## Property Data

### Akulon® F223-D

**PA6**  
**Low/Medium Viscosity**

**Print Date:** 2016-04-01

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### Typical Data

<table>
<thead>
<tr>
<th>Properties</th>
<th>Typical Data</th>
<th>Unit</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rheological properties</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molding shrinkage (parallel)</td>
<td>1.1/*</td>
<td>%</td>
<td>ISO 294-4</td>
</tr>
<tr>
<td>Molding shrinkage (normal)</td>
<td>1.1/*</td>
<td>%</td>
<td>ISO 294-4</td>
</tr>
<tr>
<td><strong>Mechanical properties</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensile modulus</td>
<td>3200/1000</td>
<td>MPa</td>
<td>ISO 527-1/-2</td>
</tr>
<tr>
<td>Yield stress</td>
<td>85/45</td>
<td>MPa</td>
<td>ISO 527-1/-2</td>
</tr>
<tr>
<td>Yield strain</td>
<td>4/25</td>
<td>%</td>
<td>ISO 527-1/-2</td>
</tr>
<tr>
<td>Nominal strain at break</td>
<td>20/50+</td>
<td>%</td>
<td>ISO 527-1/-2</td>
</tr>
<tr>
<td>Flexural modulus</td>
<td>2600/</td>
<td>MPa</td>
<td>ISO 178</td>
</tr>
<tr>
<td>Flexural strength</td>
<td>100/</td>
<td>MPa</td>
<td>ISO 178</td>
</tr>
<tr>
<td>Charpy impact strength (+23°C)</td>
<td>N/N</td>
<td>kJ/m²</td>
<td>ISO 179/1eU</td>
</tr>
<tr>
<td>Charpy impact strength (-30°C)</td>
<td>N/N</td>
<td>kJ/m²</td>
<td>ISO 179/1eU</td>
</tr>
<tr>
<td>Charpy notched impact strength (+23°C)</td>
<td>8/35</td>
<td>kJ/m²</td>
<td>ISO 179/1eA</td>
</tr>
<tr>
<td>Charpy notched impact strength (-30°C)</td>
<td>5/5</td>
<td>kJ/m²</td>
<td>ISO 179/1eA</td>
</tr>
<tr>
<td><strong>Thermal properties</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melting temperature (10°C/min)</td>
<td>220/*</td>
<td>°C</td>
<td>ISO 11357-1/-3</td>
</tr>
<tr>
<td>Temp. of deflection under load (1.80 MPa)</td>
<td>60/*</td>
<td>°C</td>
<td>ISO 75-1/-2</td>
</tr>
<tr>
<td>Temp. of deflection under load (0.45 MPa)</td>
<td>160/*</td>
<td>°C</td>
<td>ISO 75-1/-2</td>
</tr>
<tr>
<td>Coeff. of linear therm. expansion (parallel)</td>
<td>0.9/*</td>
<td>E-4/°C</td>
<td>ISO 11359-1/-2</td>
</tr>
<tr>
<td>Coeff. of linear therm. expansion (normal)</td>
<td>1/*</td>
<td>E-4/°C</td>
<td>ISO 11359-1/-2</td>
</tr>
<tr>
<td>Burning Behav. at 1.5 mm nom. thickn.</td>
<td>V-2/*</td>
<td>class</td>
<td>IEC 60695-11-10</td>
</tr>
</tbody>
</table>

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**HEALTH • NUTRITION • MATERIALS**
### Property Data

#### Akulon® F223-D

Print Date: 2016-04-01

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**Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Typical Data</th>
<th>Unit</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness tested</td>
<td>1.5/*</td>
<td>mm</td>
<td>IEC 60695-11-10</td>
</tr>
<tr>
<td>Burning Behav. at thickness h</td>
<td>V-2/*</td>
<td>class</td>
<td>IEC 60695-11-10</td>
</tr>
<tr>
<td>Thickness tested</td>
<td>0.75/*</td>
<td>mm</td>
<td>IEC 60695-11-10</td>
</tr>
<tr>
<td>Oxygen index</td>
<td>26/*</td>
<td>%</td>
<td>ISO 4589-1/-2</td>
</tr>
<tr>
<td>Glow Wire Flammability Index GWFI</td>
<td>800/-</td>
<td>°C</td>
<td>IEC 60695-2-12</td>
</tr>
<tr>
<td>GWFI (Thickness (1) tested)</td>
<td>1.5/-</td>
<td>mm</td>
<td>IEC 60695-2-12</td>
</tr>
<tr>
<td>Glow Wire Ignition Temperature GWIT</td>
<td>775/-</td>
<td>°C</td>
<td>IEC 60695-2-13</td>
</tr>
<tr>
<td>GWIT (Thickness (1) tested)</td>
<td>1.5/-</td>
<td>mm</td>
<td>IEC 60695-2-13</td>
</tr>
</tbody>
</table>

**Electrical properties**

- **dry / cond**
  - Relative permittivity (100Hz)  | 3.4/15 | -   | IEC 60250
  - Relative permittivity (1 MHz) | 3.1/4.7 | -   | IEC 60250
  - Dissipation factor (100 Hz)   | 65/3900 | E-4 | IEC 60250
  - Dissipation factor (1 MHz)    | 165/1300 | E-4 | IEC 60250
  - Volume resistivity            | 1E13/1E10 | Ohm*m | IEC 60093
  - Surface resistivity           | */1E14 | Ohm | IEC 60093
  - Electric strength             | 30/20 | kV/mm | IEC 60243-1
  - Comparative tracking index    | */600 | -   | IEC 60112

**Other properties**

- **dry / cond**
  - Water absorption               | 10/*   | %   | Sim. to ISO 62
  - Humidity absorption            | 2.8/*  | %   | Sim. to ISO 62
  - Density                        | 1130/- | kg/m³ | ISO 1183

**Material specific properties**

- **dry / cond**
  - Viscosity number               | 129/*  | cm²/g | ISO 307, 1157, 1628

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Recommendations for injection molding

Akulon® F223-D
PA6
Low/Medium Viscosity

GRADE CODING
Akulon® PA6 non reinforced and non flame retardant injection molding grades.

MATERIAL HANDLING

Storage
In order to prevent moisture pick up and contamination, supplied packaging should be kept closed and undamaged. For the same reason, partial bags should be sealed before re-storage. Allow the material that has been stored elsewhere to adapt to the temperature in the processing room while keeping the bag closed.

Packaging
Akulon® grades are supplied in airtight, moisture-proof packaging.

Moisture content as delivered
Akulon® grades are packaged at a moisture level ≤ 0.15 w%.

Conditioning before molding
To prevent moisture condensing on granules, bring cold granules up to ambient temperature in the molding shop while keeping the packaging closed.

Moisture content before molding
Since Akulon® is delivered at molding moisture specification (≤ 0.15 w%), the resin can be molded without pre-drying. However, to overcome the fluctuation from package to package we advise to pre-dry (see drying section below). Furthermore, pre-drying is required in case the material is exposed to moisture before molding (package damage or open for longer period of time). Moisture content can be checked by water evaporation methods or manometric methods (ISO 15512).
Recommendations for injection molding

Akulon® F223-D

**Drying**

Akulon® grades are hygroscopic and absorb moisture from the air relatively quickly. Preferred driers are dehumidified driers with dew points maintained between -30 and -40°C / -22 and -40°F. Vacuum driers with N₂ purge can also be used. Hot air ovens or hopper driers are not suitable for pre-drying Akulon® grades; the use of such driers may result in non-optimum performance.

<table>
<thead>
<tr>
<th>Moisture content</th>
<th>Time [h]</th>
<th>Temperature [°C]</th>
<th>Temperature [°F]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1-0.2 and as delivered</td>
<td>2-4</td>
<td>80</td>
<td>176</td>
</tr>
<tr>
<td>0.2-0.5</td>
<td>4-8</td>
<td>80</td>
<td>176</td>
</tr>
</tbody>
</table>

**Regrind**

Regrind can be used taking into account that this regrind must be clean/low dust content/not thermally degraded/dry, of same composition and similar particle size as the original material. The acceptable level of regrind depends on the application requirements (e.g. UL Yellow Card). Be aware that regrind can cause some small color deviations.
Recommendations for injection molding

Akulon® F223-D

MACHINERY

Akulon® grades can be processed on general injection molding machines.

**Screw geometry**
Typically 3-zone screw designs with volumetric compression ratios of approximately 2.5 work fine.

**Steel type**
Abrasive resistant tool steels which are normally used for glass and/or mineral reinforced materials are also to be used for Akulon® polymers in tools, nozzles and screws.

**Nozzle temperature control**
The use of an open nozzle with good temperature control and an independently-controlled thermocouple nearby the tip and heater bands with sufficient output is recommended.

**Hot runner layout**
Try to achieve a close contact with your hot runner supplier and DSM as the material supplier, to be sure that the right hot runner system is chosen.

When processing Akulon® with hot runners, keep in mind these basic rules:

- Central bushing heated separately
- Only use external heated system
- Manifold heated from both sides
- Tip with thermocouple in front (near gate)
- Very accurate temperature control in the gate area
TEMPerature SETTINGS

Mold temperature
Akulon® can be used with a wide range of tool temperatures (50 - 80°C / 122 - 176°F). However, we recommend a low mold temperature for parts with thick walls and a high mold temperature for good dimensional stability, flow properties and surface aesthetics. Furthermore, for impact modified grades (P in the grade coding) a low mold temperature can prevent mold sticking, resulting in a better surface appearance.

Barrel temperature
Optimal settings are governed by barrel size, residence time and melt viscosity. Be aware that melt viscosity is related to the barrel temperature settings. Due to the high melting point of Akulon® this temperature should be set high enough to provide a homogeneous melt without getting too near to the degradation temperature of 300°C / 572°F. A flat or rising temperature profile is recommended.

<table>
<thead>
<tr>
<th>Mold</th>
<th>Melt</th>
<th>Nozzle</th>
<th>Front</th>
<th>Center</th>
<th>Rear</th>
</tr>
</thead>
<tbody>
<tr>
<td>122 - 176°F</td>
<td>464-527°F</td>
<td>464-518°F</td>
<td>464-500°F</td>
<td>455-482°F</td>
<td>446-455°F</td>
</tr>
</tbody>
</table>

Melt temperature
To generate a good and homogeneous melt, the melt temperature should always be above 240°C / 464°F. Optimal mechanical properties will be achieved at melt temperatures between 240-275°C / 464-527°F. We advise to frequently measure the melt temperature by pouring the melt in a Teflon cup and inserting a thermo probe into the melt.

Hot runner temperature
A hot runner temperature set to the same level as the nozzle temperature should work fine and not lead to excessive overheat of the Akulon® grade. When starting up, an increased tip temperature may be necessary to overcome a frozen nozzle.
Recommendations for injection molding

Akulon® F223-D

GENERAL PROCESSING SETTINGS

Screw rotation speed
To realize a good and homogeneous melt, it is advised to set a screw rotation speed resulting in a plasticizing time that is just within the cooling time. The rotational speed of the screw should not exceed 6500 / D RPM (where D is the screw diameter in mm).

Back pressure
Back pressure should be between 30-100 bars effective. Keep it low in order to prevent nozzle-drooling, excessive shear heating and long plasticizing times.

Decompression:
In order to prevent nozzle drool after plasticizing and retracting the nozzle from the mold, a short decompression stroke can be used. However, to prevent oxidation of the melt, which may result in surface defects on the parts, it is recommended to keep this as short as possible.

Injection speed
Moderate to high injection speeds are required in order to prevent premature crystallization in the mold during injection phase and to obtain a better surface finish. Adequate mold venting is required to avoid burning at the end of the flow path (due to diesel effect).

Injection pressure
The real injection pressure is the result of the flowability of the material (crystallization rate, flow length, wall thickness, filling speed). The set injection pressure should be high enough to maintain the set injection speed (use set injection pressure higher than the peak pressure if possible). Tooling air vents must be effective to allow optimum filling pressure and prevent burn marks.

Holding time
Effective holding time is determined by part thickness and gate size. Holding time should be maintained until a constant product weight is achieved.

Holding pressure
The most adequate holding pressure is the level whereby no sinkmarks or flash are visible. A too high holding pressure can lead to stresses in the part.

Cooling Time
Actual cooling time will depend on part geometry and dimensional quality requirements as well as the tool design (gate size).
Recommendations for injection molding

Akulon® F223-D

RESIDENCE TIME

Melt residence time (MRT) for Akulon® in general should not exceed 6 minutes with preferably at least 50% of the maximal shot volume used. A formula to estimate this MRT is described below:

\[ MRT = \frac{\pi D^3 \rho \times \frac{1}{m}}{\frac{t}{50}} \]

Whereas:

- MRT = Melt Residence Time [minutes]
- D = Screw Diameter [cm]
- \( \rho \) = Melt Density [g/cm³]
- m = Shot Weight [g]
- t = Cycle Time [s]

Optimal melt residence time for Akulon® F223-D is 4 minutes.

Please note: In the calculation above, the hotrunner volume has not been taken into account. When a hotrunner is part of the setup, please add the hotrunner volume to the calculation.

SAFETY

For the safety properties of the material, we refer to our MSDS which can be ordered at our sales offices. During practical operation we advise to wear personal safety protections for hand/eye/body.

STARTUP/SHUT DOWN/CLEANING

Production has to be started and stopped with a clean machine. Cleaning can be done with Akulon® F223-D, applicable cleaning agents or HDPE. Hot runners can also be cleaned and put out of production cleaning them with Akulon® F223-D.

PRODUCTION BREAKS

During production breaks longer than a few minutes, we advise emptying the barrel. The temperature of the barrel and the hot runner [if applicable] should be reduced to a level far enough below the melting point of the compound in order to stop decomposition of the compound.

When the hot runner, nozzle, or even the screw is blocked, be aware that under these conditions a sudden outburst of molten material can take place. Always wear personal safety protections for hand/eye/body.

TROUBLESHOOTING

See our trouble shooting guidelines on the internet.

Contact DSM in case more information is required from the aspect of material or processing.

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Steel recommendations for molds, screws and barrels for injection molding EP materials.
1- Engineering Plastics

The use of engineering plastics in the injection molding process is worldwide common business. The processing of these polymers is done at relatively high processing (barrel- and mold) temperatures. To get specific property performances for these polymers, fillers like glass, carbon, flame retardants are very often used.

The combination of these high processing settings, the use of fillers and moisture present in the melt on their turn may have a negative influence like abrasion and/or corrosion of the used steel in mold, screw and barrel.

In other words, special requirements to overcome this and increase the life time of the steel type are obligated.

High process temperatures

EP polymers like Akulon®, Arnitel®, Arnite T®, Arnite A®, EcoPaxx®, Stanyl®, Stanyl ForTi® are processed at melt temperatures range of respectively 250°C up to 340°C.

Generally may be stated the higher the temperature, the faster chemical reactions leading to wear will take place, the more precautions have to be taken to prevent steel wear.

Fillers:

Using unreinforced, non flame retardant EP polymers, abnormal abrasive wear or corrosion is not to be expected. However many times fillers are used to get a specific performance on properties. These fillers like glass, carbon, minerals, w&f additives are in fact “hard” components in the melt that potentially can cause abrasive wear.

On top of that the use of (halogen free) flame retardant's can contribute to corrosion of the used steels.

Moisture:

EP polymers are hygroscopic, meaning the material have to be dried before processing. Although good drying some low amounts water may still be present in melt stage.

Water will initiate a chemical reaction leading to lower material properties but also to corrosion of the used steels.

2- Tool steel selection

General advice

To be able to process high-end engineering plastics, high-end tool steels are of utmost importance.

Therefore we recommend using ESR/VIM (Electro slag Re-melting/Vacuum Induction Melting) or PM (Powder Metallurgical) steel types. These steel types ensure high purity and optimal morphology.

The choice for a specific tool steel type will always be a compromise between several properties, this leaflet will give you a good guidelines to do so.

Toolsteel number/identification code number:

In the second column in the tool steel table a W.nr (Werkstoffnummer) is plotted (US equivalent ASTM). These identification codes are still commonly used to indicate steel types.

One should be aware that this system is an aged system. The identification number only (for example 1.2083) is insufficient. This identification system cannot fully cover the modern high tech steel types on the market. Therefore we need to specify a specific brand name and type to be sure to get the right steel choice. Additional to this, the heat treatment of the steel is of utmost importance to obtain the desired properties.

For detailed advice please contact us or the applicable steel supplier directly.

Topics to select best tool steel;

To be able to choose the correct tool steel and heat treatment for a specific mold, the most important questions are the following:

1) Identify the dominated failure mechanism (often more than one mechanism is applicable. In this case the most dominant needs to be considered).
2) Operating temperature.
3) What kind of polymer/filler.
4) Size and/or complexity of the mold.
5) What kind of surface finish required (High polish, textured etc.).
6) Production size.

These are the most important questions, tool steel supplier's need answered, to make a good choice on the specific type of tool steel. In injection molds this choice is likely to be a compromise between several properties.

3- Failure mechanisms for tool steel

1) Wear: here we can distinguish;
   a) Abrasive wear (due to sliding contact)
   b) Adhesive wear (due to sliding contact)
2) Plastic deformation (local exceeding of yield stress due to contact pressure).
3) Chipping (parts flaking of due to fatigue).
4) Cracking (Total crack due to mechanical or local high thermal load)
5) Corrosion (can have a number of causes).

Ad 1a:

Abrasive wear is in principal the erosion of the steel matrix between the carbides. This is highly influenced by abrasive fillers like; glass fiber, mineral fillers etc.

The solution direction;  
- High purity steel.
- Steel with high carbide level.

Ad 1b:

Adhesive wear is in principal a local “cold welding” situation.

The solution direction;  
- Steel with high carbide level.
- High tempering temperatures.
- Steel containing Aluminum as an alloy component.
- Use of CVD or PVD coatings.

Ad 2-3&4:

These failure mechanisms are a combination of fatigue and exceeding yield stress. Be aware, that in Al alloyed steel, the Al2O3 can be a source of fatigue crack initiation.

The solution direction;  
Correct heat treatment process of the steel type used (See steel supplier recommendations). Aim is to obtain an as large as possible martensitic structure. This can be achieved by using high hardening temperatures.
Ad 5:
Corrosion can be initiated by; moisture (hence drying of the resin is very important), hot gasses, aggressive fillers like flame retardants, aggressive cleaning agents etc. Corrosion resistance is driven by two major factors;
1) Chromium content of the steel should be >13%.
2) Heat treatment of the steel (tempering temperature level).

4- Life time of a mold

The life time of a mold is depending on a number of factors;
• Choice of tool steel.
• Type of polymer/filler.
• Complexity.
• Operating temperature.
• Maintenance level (a high precision tool running a 24/7 production at elevated temperature should be disassembled and cleaned every 3 months to ensure maximum life).

5- Machining tool steel

In case of EDM (Electric Discharge Machining), it is very important to remove the so called “White layer” after this process. This is a thin layer which is very brittle, and can initiate cracking (this layer already contains micro cracks, which can propagate). In case of difficulties removing this layer, due to for example narrow spaces there should at least be a soft annealing step of the steel (50°C below tempering temperature).

6- Coatings tool steel

In case of a coating, one should make sure the coating process temperature is at least 50°C below the last tempering temperature. If the coating process temperature has been too high, the hardening of the steel will be destroyed. When applying a coating the base hardness of the steel should be high enough to prevent the egg-shell effect.

7- High end Tool Steel suppliers:

Table 1 on the next page shows the recommended steel types for a number of tool parts. This table is developed in cooperation with, and based on the experience of the above mentioned tool steel suppliers (Bohler, Uddeholm, Assab).

8- Barrel, screw:

Taken into account the polymer portfolio you are using on a molding machine, the choice for best cylinder/screw/nozzle/etc. can to be done. Each machine supplier has their own trade names on applicable hardware to use. In table 2 on page 5 you can find suggestions applicable for the machine suppliers Arburg/Demag/Engel/Fanuc/Xaloy for screw and barrel, molding Engineering plastics.
<table>
<thead>
<tr>
<th>Application</th>
<th>W.nr.</th>
<th>Recommended heat treatment and hardness</th>
<th>Suppliers</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chassis blocks / Runner blocks</td>
<td>1.2363</td>
<td>K340 1040/N, 2x 540 60-62 HRc Rigor 950/N, 2x 540 54~56 HRc</td>
<td>K340 / Rigor / XW-10</td>
<td>Good machine-ability , wear resistance and hardness</td>
</tr>
<tr>
<td>Slider Guides</td>
<td>1.2379</td>
<td>1070/N, 2x 550 60-62 HRc</td>
<td>K110 / Sv. 21 / XW-41</td>
<td>Excellence wear resistance and toughness</td>
</tr>
<tr>
<td>Sliders</td>
<td>1.2363</td>
<td>K340 1040/N, 2x 540 60-62 HRc Rigor 950/N, 2x 540 54~56 HRc</td>
<td>K340 / Rigor / XW-10</td>
<td>Good machine-ability , wear resistance and hardness</td>
</tr>
<tr>
<td>Wear Plates</td>
<td>1.2379</td>
<td>1070/N, 2x 550 60-62 HRc</td>
<td>K110 / Sv. 21 / XW-41</td>
<td>Excellence wear resistance and toughness</td>
</tr>
<tr>
<td>Gate Inserts</td>
<td>No equivalent nr</td>
<td>S790 1100/N, 3x 560 61-63 HRc Vanadis 23 1100/N2 3x560 61-63 HRc</td>
<td>S790 / Vanadis 23 / ASP 23</td>
<td>High speed steel. Excellence wear resistance, high toughness and high hot hardness</td>
</tr>
<tr>
<td>Generic Inserts, Cavity, Core</td>
<td>No equivalent nr</td>
<td>M333 Isoplast 1020/N, 2x 510 51-53 HRc Stavax ESR 1050/N, 2x520 50-52 HRc</td>
<td>M333 / Stavax ESR / Stavax</td>
<td>High Chrome steel with superior polishability and corrosion resistance</td>
</tr>
<tr>
<td></td>
<td>1.2344</td>
<td>1050/N, 2x 550 51-53 HRc</td>
<td>W302 / Orvar / 8407 (H13)</td>
<td>Good machineability with high toughness, wear resistance and high hot hardness</td>
</tr>
<tr>
<td></td>
<td>1.2358</td>
<td>56~58</td>
<td>Calmax / Calmax</td>
<td>High toughness and wear resistance</td>
</tr>
<tr>
<td></td>
<td>No equivalent nr</td>
<td>1000/N, 2x 510 54-56HRc</td>
<td>M340 Isoplast</td>
<td>High chrome steel with extremely good corrosion resistance and wear resistance</td>
</tr>
<tr>
<td>Critical Inserts w(long and thin)</td>
<td>No equivalent nr</td>
<td>M390 Isomatrix 1100/N, 2x 510 59-61 HRc Elmax 1050/N, 2x520 50-52 HRc</td>
<td>M390 / Elmax / Elmax</td>
<td>Powder tool steel with extremely good wear and corrosion resistance</td>
</tr>
</tbody>
</table>

Note: Listed information in the table may not be the latest developments. Always contact your tool steel supplier to get his advice.
<table>
<thead>
<tr>
<th>Screw</th>
<th>Cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EP polymer</td>
</tr>
<tr>
<td>Arburg</td>
<td>Arbid</td>
</tr>
<tr>
<td>Demag</td>
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<td>Xaloy</td>
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Note: Listed information in the table may not be the latest developments. Always contact your machine supplier to get his advice.