INJECTION MOULDING GUIDELINES
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INTRODUCTION

This guide was prepared with the objective of helping injection moulders to run their projects smoothly without problems deriving in costly situations. The guide is divided in two main parts related to the stage of the project: design or production. The first one will offer some clues for selecting the right equipment, tools and processing parameters in order to achieve a good performance in your injection projects when using ELIX materials. Different aspects like the selection of an appropriate injection machine, screw design, screw rotation speed, drying conditions, among other processing parameters will be dealt with.

The second part will assist injection moulders during production to face some of the most common defects found. Each defect will be described with the signs needed to recognize it, the root causes of the defect and a procedure to solve the issue. Different possibilities will be contemplated in the troubleshooting procedures and they will be shown in the recommended order to follow. Only one parameter must be changed at a time in order to avoid interactions that may bring confusion about the correct path to solve the problem.

The procedures and hints contained in this guide are not intended to be followed literally but to serve as guidance. Selection of equipment, tools and processing parameters must be done case by case taking into account a great number of variables and no guide can contemplate all the possibilities. ELIX Polymers will not accept any responsibilities for the usage of this guide or any of the contents here contained. For more detailed information about any specific application, please contact our technical customer service.
ELIX Polymers, the European engineering plastic player, started to act independently on October 2011, with a manufacturing capacity of 180kton/year and the experience of 40 years producing ABS and its blends at our plant in Tarragona (Spain).

State of the art technology, safe and environmentally responsible processes and an experienced sales & technical marketing team are the back-bone of our commitment to continuously bring value to our customers based all over the world.

ELIX Polymers products comprise a wide range of ABS products and derivates formulated for several processing techniques and different applications.

ELIX Polymers offers to their customers a wide range of injection moulding grades for several applications: general purpose, high heat, medical, food contact, electroplating, flame retardant, among others.

Every ELIX Polymer ABS grades can be prepared under a catalogue of more than 2,000 colors in addition to the several additive packages that fulfill our customer requirements.
Selecting the right machine size and the auxiliary equipment is not an easy task and several data must be known:

<table>
<thead>
<tr>
<th>Material characteristics</th>
<th>Shot weight and volume</th>
<th>Mould mounting dimensions</th>
<th>Clamping force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeding zone</td>
<td>(50% - 60%)</td>
<td>(20% - 25%)</td>
<td></td>
</tr>
<tr>
<td>Compression zone</td>
<td>(20% - 25%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metering zone</td>
<td>(20% - 25%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ELIX Polymers recommends the use of standard screw geometry where a feeding zone, a compression and a metering zone are present. Lengths of those zones should be kept in the following ranges:
As ELIX provides all grades in a great range of colours, there is no need for the processor to use specific designs with mixing or shearing sections in the metering zone. Only in the case the processor needs to colour ELIX grades the presence of these sections may be desirable.

Screw diameter should be chosen on the basis of the shot weight (or volume) needed to fill the mould. Recommended metering stroke is between 1D and 3D (where D, is the screw diameter). Larger values will result in to defects due to air entrapment and of properties. This residence time range should be shortened in the case of Flame Retardant grades as these materials are especially sensitive to heat and flame retardant action could be lost.

Open nozzles are recommended. Shut-off nozzles can be used in easy flow materials but attention must be paid to degradation issues related to excessive shear or residence time. All nozzles should be heated and controlled independently. Dead spots and/or flow divisions must be avoided in all cases with a proper design using flow engineering tools.

shorter values will lead to thermal degradation due to excessive residence times.

Other recommended screw design parameters are an L/D ratio between 20:1 and 23:1, a flight depth ratio between 2:1 and 2.5:1 and a pitch of 1D. Variations from these parameters must be tested individually.

Residence time of ELIX materials should be kept between 4 and 6 minutes. Lower residence times could lead to insufficient melt formation while greater values will generate polymer degradation and loss of properties. This residence time range should be shortened in the case of Flame Retardant grades as these materials are especially sensitive to heat and flame retardant action could be lost.

Open nozzles are recommended. Shut-off nozzles can be used in easy flow materials but attention must be paid to degradation issues related to excessive shear or residence time. All nozzles should be heated and controlled independently. Dead spots and/or flow divisions must be avoided in all cases with a proper design using flow engineering tools.

On all nozzles care should be taken to ensure a good fit between the diameter of the nozzle aperture and the diameter of the gate. Alignment of the sprue-bush and nozzle aperture must be checked to avoid malfunctions.

In the case of using mineral filled or glass filled grades attention should be given to the abrasion protection in screws and barrels. While using flame retardant grades attention should be given to corrosion protection in screws and barrels.
4.1 DRYING

ABS is an hygroscopic polymer and therefore it will absorb moisture from the surrounding air. Residual moisture in the granules should be removed prior to processing in order to avoid problems. Storage of dry pellets should be done in moisture-proof containers and when possible dry pellets should be processed immediately after drying. Residual moisture could lead to surface defects, bubbles, moisture streaks, and in extreme cases foamy parts.

Drying time does not start until granulates reach the specified temperature. Most drying problems are caused by a poor temperature distribution within the material. To solve this, the temperature should be measured at several points in the hopper. Notice that drying time should be doubled with a 10ºC reduction compared with specified values.

Recommended drying conditions for ELIX ABS grades are the following:

<table>
<thead>
<tr>
<th>ELIX GRADE</th>
<th>DRYING TEMPERATURE (°C)</th>
<th>PERMITTED RESIDUAL MOISTURE CONTENT (% WEIGHT)</th>
<th>DRYING TIME (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CIRCULATION DRYER (50% FRESH AIR)</td>
<td>FRESH AIR DRYER (HIGH SPEED)</td>
</tr>
<tr>
<td>ELIX ABS</td>
<td>80</td>
<td>&lt;0,15</td>
<td>4 - 6</td>
</tr>
<tr>
<td>ELIX Ultra</td>
<td>90</td>
<td>&lt;0,05</td>
<td>4 - 8</td>
</tr>
</tbody>
</table>
4.2 SETTING TEMPERATURES

Temperature profiles should depend on the molecular ratio in the formulation, with higher acrylonitrile content requiring a higher processing temperature range. In the table below ABS temperature processing ranges can be found. Barrel temperatures shown below are recommendations for achieving the correct melt temperature and appropriate modifications to these recommendations should be done by the processor attending to the specific characteristics of each machine and application. Performing direct temperature measurements in the melt is highly desirable.

Problems derived from malfunction on thermocouples and temperature regulators can be avoided with simple routine checks.

Even with correct processing conditions, volatile organic compounds and other decomposition products could be emitted during processing. In order to avoid risks to health due to exposure to these products, tolerance limits for the work environment must be ensured by an efficient exhaust ventilation and fresh air at the workplace in accordance with our Safety Data Sheets.

<table>
<thead>
<tr>
<th>ELIX GRADE</th>
<th>MELT TEMPERATURE (°C)</th>
<th>MOULD TEMPERATURE (°C)</th>
<th>BARREL TEMPERATURE (°C)</th>
<th>FEEDING SECTION</th>
<th>METERING SECTION</th>
<th>COMPRESSION SECTION</th>
<th>NOZZLE</th>
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</thead>
<tbody>
<tr>
<td>ELIX PC/ABS</td>
<td>200 - 240</td>
<td>60 - 80</td>
<td>180 - 210</td>
<td>210 - 230</td>
<td>220 - 230</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>ELIX FR GRADES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.3 SCREW SPEED AND BACK PRESSURE

Typical aspects to be taken into account when setting screw speed are achieving a correct polymer melting without overheating and minimizing cycle time. With these objectives in mind, ELIX recommends the following peripheral speeds (m/s) which can be later correlated to screw revolution units (min⁻¹) depending on the screw diameter. Back pressures should be set in order to assure an appropriate melting of the polymer. Back pressure levels in the order of 100 - 150 bar (hydraulic pressure between 5 and 15 bar) should ensure complete melting of the material.
4.4 INJECTION AND HOLDING PHASE

Injection and holding pressures (also injection speed) will depend largely on the characteristics of the end product and must be high enough to achieve sufficient cavity pressure to enable a complete fill of the mould cavity, without sink marks. Those values must be low enough to avoid excessive shear in nozzle and mould in order to prevent material degradation. The pressure values can differ considerably for a given mould, depending on factors such as injection speed, melt temperature and nozzle geometry.

Injection speed should be set depending on the size and shape of the moulded part and should be as fast as possible. Injection pressure should be kept high enough in order to ensure that the pressure value does not drop below the required set point values during the entire cycle. An injection pressure drop at the end of injection will mean that injection pressure is too low or the set speed is too high. Best results will be achieved if injection speed is set slow at the start of the injection process and sharply increased after. Implementing a speed profile can lead to a constant flow-front and therefore avoid flow engineering problems like entrapped air, weld lines, bubbles, tear drops, streaks, diesel effect, among others. Reduction of the injection speed directly prior to switchover can help to prevent a backflow of melt.
In order to avoid overpacking of the injected part it is important to switch to holding pressure at the right moment. Holding pressure will compensate the shrinkage of the part when cooling. Levels of holding pressure will depend on the nature of polymer (amorphous or semi-crystalline) and required surface quality. For economic reasons, holding pressure must be set as low as possible.

Holding pressure should be kept until the polymer in the gate has solidified in order to avoid back flow of the melt. Minimum holding pressure should be set through weight checks on the moulded part or from the characteristics of the cavity pressure curve.
4.5 COOLING TIME

Cooling time will be affected by the material type, wall thickness, mould temperature and melt temperature. The most influencing factors are wall thickness and mould temperature while melt temperature will have little influence on the cooling time.

* Melt Temp / Mould Temp
4.6 CLEANING THE PLASTICIZING UNIT

A good cleaning procedure should minimize material and colour change times as well as the quantity of cleaning material used. With these objectives in mind, ELIX recommends planning colour changes from light colours to dark ones and from low viscosity to high ones. The plasticizing unit should be purged with an appropriate high-viscosity purging compound immediately after use.

Purging compounds will normally fall into one of the following cleaning mechanisms:

1. Abrasive mineral filled material. When using these kind of compounds, firstly, the barrel should be kept full of material and then the purging compound slowly added. Once the purging agent has displaced the production resin, increase back pressure to the maximum safe amount. Increase screw speed while keeping the screw in the forward position. Continue until no contamination can be seen in the purging compound. If remaining contamination is found in the check ring and nozzle areas, perform a series of high speed shots to the air.

2. Chemical purge to break down resins and contaminants. In this case, procedure described above should be followed except for the soak time. Production material should be displaced by the chemical purging compound until the purge exits the plasticizing unit. Then, stop the screw and let the material soak between 10-15 minutes (always follow purge compound manufacturer recommendations) so the purging material expands into negative flow areas. Variation of screw speeds during purging can help to obtain faster results.
3.

Hard resin filled with surfactants. Follow the procedure described for the abrasive mineral filled material.

If purge is done with standard materials, the following should be chosen depending on the material to be purged:

<table>
<thead>
<tr>
<th>ELIX GRADE TO BE PURGED</th>
<th>PURGE MATERIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELIX ABS</td>
<td>CAST ACRYLIC, POLYSTYRENE</td>
</tr>
<tr>
<td></td>
<td>NATURAL ABS, SAN</td>
</tr>
<tr>
<td>ELIX PC/ABS BLENDS</td>
<td>CAST ACRYLIC, POLYSTYRENE, HDPE</td>
</tr>
</tbody>
</table>

ELIX Polymers
TECHNICAL DOCUMENT
CLEANING TIPS & HINTS

1. If hard incrustations are found, the use of a cleaning barrel agent for cleaning followed by the use of a purging compound is advised.

2. When incrustations are difficult to remove with the indications above, it could be necessary to dismantle the screw and clean it manually. To do this use a steel or bronze brush for polishing while the screw is still hot and finish cleaning with a cloth and a polishing paste. Take caution with wear caused by abrasive cleaning mediums (e.g., sand paper). Ultrasound hot baths with specific detergents can help cleaning difficult residues.

3. Pyrolysis furnaces followed by the use of ultrasonic baths are another recommended cleaning technique but caution must be taken with screw and barrel surface treatments as high temperatures can damage them. Check manufacturer indications to set furnace temperature and time. Never use acetylene torches as part of the cleaning procedure as they can destroy the surface treatment of the screw leading to loss of wear resistance, mechanical properties and in the most severe cases breakage due to torque.
Factors such as machine specifications, injection moulding parameters, compound properties, and mould geometry, will affect the final properties and quality of a moulded part. The high quantity of factors involved in the final result will most of the times make it hard to recognize the origin of the problem and take immediate corrective actions.

This guide aims to help the processor in determining which factors have a relevant influence on certain quality problems and help with suggested courses of actions in order to reduce or avoid problems and/or defects. Flow diagrams will be shown in each specific case to be used as a procedure to detect and correct adverse effects.

When trying to solve any part quality issue, changes in processing parameters should be done parameter per parameter, as multiple changes could have mutual influence and lead to interpretation failures. After any change, multiple cycles must be completed in order to assure stable operating conditions.
JETTING

DIESEL EFFECT

STRESS WHITENING / CRACKS

VISIBLE EJECTOR MARKS

DEFORMATION DURING DEMOULDING

FLAKING OF THE SURFACE

COLD SLUGS (FLOW LINES)

ENTRAPped AIR (BLISTERS)

DARK SPOTS
5.1 MOISTURE STREAKS

**CAUSE**
Hygroscopic materials tend to absorb moisture from the air. If not correctly dried, water vapour will be formed in the melt causing streaks, voids and surface defects.

**SIGNS**
- When injecting the melt in the air, blisters or steam can be seen.
- Moisture levels prior to processing are high.
- When doing partial fillings of the mould, crater-like structures can be found.

**CORRECTIVE PROCEDURE**

Are moisture levels in the material lower than the recommended values?
- Yes → 1. Check air streaks procedure
- No → 1. Check drying system

Moisture is on the mould surface?
- Yes → 2. Check mould cooling for leaks
- No → 3. Increase mould wall temperature

1. Check drying system
2. Check drying conditions
3. Check transport & storage conditions
4. Reduce residence time in hopper
5. Use vented plasticizing unit
5.2 COLOUR STREAKS

**CAUSE**
Defects in melt mixing and compatibility issues between masterbatches and substrate. Internal stresses or warpage.

**SIGNS**
Colour differences between zones inside a plastic part.

**CORRECTIVE PROCEDURE**

Does the material stand more shearing?
- Yes
- No

Colouring process is done via Masterbatch?
- Yes
- No

Change machine or plastic unit:
1. Increase L/D ratio
2. Use mixing sections in screw
3. Use non-return valves with intensive mixers

1. Increase back pressure and screw speed
2. Increase injection rate
3. Use smaller gates

1. Use precoloured materials
5.3 AIR STREAKS

CAUSE

Entrapped air during mould filling.

SIGNS

Visible blisters in the injected material.
Partial filling of the mould shows crater-like structures.

CORRECTIVE PROCEDURE

Are there air hooks?

Yes

No

Air streaks near the gate?

Yes

No

1. Reduce injection rate
2. Avoid sharp edges or transitions
3. Reduce depth of engraving

Reduce screw return speed during decompressions
Reduce decompression
Use shut-off nozzle

1. Reduce injection rate
2. Increase back pressure
3. Avoid sharp edged transitions
4. Check nozzle sealing
5. Move gate
5.4 BURN STREAKS

**CAUSE**
Thermal damage which can decrease length of molecule chains or cause changes in the macromolecules.

**SIGNS**
- Grey decolouration: reduction of molecular weight.
- Brownish decolouration: changes in macromolecules.
- Higher melt temperature than specifications.

**CORRECTIVE PROCEDURE**

Is melt temperature higher than recommended?

- Yes
  - Reduce cylinder temperature
  - Reduce screw speed
  - Reduce back pressure

- No
  - Melt residence time excessively high?
    - Yes
      - Avoid dead spots in the gate system and plasticizing unit
      - Check plasticizing unit for wear
      - Check granules condition
    - No
      - Burnt streaks appearing periodically?
        - Yes
          - Use injection speed profile
          - Check hot-runner
          - Avoid sharp edges in the gate mixers
        - No
          - Burnt streaks near the gate?
            - Yes
              - Check drying process
              - Use a compound with higher thermal stability
            - No
              - Avoid small runners
              - Check nozzle cross-section
              - Check shut-off nozzle
5.5 GLOSS VARIATIONS

**CAUSE**

Differences in shrinkage and/or cooling conditions. Differences in mould surface quality.

**SIGNS**

Different zones of the part show differences in gloss appearance.

**CORRECTIVE PROCEDURE**

**Polished surface:**
1. Increase mould temperature
2. Increase melt temperature
3. Increase injection speed
4. Improve polish quality of mould

**Textured surface:**
1. Reduce mould temperature
2. Reduce melt temperature
3. Reduce injection speed
4. Finer surface structure

---

Not enough gloss on the surface?

- **Yes**

Despite good polishing quality, still gloss differences appear?

- **Yes**

- **No**
5.6 WELD LINES

**CAUSE**

Orientations of pigments and dyes near the weld line. Flow behaviour is not correct. Mould geometry (gates, wall thickness) not correct.

**SIGNS**

Creation of notches near weld lines.

**CORRECTIVE PROCEDURE**

1. Increase mould wall temperature
2. Increase injection rate
3. Increase melt temperature
4. Increase holding pressure
5. Check ventilation
6. Increase roughness in mould wall
7. Move gate (move weld line to a non visible area)

If the weld line poor performance is No, then check ventilation and move gate.
5.7 SINK MARKS

**CAUSE**

Thermal contraction caused by cooling is not equal in certain areas. Causes can be due to a too slow cooling, too short holding phase or problems transferring holding pressure to the mould.

**SIGNS**

Outer layer sinks because of internal stresses.

**CORRECTIVE PROCEDURE**

Is residual melt cushion too small?

- Yes
  - 1. Increase metering stroke
  - 2. Check non-return valve
- No

Sink marks are near the gate or in thick wall areas?

- Yes
  - 1. Optimise holding phase time
  - 2. Increase holding pressure
  - 3. Reduce melt temperature
  - 4. Reduce mould temperature
  - 5. Reduce injection speed
- No

Sink marks away from gates or in thin wall areas?

- Yes
  - 1. Optimise holding phase time
  - 2. Increase holding pressure
  - 3. Increase injection speed
  - 4. Increase melt temperature
  - 5. Increase mould temperature
- No

Sink marks after demoulding?

- Yes
  - 1. Check mould ventilation
  - 2. Check sprue and gate dimensions
  - 3. Adapt mould temperature control
  - 4. Remove material accumulations
  - 5. Consider wall thickness/rib ratio
- No

1. Increase cooling time
5.8 JETTING

UNIT 5.8 JETTING

CAUSE

Melt strand enters the mould with uncontrolled movements and cools sufficiently so it cannot be fused together with the rest of the polymer.

SIGNs

Snake-shaped defect. Normally visible to the naked eye.
Colour and gloss variations.

CORRECTIVE PROCEDURE

Can injection speed be reduced?

Yes

1. Create an injection profile slow-fast

No

2. When injection profile is not possible, reduce injection speed

Can the melt temperature be reduced?

Yes

1. Increase melt temperature

No

1. Check position of mould

2. Round off transition gate/moulded part

3. Increase gate diameter

4. Move gate

5. Use impact die
5.9 DIESEL EFFECT

**CAUSE**

Entrapped hot air increases its temperature due to an increase in pressure and burns the polymer around. It is caused by a venting problem.

**SIGNS**

- Burnt areas.
- Mould surface damage.
- Near blind holes, fillets, end of flow paths and near points where several flow fronts are fused.

**CORRECTIVE PROCEDURE**

1. Is a periodical defect?
   - Yes: Check venting for blocking
   - No:
     1. Can clamping force be reduced?
        - Yes: Reduce clamping force up to 1.2 times the minimum acceptable value (safety factor to avoid overspraying)
        - No:
          1. Reduce injection speed
          2. Improve ventilation
          3. Change flow distribution to avoid entrapment of air
## 5.10 STRESS CRACKS (WHITENING)

### CAUSE

Internal stresses caused during part processing due to high deformations, cooling differences or internal expansion when demoulding.

### SIGNS

- No external sign may be observed until a long time after moulding.
- Whitening of the surface due to crack formation.
- Use of acetic acid can show stresses within the part.

### CORRECTIVE PROCEDURE

<table>
<thead>
<tr>
<th>Stress whitening due to strong deformations (shear)?</th>
<th>Yes No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demoulding under excessive residual pressure?</td>
<td>Yes No</td>
</tr>
</tbody>
</table>

#### Yes

1. Increase cylinder temperature
2. Reduce screw speed
3. Reduce back pressure
4. Earlier change over to holding pressure.
5. Reduce holding pressure
6. Reduce demoulding temperature (increase cooling time)
7. Stiffen mould (change design)
8. Increase mould wall temperature
9. Increase melt temperature
10. Reduce holding pressure
11. Increase injection speed
12. Reduce cooling time
5.11 FLASHES

**CAUSE**
Flashes occur because gap widths exceed allowed values, or clamping force of the machine is insufficient, or internal mould pressures are too high, or compound viscosities are too high.

**SIGNS**
Formation of film-like plastic edges.

**CORRECTIVE PROCEDURE**

1. Can clamping force be increased? 
   - Yes: Increase clamping force
   - No: Further checks...

2. High mould deformation? 
   - Yes: Optimise change over point
   - No: Further checks...

3. Flashes near the gate? 
   - Yes: Set injection profile slow-fast
   - No: Further checks...

1. Earlier change over to holding pressure
2. Lower injection speed
3. Set injection profile slow-fast
4. Reduce mould wall temperature
5.12 FLAKING

**CAUSE**
When layers of material are not well and homogenously joined together they may start flaking.

**SIGNS**
Delamination of surface layers.

**CORRECTIVE PROCEDURE**

Does the defect occur after a change of material or colour?

- **Yes**
  1. Check pellets for impurities
  2. Check moisture content
  3. Check melt homogeneity and plasticizing performance

- **No**
  1. Reduce injection speed
  2. Reduce melt temperature
  3. Increase mould wall temperature
5.13 COLD FLOW LINES

CAUSE
Melt solidified in the gate previous to injection and transported into the mould in the shot sequence.

SIGNS
Marking all over the moulded part.
Surface defects similar to weld lines.

CORRECTIVE PROCEDURE

Can decompression be reduced?
Yes
1. Reduce decompression

No
Can the plasticizing unit be retracted earlier?
Yes
1. Retract plasticizing unit earlier

No
No
1. Check nozzle temperature
2. Increase nozzle temperature
3. Increase nozzle cross-section
4. Apply longer gate extension
5. Use shut-off nozzle
5.14 DARK SPOTS

**CAUSE**
Black spots are caused by wear, thermal damage or dirt. The causes can be found in the process conditions, in the mould, in the machine or in the compound.

**SIGNS**
- Black spots visible on the surface.
- Speckled parts.

**CORRECTIVE PROCEDURE**

- Impurities in the granule?
  - No
  - Do dark spots appear after a change of materials?
    - No
    - Is melt temperature exceeding the processing range?
      - No
      - Is the melt residence time too long?
        - No
        - Reduce hot runner temperature
        - Check plasticizing system, gate system and hot runners for impurities, wear and dead edges
        - Check compatibility of compounds (if applicable)
        - Reduce recycled material content (if applicable)
    - Yes
      - Reduce cycle time
      - Increase plasticizing time delay
      - Check dimensions of plasticizing unit
  - Yes
    - Check nature of impurities
    - Clean plasticizing unit
    - Reduce cylinder temperature
    - Reduce screw speed
    - Reduce back pressure
5.15 TRAPPED AIR IN THE INJECTED PARTS

**CAUSE**
Air blisters and voids are formed due to an excessive decompression or to a poor plasticizing performance

**SIGNS**
Voids and bubbles in the part

**CORRECTIVE PROCEDURE**

1. Is it possible to reduce decompression?
   - Yes: Reduce decompression
   - No: Is it possible to retract the plasticizing unit earlier?
      - Yes: Retract plasticizing unit earlier
      - No: Check nozzle temperature measurements

2. Increase nozzle temperature
3. Increase nozzle cross-section
4. Apply longer gate extension
5. Use shut-off nozzle