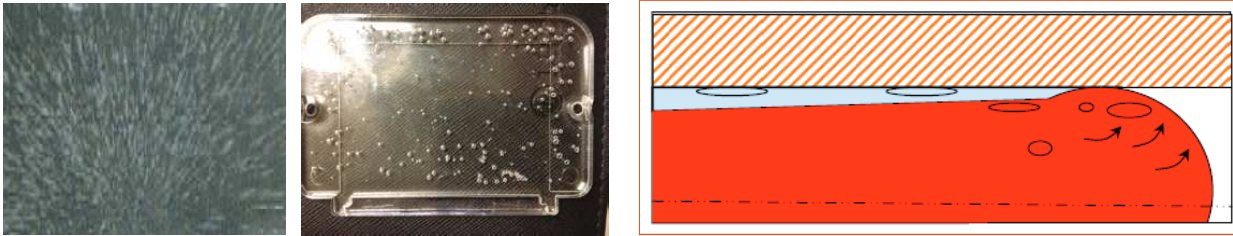
Figure 25.4 Melt flow and gas bubles during the cavity filling; source: Ascamm

Residual humidity in the melt causes gas evaporation of water inside. These gas bubbles tend to come out to the surface by the advancing flow effect from inside to outside. Trapped bubbles burst at the surface with the application of pressure, creating the visible effect of the streak.

Verifications—To Check:

- Hygroscopic materials such as PA, PBT, ABS, PC, PMMA, TPU, and others need a thorough pre-processing dehumidification. Check the polymer manufacturer's recommendations.

- When material is ejected, the purge bubbles may appear and release steam if the material is not sufficiently dehumidified (inconsistency of purging).

- The flow front has crater-like structures.

25.1.2.3 Streaks Caused by Trapped Air

Figure 25.5 Examples of streaks caused by trapped air; source: Ascamm

They appear as matte, silver, or white streaks near the last filling zone. They also appear in areas with ribs, thickness variations, letters, reliefs, etc. The air concentrated in the ribs and grooves can be surpassed by the flow front and be trapped in the melt.

The air unable to escape during filling goes to the surface and becomes compressed in the direction of flow during the hold pressure stage.
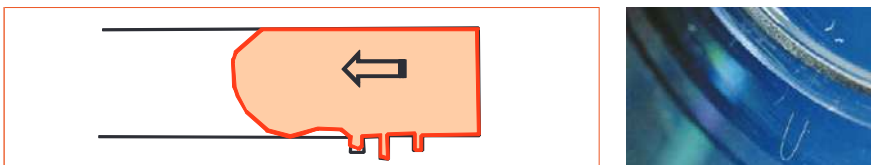
Verifications—To Check:

■ Make sure that the suction is not the cause of the problem.

■ Perform tests decreasing the injection speed to minimize the problem.

■ See if ejection purge shows bubbles or explosions and if the flow front has craters.

■ Verify the back pressure. If the back pressure is low, the air is not completely removed from the pellets during dosing.

■ Verify possible wear in the screw barrel of the plasticizing unit.

25.1.3 Weld Lines

When several flow fronts face each other, the flow front edges that are rounded come in contact and are crushed against each other. If temperature and pressure are not high enough, the corners in contact with the cavity will not bind on the entire surface and microcracks appear. Fluids do not mix homogeneously. At this time it is very important that the aeration or venting of the mold has been effective.

Figure 25.6 Weld lines

Figure 25.7 Weld lines between two flow fronts can cause air entrapments

Verifications—To Check:

The flow fronts must coincide quickly and with a higher temperature to reduce the incidence of the defect. To achieve this, the following conditions could be tested and checked:

■ Material with higher melt flow

■ Increased mold temperature

■ Increased melt temperature

■ Increased injection speed

■ Proper venting in critical areas

■ Increased hold pressure

■ Gates dimensions

■ Gates location

Sometimes, we can adapt overflow areas in the welding lines position to promote that the weld line be placed out of the critical zone of the part. However, we must re-work and cut this area later.

25.1.4 Grooves, Vibrations, and Corona Effects

Very fine grooves formed by concentric rings, like those of a vinyl record, can be seen on the surface of the part. Their appearance is due to the formation of a solid layer behind the flow front, which is cooled very rapidly. The cooling of the peripheral layer also causes cooling of part of the flow front. When this happens, a new layer from the melt flow passes through the cold flow front, creating a new groove or line.
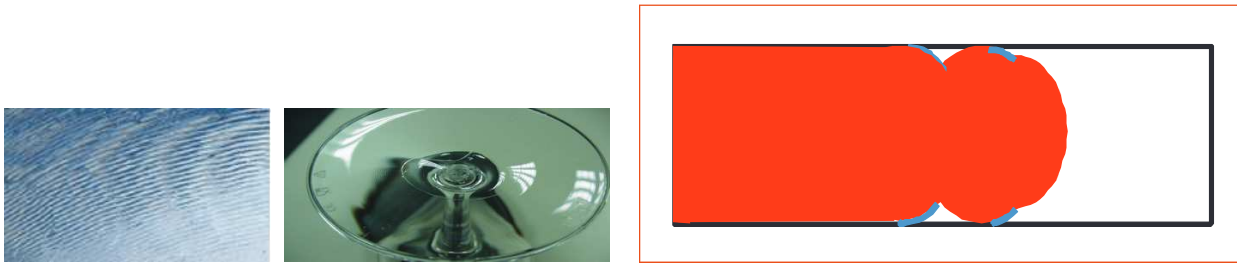
Verifications—To Check:

These actions help to increase the speed of advance of the flow:

- Increase the injection speed
- Increase the maximum injection pressure (no limited process)
- Increase the melt temperature
- Avoid small gates and channels
- Use materials with less viscosity (more fluid)

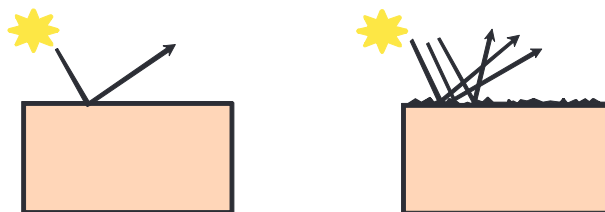## 25.1.5 Gloss

Figure 25.8 Gloss

Figure 25.9 Left: high gloss, light reflection, narrow intensity distribution; right: low gloss, light reflection, broad intensity distribution

The brightness of a part is due to the refraction of light on its surface. Gloss differences are due to the different behavior of this surface, caused by various reasons (differences in mold surface, shrinkage differences, cooling differences, different mold temperature, inner vacuoles, orientation of pigments, fillers, etc.).
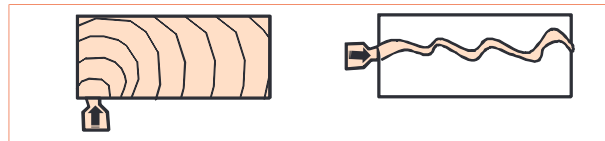
Verifications—To Check:

- Check the mold temperature (a high temperature causes parts with higher gloss)
- Check the melt temperature (a high temperature causes parts with higher gloss)
- Injection speed: a high injection speed usually increases the part's surface gloss
- Cavity mold surface texturing
- Design of ejection system
- Radiate sharp corners
- Design with uniform thickness
- Provide operational venting channels
- Take into account the different temperatures in molds, runners, ejectors, etc.; these thermal gradients generate differences in surface gloss

25.1.6 Jetting

Jetting is a free melted material jet forcing the melt to zigzag within the cavity. When the melt touches the walls of the mold, it is cooled and cannot melt homogeneously with the rest of material that goes into the cavity.

Figure 25.10 Correct and incorrect gate position; it can cause jetting in the molded part

Verifications—To Check:

- Reduce first injection speed to pass through the gate
- Increase melted mass temperature

Advice:

- Use lubricant grease or oils that are compatible with the polymer used
- Manufacture molded parts without stress. With this purpose:
  - Use the adequate melt temperature as recommended by the manufacturer
  - Minimize residence time of the material in the injection unit
  - Dry the material properly

26.2.2 Material Selection

If the stresses exceed the strength of ABS, it shall be broken without remedy. If it is possible to know the stresses applied, we can find a material that brings us a safety margin during its use.

In summary	
Problem	Broken parts during use
	Material: ABS
Causes	Stress cracking
	No radii
	Polymer degradation
Advice	Replace chemicals
	Apply radii
	Change melt and dry temperatures

26.3 Broken Gears

> The absence of radii, a careless dehumidifying, and the low crystallinity of the material obtained in injected parts causes brittle fractures under stress during use.

I received several parts with visible breaks. I started watching the pieces for possible problems. They were mechanical parts used in gears, with a central housing for a square shaft. I applied a flame to try to identify the type of material and I got a strong scent: it smelled similar to a "burning horn". When the piece burned, it formed dripping threads. It was made of polyamide (PA).

I also noted bursts and microbubbles in the surface of most parts received. Some had pores or vacuoles in the section break. I also saw the remains of a direct gate. All pieces had a very pronounced weld line in front of the gate.

Possible Causes of Brittleness

The samples indicate that the dehumidifying was not enough. There are traces of humidity everywhere.

The central core, squared, is not radiated on the front side, where it meets the bottom wall of the piece. This generates shear and accumulation of stresses. I

passed the pen on the radii and could clearly see a double line, indicating the absence of radius.

I observed two types of gate: a submarine and other direct by piece. If both work separately and individually, they are not sufficient to fill and package the part.

Advice:

- Dry the raw material (in this case PA) at 80 °C for 12 hours.

- Increase the mold temperature for maximum crystallinity of the polymer (80 °C would be suitable). This would provide more and better mechanical properties.

- Humidify or condition the parts and prepare them before including them in the assembly step. PA parts have to be conditioned to reach their equilibrium of humidity absorption, to achieve the properties of use.

- Radiate cores in the central square of the base, where it meets the wall of the part.

- Increase direct gate in order to compensate the shrinkage that promotes the internal vacuoles.

In summary	
Problem	Broken parts during use
	Material: PA
Causes	Mold temperature
	No radii
	Irregular drying
	Gate with incorrect dimensions
Advice	Increase mold temperature
	Apply radii
	Correct and proper material drying
	Increase the gate dimension

26.4 Unfilled PC Cover

Improper thickness of the wall connected to the gate prevents the proper filling of the transparent PC sheet.

In this case, the problem was in a transparent cover made of polycarbonate (PC). The filling of the cavity was hard and flow lines and corona effect (see Chapter 15) were seen in areas far away from the gate.

After cutting the piece, I noticed that the wall where the gate is located (this is in the center of the part) was too thin (1 mm) in relation to the perimeter side walls (4 mm), rather thick.

The "thick to thin" rule is not observed in this case. Neither has been included a semi-spherical facilitator flow in front of the gate. This simple mechanization

facilitates filling, especially at first, and minimizes friction and shear near the gate.

The gate is too small for the volume and section of the part. If we double the gate section, we quadruple the volume that can pass through it.

It is recommended that the wall connected to the gate should be the thinner wall of the part. Flow restriction prevents the filling and holding pressure of the cavity in the thicker areas.

Advice:

- Review design to increase the thickness of the wall connected to the gate
- Warm the mold (PC can be worked at 90–100 °C)
- Have a facilitator flow in front of the gate
- Increase the gate section for easy filling and packing of the cavity
- Use a more fluid PC

In summary	
Problem	Incomplete parts
	Material: polycarbonate
Causes	Wall design with incorrect gate
	No flow facilitator in front of gate
	Gate with inadequate dimensions
Advice	Increase mold temperature
	Mechanize facilitator for easy filling
	Increase the gate section
	Use more fluid material

26.5 Dimensional Instability in Parts

> Cavity filling imbalances cause unacceptable dimensions differences in the parts.

In this case, the difficulties encountered to manufacture consistent dimensions in precision parts make it impossible to carry out the work.

During fabrication of a colored transparent polystyrene (PS) ring, the degree of dispersion of the dimension obtained exceeds the specified tolerance for this product. The tolerances for these products are very low and cannot stabilize the dimensions variation range.

After a meeting with the customer, I visited the injection plant to observe the full injection process. The three plates mold has eight cavities. Such a high number of cavities is not recommended when one wants to make very high precision parts.

I decided to measure the parts and analyze the cavity number groups. I saw a significant spread between the parts obtained from different cavities number.

At this point I wondered:

■ Is the switching point correct?

■ On many occasions this point is not properly programmed, causing:

1. Overcompaction

2. Partial filling of the part during the hold pressure stage, without speed control

■ Is the injection pressure limit being reached?

  Often, the filling is limited by the injection pressure limit and we have no control of the speed of filling the cavity.

■ Does the flow front advance uniformly?

  Normally, injection speed profile curves are set flat or with a constant injection volume during all the filling stroke. This causes the flow to accelerate or decelerate according to the sections of passage of the material, runners, etc. We do not control the flow front speed.

■ Is the hold pressure time right?

  Normally, this time is set depending on the weight (there are two limits) or depending on the part (dimensions, flashes, grips, etc.), or when the part fails to gain weight. We should not make perfect runners by increasing hold pressure time, cycle, or energy expenditure.

■ Do we want to switch to hold pressure stage by hydraulic pressure?

  Normally, this system is not too used although it is the most reliable (outside the cavity pressure switching) and is available in almost all current standard machines. We must make better use of available technology in factories.

We make a start from zero, following these steps:

Injection Pressure Limit

Set the pressure value above the real pressure needed to ensure that we do not limit the injection process. There is nothing worse than a pressure-limited process.

Holding Pressure

Set the hold pressure time and hold pressure to zero.

Switching Stroke

Set the switching point close to the dosage point in order to inject a little injection volume in the cavity. We want to fill only a small amount of the part.

With these premises, we can start the progressive filling of the cavities.

During filling, we modify the switching point position to inject a greater quantity of material in each cycle. Suddenly, we find that certain cavities are completely filled while others are not. The eight cavities have not been filled in a balanced way. The probable cause is the small differences in gates and/or runners channels, in addition to the "spiral" effect. Here we identify a cause of the spread of dimensions between cavities.

We cannot obtain narrow dimensional tolerances in an unbalanced mold during filling.

After obtaining the correct switching point position, we proceed to pressurize and pack the cavities. We use the gate seal analysis. First we select a hold pressure time excessively overrun, which ensures that the gate will be closed or sealed and a low hold pressure level.

We increase the pressure values until the pieces are aesthetically and dimensionally correct. At this point we have an excessive holding pressure time, which ensures the gate seal. Then we weigh the injected parts without runner and we gradually reduce the holding pressure time, controlling the weight of each shot.

There will come a moment when the weight will decline. This indicates that the gate was not sealed. So we increase in the previous the step holding pressure time, 1 second or so, and ensure the sealed gate with the shortest hold pressure time possible and, therefore, the optimum time.

Finally, we decrease the pressure injection limit to a value slightly above the necessary real filling pressure. In this way we ensure that it does not interfere with normal filling cavities, and it becomes a security element to any clogged or closed cavity.

With these steps, the dimensions of injected parts are dimensionally repetitive and consistent and will be dimensionally stable although the cavities filled first are bigger. To eliminate this last problem we have to ensure that the dimensions of channels and gates are identical.
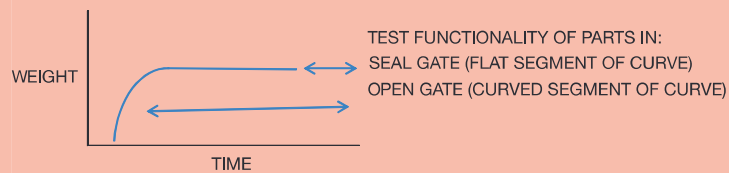

Hold pressure

Key points:

    1. Do we work with a sealed gate or with an open gate?

    2. How much time will be set in hold pressure stage?

    3. How much hold pressure will be set?

Points 1 and 2 determine if we work with sealed or open gates.

    1. Place a hold pressure time much longer than necessary to seal the entrance

    2. Start with a low hold pressure and gradually increase until the piece is OK. This pressure is to study the sealing time of the gate. It is not the pressure with which we will work

    3. Weigh the part

    4. Gradually reduce hold pressure time and weigh the part until we have 0.5 seconds holding pressure

    5. Reflect times and weights on a chart

TEST FUNCTIONALITY OF PARTS IN:
SEAL GATE (FLAT SEGMENT OF CURVE)
OPEN GATE (CURVED SEGMENT OF CURVE)

WEIGHT

TIME

Sealed gate processes are better and more stable.

Advice:

■ Match and balance filling between cavities; adjust gates and channels if necessary

■ Change the injection process for an optimum hold pressure time with sealed gate

■ Adjust any cavity if it is outside the tolerance range

In summary	
Problem	Process with little robust dimensions
	Dimensional instability
Causes	Cavity unbalanced
	Unoptimized hold pressure
Advice	Balance filling between cavities
	Set post-pressure correctly
	Work with sealed gate

26.6 Insufficient Filling

➡ A change in the polymer used may hinder the filling of the cavity.

In this case, the part was made with a blend of PC-ABS. This blend is a material of high/medium viscosity. The flow path respect to the average thickness of the part was quite unfavorable. The average thickness of the part was 2.5 mm.

Looking at the gates, two submarine gates of small dimensions were connected to the rear walls. These walls were too thin.

In this case there had been a change of material. Previously, the material filled perfectly with this mold. The filling problems began when it was replaced by the new blend.

Given the large difference in viscosity between the two materials, it was necessary to review and modify certain aspects of the mold to properly fill the cavity.

Although the value of the MFI in each case is important, it can lead to certain errors. For example, if we look at a PP and a PC with a melt index of 4 g/10 m, this does not mean that we can fill the same cavity with both materials. In the case of PP, its viscosity may decline by a factor of 100 because of the shear rate, and, in the case of PC, the viscosity can be reduced by only a factor of 5.

Advice:

■ Modify distribution channel, increasing the section

■ Increase the section of the runner and submarine gate

■ Increase the gate section

■ Increase real walls section connected to the gate