Processing Parameters
Injection molding

TPU
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### Machine Configurations

Injection molding of IROGRAN® TPU can be conducted on most injection molding machines. The main types used are:

**K1:**
These are standard injection molding machines with a single shot barrel injecting into a single or multi cavity mold. The weight of the injected part can be as high as several kilograms. Mold clamping forces range from a few tonnes to several thousand tonnes.

**K2:**
Is similar to K1 but uses two barrels and this permits the molding of several materials at the same time. Again, machine capacity can vary over a wide range.

### Which screw should be used?

A conventional general purpose screw is recommended for the production of IROGRAN® TPU. It is also possible to process softer grades on a PVC type screw, however, care should be taken to avoid overheating during processing as this can lead to degradation of the TPU. The general purpose screw is split into 3 distinct zones and each zone plays an important part in changing the state of the material.

**Screw Tip**

- **Metering Zone:** The purpose of this zone is to ensure that the melt is fully mixed and homogenised. Flight depth is constant here. The metering zone length should be between 30-40% of the total length.

- **Compression Zone:** This is the zone where the TPU material is melted. The flight depth in this zone is constantly diminishing, which increases the pressure and ensures an increased contact with the cylinder wall. Compression ratios within this zone should be between 2.5 : 1 and 3.5 : 1.

- **Feed Zone:** This is directly below the hopper. As the material passes through this zone it picks up conducted heat from the cylinder walls. At the end of this zone the material should be near its softening point. The flight depth in the feed zone is constant. The feed zone should ideally be between 30 – 40% of the total length of the screw for processing IROGRAN® TPU materials.
Sprues
Maximum diameter should not exceed the wall thickness. The sprue length should be as short as possible with a minimum taper of 6 degrees to allow extraction. A sprue puller should be used where possible to assist ejection on sprue bush.

Hot tips have successfully been used. They have been found to reduce cycle times where sprue ejection is a problem. Temperature of the hot tip must be controlled to ensure no heat damage to the IROGRAN® TPU.

Runners
A large diameter is preferred. This avoids localised shearing and ensures maximum pressure transfer. It is advisable to avoid sharp edges at points where the material changes flow direction, this prevents excess material sheer. Care should be taken to ensure runners are capable of cooling at least as fast as the components, keeping cycle times to a minimum.

Gates
Large gates ensure effective holding pressure and also reduce the amount of shear. Common designs are ring, film, diaphragm and fan. Submarine gates should not be used. Aspect ratio of gates should be kept at 1:1 where possible.

Vents
Channels of 0.02-0.05mm depth are needed to allow the air to escape during the injection molding process. Ensure all are vents escape to atmosphere either by short runs from the cavity to mold edge or direct to a suitable air escape route, this can be via the ejection pins, inserts or large venting outlets.
Consideration must be given to avoiding vacuum between the mold face and components. This is a problem seen particularly on large flat areas and deep cavities. On flat areas some air ejection can help. On deep cavities it is best to step vertical sides rather than have full tapered edge. By this method it is possible to reduce the contact on molding to mold surface by at least half.

Shrinkage
It is difficult to quote exact shrinkage figures because of the influences from mold design and processing conditions (injection pressure, holding pressure, mold temperature, etc.) It is observed that section thickness, component design, material hardness will influence shrinkage. As a general guide it can be expected the IROGRAN® TPU will shrink by 1% to 2%. We would recommend that all molds should be tested for final component size before hardening.
Moisture contamination is the single biggest cause of material failure. The IROGRAN® TPU used needs to remain dry and therefore care should be taken to avoid moisture ingress. Drying is best done in a de-humidifier with a dew point of 30 deg C. A moisture content of 0.2% will reduce to 0.03% after 2-3 hours. If the material is wet and a desiccant dryer is not available then the material should be dried for 3-4 hours at 110°C in a hot air circulation dryer.

In extreme cases the material can be dried overnight, however this should be avoided if possible. Controlled drying times helps maintain consistency. The effect on molding the same IROGRAN® TPU material at a range of moisture contents can be seen in the table below.

<table>
<thead>
<tr>
<th>Moisture Content</th>
<th>Unit</th>
<th>0.03%</th>
<th>0.08%</th>
<th>0.2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>Shore A</td>
<td>82</td>
<td>80</td>
<td>79</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>Mpa</td>
<td>49</td>
<td>26</td>
<td>12</td>
</tr>
<tr>
<td>100% Modulus</td>
<td>Mpa</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>300% Modulus</td>
<td>Mpa</td>
<td>12</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Elongation</td>
<td>%</td>
<td>580</td>
<td>630</td>
<td>570</td>
</tr>
<tr>
<td>Compression Set</td>
<td>%</td>
<td>33</td>
<td>48</td>
<td>72</td>
</tr>
<tr>
<td>Tear Strength</td>
<td>KN/m</td>
<td>102</td>
<td>97</td>
<td>72</td>
</tr>
<tr>
<td>Abrasion Resistance</td>
<td>mm³</td>
<td>30</td>
<td>80</td>
<td>140</td>
</tr>
</tbody>
</table>

**IROGRAN® Drying Conditions**

- **110°C**
- **Dry air dryer 90 °C**

**How to recognize excessive moisture?**
Foaming of plastified material or the formation of bubbles may indicate that the moisture content is too high.

**Common faults when drying the material**
When using color masterbatches and additives it must be ensured that they are also dry. Therefore the granulate should be mixed before drying to ensure that the entire material is dry.

IROGRAN® TPU is hygroscopic and therefore absorbs moisture from the air. When stored in open bags IROGRAN® absorbs up to 1.5% moisture after a relatively short period of time.

**Coloring**
Addition of a color masterbatch is the usual and easiest way to color IROGRAN®. TPU based masterbatches are recommended for optimal performance although other masterbatches may be used. Please contact your technical representative for the supply of suitable color masterbatches.
Temperatures
Typical temperature profiles are based on gradually increasing temperature during the compression phase with cooling at the nozzle. More detailed information on the recommended temperature setting for each IROGRAN® TPU grade can be found on the product datasheet. For more detailed information on the modification of the profile please contact your technical service representative.

Injection
A slow to moderate injection speed should be used if injection speed is too fast. The frictional heat can cause surface imperfections.

Mold Temperature
We recommend for general molding a mold temperature between 10°C to 40°C. However for certain grades and end applications a reduction below 10°C has been found to offer advantages with cycle time. When using temperatures below 10°C care must be taken to ensure cavities will consistently fill and no condensation appears on the mold face.

Mold Cooling
The purpose of mold cooling is to control the rate at which heat is removed from the molding. If there is no cooling on the mold then initially the mold will be cool and will heat up due to the heat transfer from the molded parts. This effect can result in varying shrinkage rates. Mold cooling is therefore recommended and the cooling channels should be evenly distributed in the mold. Unbalanced cooling will also have a detrimental effect on the quality and consistency of the product produced.

Demolding
IROGRAN® TPU is a material with rubber like properties, and therefore consideration must be given to how best to eject components from cavities. Large diameter ejector pins or where possible ejector sleeves and stripper plates are best. Successful ejection of parts with undercuts can be achieved with soft IROGRAN® TPU grades with a minimum of distortion. Elongation caused by ejection of not more than 5% without expected deformation can be seen. IROGRAN® materials will exhibit non-compressible tendencies consequently if ejection is too fast the material will deform perpendicular to the applied force by reducing in height but growing in width at 90 degrees to the force, causing parts to appear to stick in cavities.

Secondary treatment of molded parts
Parts made out of IROGRAN® TPU achieve their ultimate properties only after tempering for 24 hrs at 80-100 °C. However, frequently this post-treatment is unnecessary because acceptable physical properties develop at room temperature within a few weeks.
IROGRAN® TPU can be recycled up to levels of 100% however, to obtain good performance a maximum level of 15% is recommended during day-to-day processing. Levels above this should only be used if some reduction in final physical properties can be tolerated.

Sprues and rejects can be granulated and re-used. Care must be taken to ensure no contamination with other materials and the procedure related to drying of the IROGRAN® TPU, as described earlier must be fulfilled.

It is possible to demonstrate the effect of recycling on the physical properties of a standard TPU. In the following table the tensile strength of a multi play re-injected material is described.
Trouble Shooting

Short Shot
In principle, the molten material has not filled the mold.

Rectifying Methods:
1. Increase shot size to provide an adequate cushion
2. Increase the injection pressure
3. Increase the injection time
4. Increase the mold temperature
5. Increase the barrel temperature
6. Increase the back pressure
7. Increase the cycle time
8. Ensure the polymer is dry
9. Ensure the screw tip and check ring are functioning
10. Shot weight is not too high for the machine to process
11. Assess nozzle diameter, gates and runners. Is there a restriction?
12. Ensure adequate venting of cavity

Sink Marks
Sink marks manifest themselves as areas of partially underfilled moldings. The general cause is opening the mold before the gate is frozen.

Rectifying Methods:
1. Increase the injection holding time
2. Increase the injection speed
3. Increase the injection pressure (note: sometimes a reduced injection pressure will rectify the situation as it may reduce the injection speed as well)
4. Vent cavity in the area of the sink marks

Weld Lines
Polymer starts to freeze where the flow fronts meet.

Rectifying Methods:
1. Increase the injection pressure
2. Increase the injection speed
3. Increase the temperature of the melt
4. Increase the mold temperature
5. Ensure the TPU is completely dry
6. Ensure the check ring is functioning

Flashing
Caused when material escapes from the mold due to the material viscosity or poor clamping.

Rectifying Methods:
1. Reduce the injection pressure
2. Reduce the injection speed
3. Reduce the melt temperature
4. Increase the size of gate
5. Ensure mold closes and seals satisfactory
6. Ensure machine has sufficient mold lock
Unmelted Particles

**Rectifying Methods:**
1. Increase the cycle time to allow the polymer to melt
2. Increase the barrel temperature
3. Increase the back pressure
4. Preheat the granules

Inconsistent Shot

A problem normally associated with the machine or due to inconsistent cycle times e.g. when inserts are loaded by hand.

**Rectifying Methods:**
1. Examine the machine capacity against shot weight ensuring there is a cushion
2. Stabilize the cycle time reducing delays with insert loading by automation
3. Check there is no screw slip
4. Check the nozzle hole for damage or blockage
5. Examine the check ring to ensure its working properly

Bubbles & Voids

**Rectifying Methods:**
1. Ensure the TPU is dry
2. Check the screw is feeding regularly
3. Increase the back pressure
4. Reduce the melt temperature
5. Reduce the screw speed to lessen the shearing effect on the TPU
6. Reduce the injection speed
7. Increase cavity venting
8. Ensure mold has not over heated

Screw Slip

**Rectifying Methods:**
1. Ensure the hopper and feed throat are free from obstructions
2. Reduce melt temperature
3. Reduce screw charging speed
4. Ensure water cooling to hopper feed throat

Screw Stall

This is common when using low powered machines

**Rectifying Methods:**
1. Increase the melt temperature
2. Check for cold areas of barrel
3. Reduce the screw back pressure
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