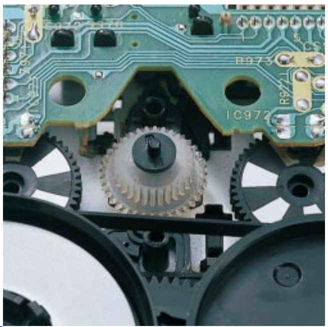
daicel degussa

VESTAMID® · DAIAMID®



Injection Molding

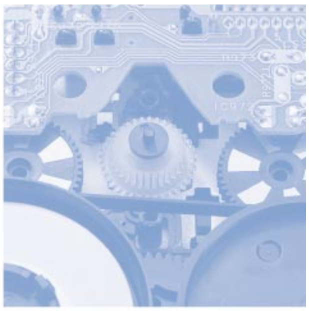
Contents

Introduction

DAIAMID and VESTAMID are Polyamide 12 engineering plastics. These crystalline thermoplastic resins offer excellent performance and balanced properties.
Polyamide 12 resin, given its chemical makeup, possesses a high degree of mechanical strength. Low water absorption results in the higher stability of its properties and dimensions, making Polyamide 12 ideal as a material for industrial applications. Moreover, with a melting point of 178ºC and decomposition point in excess of 300ºC, Polyamide 12 is moldable over a wide temperature range and is therefore easy to mold.

Features of DAIAMID and VESTAMID

1. Minimal water absorption (approx. 1/6 of Polyamide 6) for remarkable stability in properties and dimensions
2. Noise and vibration damping properties are outstanding
3. Excellent resistance to friction and abrasion
4. Excellent resistance to chemicals and oils
5. Excellent long-term resistance to weather
6. Excellent resistance to low temperatures
   (embrittlement temperature: approx. -70ºC)



I. Preparation for Molding

1. Water-Absorption Properties of DAIAMID and VESTAMID

DAIAMID and VESTAMID, based on Polyamide 12, have the lowest water absorption rate among commercially available polyamides. In fact, the equilibrium water absorption rate of DAIAMID and VESTAMID is approx. 1.5% (approximately 1/6 of the water absorption of Polyamide 6 or Polyamide 66).
In actual molding applications, however, both DAIAMID and VESTAMID must be thoroughly dried to prevent molding defects such as silver streak and void, as is the case with other polyamide resins.

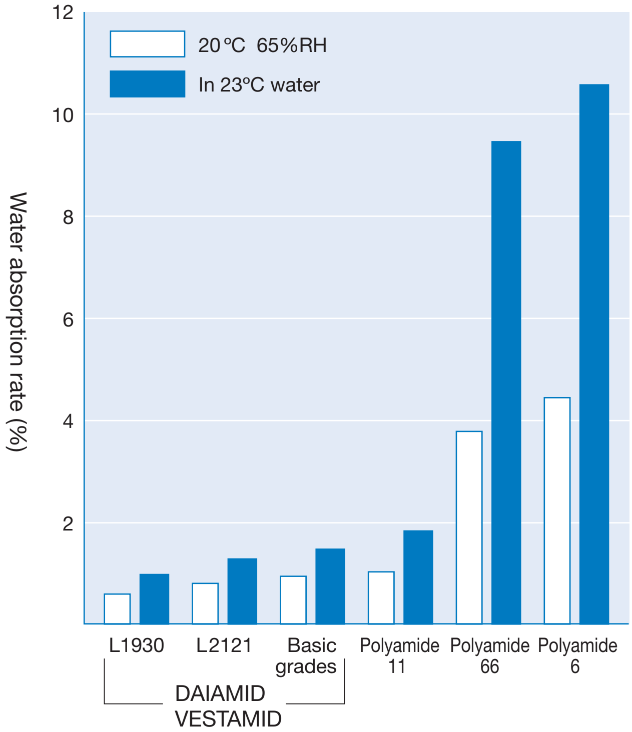


Figure 1. Water Absorption Properties of Various Polyamides

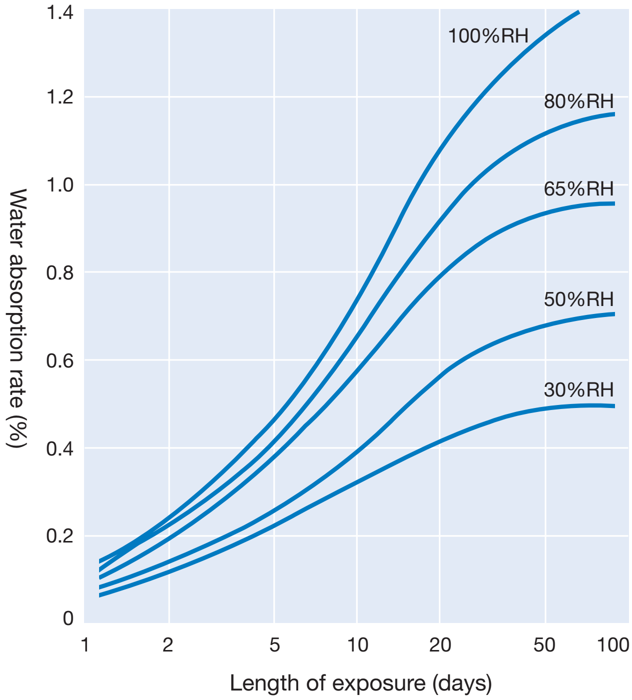


Figure 2. Water Absorption Properties of DAIAMID and VESTAMID

Every product we deliver has been dried and packed in a moisture-proof bag to maintain water absorption rate at 0.12% or less. If the product is used immediately after unpacking it isn't necessary to make pre-drying. However, if the product has been left outside the moisture-proof bag for a day or longer, the water absorption rate will reach 0.2% to 0.3%. Under such conditions direct use of the product may cause molding defects. If the product has been unpacked and left outside the moisture-proof bag for at least a day, pre-dry it thoroughly before use.

2. Pre-Drying Method

General Precautions

1) Generally, DAIAMID/VESTAMID should be dried at 80ºC to 90ºC (or approx. 100ºC in conditions of high humidity) for a period of three to four hours.
2) Drying time may be influenced by outside humidity, such as the ambient humidity of the location in which the dryer is installed. We therefore recommend the use of a dehumidifying dryer, which is less susceptible to outside humidity.
3) Heat history (temperature, time and local heating) has no significant effect on the mechanical properties of DAIAMID/VESTAMID. However, in some cases areas that have been exposed to heat may turn yellowish and affect the product's appearance. Therefore, the heat resistance of DAIAMID/VESTAMID must be verified in advance through the actual dryer to be used.
4) An excessively high temperature setting on local or general overheating may cause pellet blocking. Therefore, to ensure safety during the drying process, verify the setpoint temperature and set the overheating protection device to approximately 120ºC to 140ºC.

DAIAMID and VESTAMID can also be dried using a normal hot-air dryer (tray dryer) or hopper dryer.
The drying condition and points to note for each type of dryer are explained below:

Hot-air dryer (tray dryer)

In the case of a hot-air dryer of the tray type, it is preferable that one with a mesh bottom be used. If such a tray is not available, reduce the layer height as much as possible (preferably to 3 cm or less). This will ensure sufficient air circulation among the pellets.
The conditions of drying will vary, depending on the dryer's capacity and volume of air circulation. When dehumidified air is circulated, dry the product at 80ºC to 90ºC for around three to four hours. When dehumidified air is not used and the material is dried in humid ambient conditions such as found during the summer months, set the drying temperature higher to a range between 90ºC and 100ºC. A slight degree of yellowing may occur during drying, but this will have no significant effect on the product's mechanical properties, etc.

Hopper dryer

A hopper dryer allows more efficient air circulation among the pellets relative to a tray-type, hot-air dryer. Therefore, drying is more rapid with this type of unit. However, the drying conditions are roughly equal to those of a tray dryer.
Extra attention should be given to the possibility of overheating when a hopper dryer is used. If the pellets are heated to 150ºC or above and left in a hopper for an extended period of time, they may cause blocking and become unretrievable from the hopper. Please be sure the overheat protection device is set to a temperature not exceeding 150ºC. It is preferable that a setting of no more than 130ºC be used.
Figure 3 shows the drying-speed data of DAIAMID/VESTAMID in the pellet state.

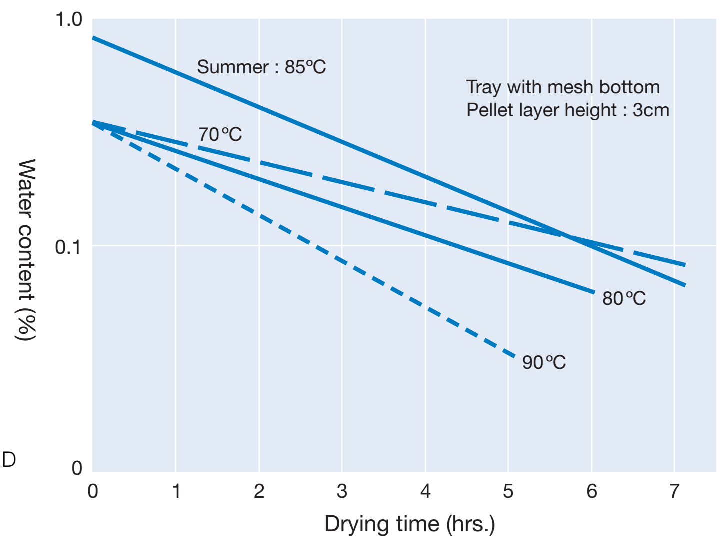


Figure 3. Drying Speeds of DAIAMID/VESTAMID

II. Molding Conditions

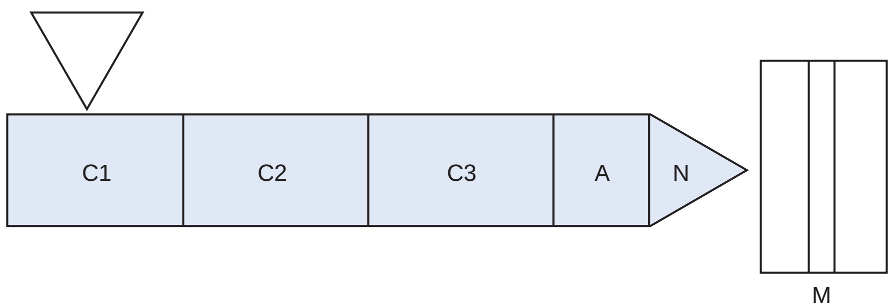
1. Setting of Molding Conditions

DAIAMID and VESTAMID can be molded in all types of molding machines commonly used today. To prevent resin leak and thread formation from the nozzle, however, it is recommended that a molding machine with a shut-off nozzle be used. DAIAMID and VESTAMID are Polyamide 12-based crystalline resins with melting points in a range of approximately 160ºC to 180ºC, although the specific melting point varies according to the grade. When setting the molding temperature, check the melting point of the applicable grade of DAIAMID/VESTAMID and set the temperatures of the C2 and C3 and nozzle parts of the cylinder to at least 10ºC above the melting point.
Table 1 shows standard molding conditions for the representative grades. As a reference, Figures 5 through 9 show melt viscosities corresponding to the representative grades.

Table 1. Setting Examples of Molding Conditions for Representative Grades

Grade	Melting point (ºC)	Moldable temperature range	C1 (ºC)	C2 (ºC)	C3 (ºC)	A (ºC)	N (ºC)	M (ºC)
L1640 L1743	180	190~240	170~180	190~220	200~220	200~220	190~210	~50
L1940 X1988	180	200~300	190~220	210~240	220~240	220~250	210~240	~50
L2140	180	220~300	200~220	220~250	230~250	230~250	220~240	~50
L1724K L1724KH	170	180~240	150~180	180~220	180~220	180~220	170~210	~50
E47	160	180~280	170~190	180~220	200~220	200~220	190~210	~50
E55	165	190~290	170~190	190~230	200~230	200~230	190~220	~50
E62	170	210~300	180~200	200~230	210~230	210~230	200~220	~50
EX9200	180	200~300	190~220	210~240	220~240	220~250	210~240	~50
L1930 L1965J L1960T	180	220~300	180~210	220~260	230~260	230~260	220~250	60~80

Figure 4. Cylinder Construction



The melt viscosities shown in Figures 5 through 9 were measured with a capillary rheometer.
In general injection molding, the conditions are set so that the melt viscosity of the resin falls between 100 and 1000 Pa-s.

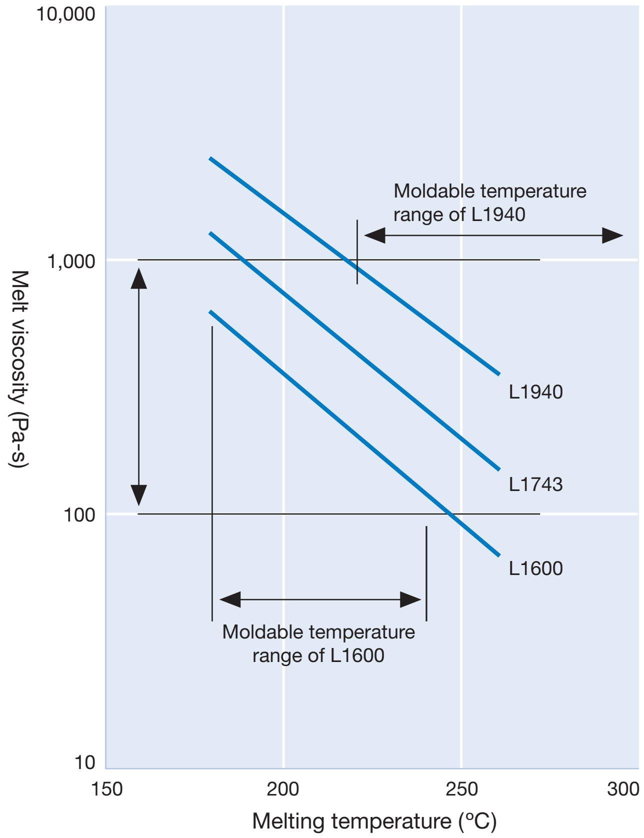


Figure 5. Melt Viscosities of Basic Grades (PA12)

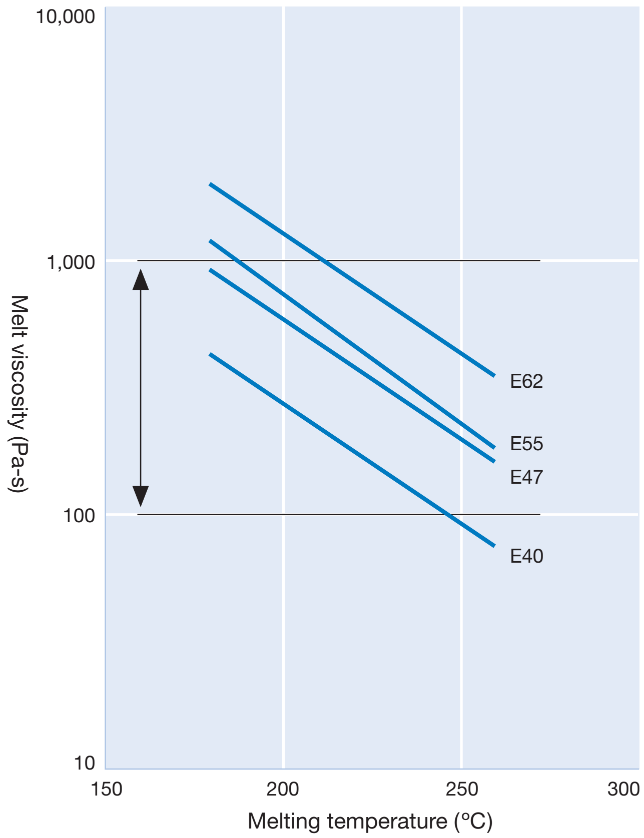


Figure 6. Melt Viscosities of PAEs

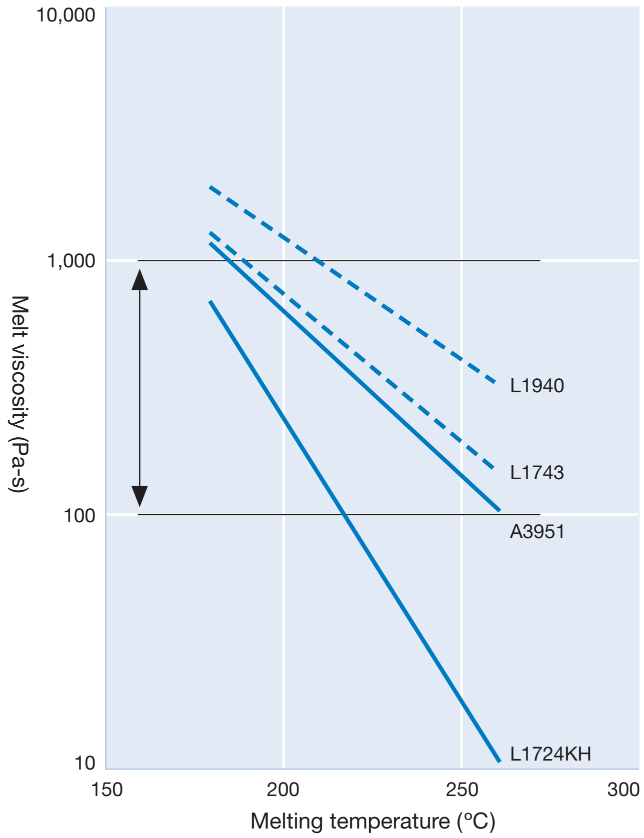


Figure 7. Melt Viscosities of Plasticized Grades

* In Figure 7, L1940 and L1743 do not contain plasticizer and are only shown for comparison.

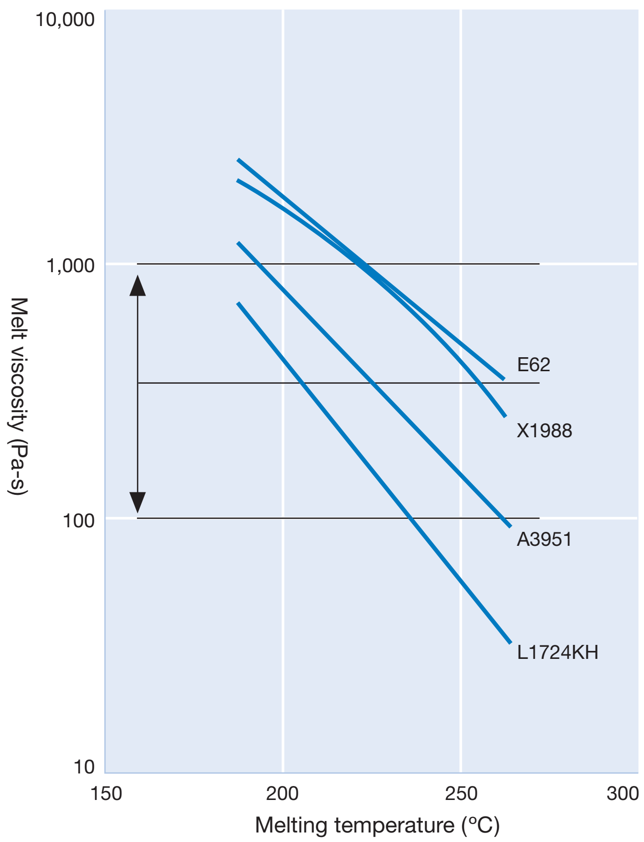


Figure 8. Melt Viscosities of Gear-Grades

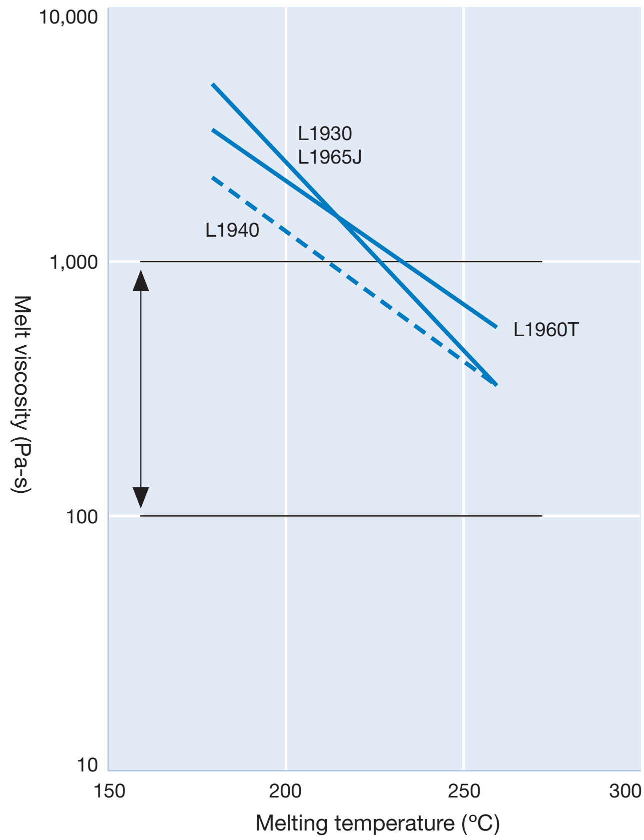


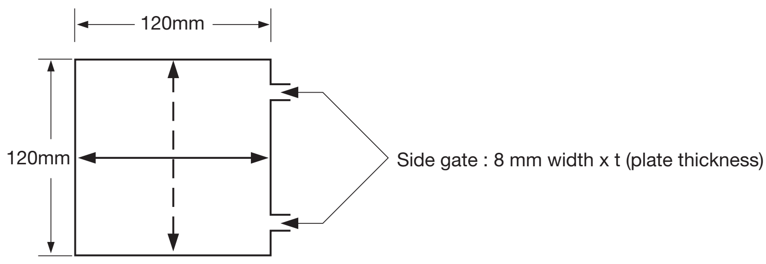
Figure 9. Melt Viscosities of Reinforced Grades

* In Figure 9, L1940 contains no filler and is therefore shown only for comparison.

2. Mold Shrinkage

Side gate

Figures 10 through 13 show the mold shrinkage rates of DAIAMID L1940 as measured on a molded plate with side gates, as illustrated below.



The following lines indicate the flow direction and the transverse direction, respectively:

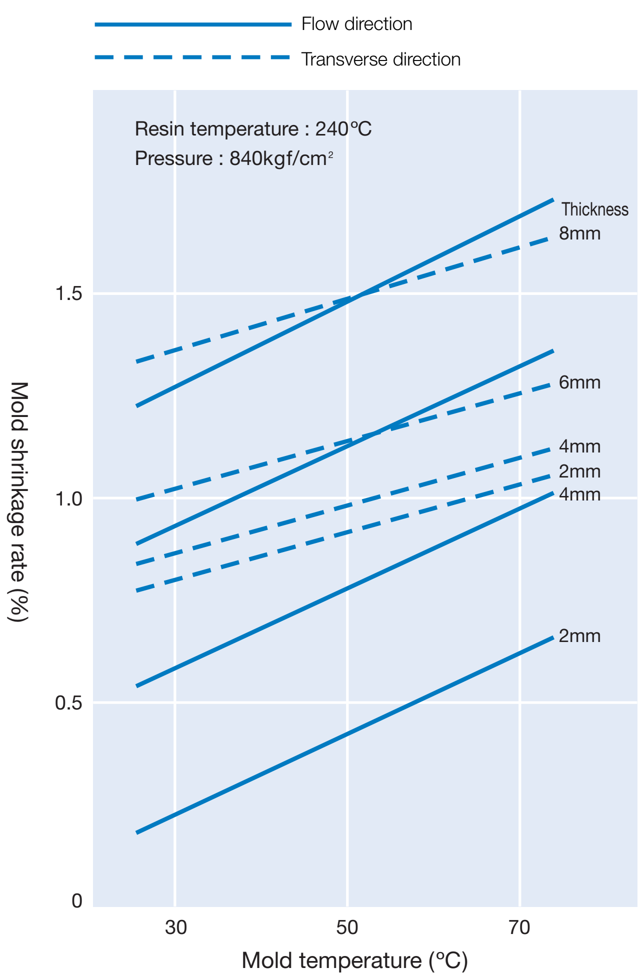


Figure 10. Dependency on Mold Temperature of L1940 Mold Shrinkage Rate

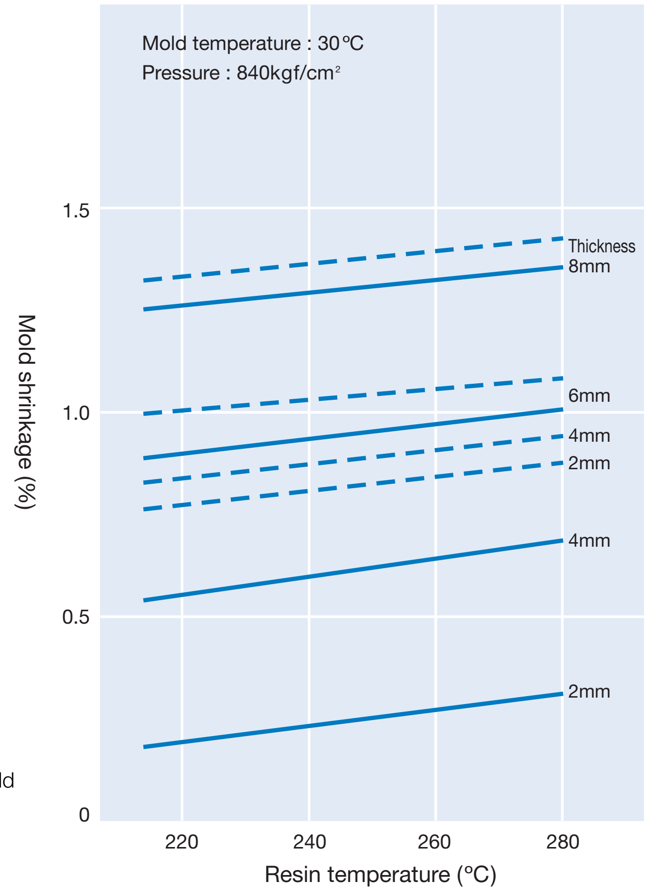


Figure 11. Dependency on Resin Temperature of L1940 Mold Shrinkage Rate

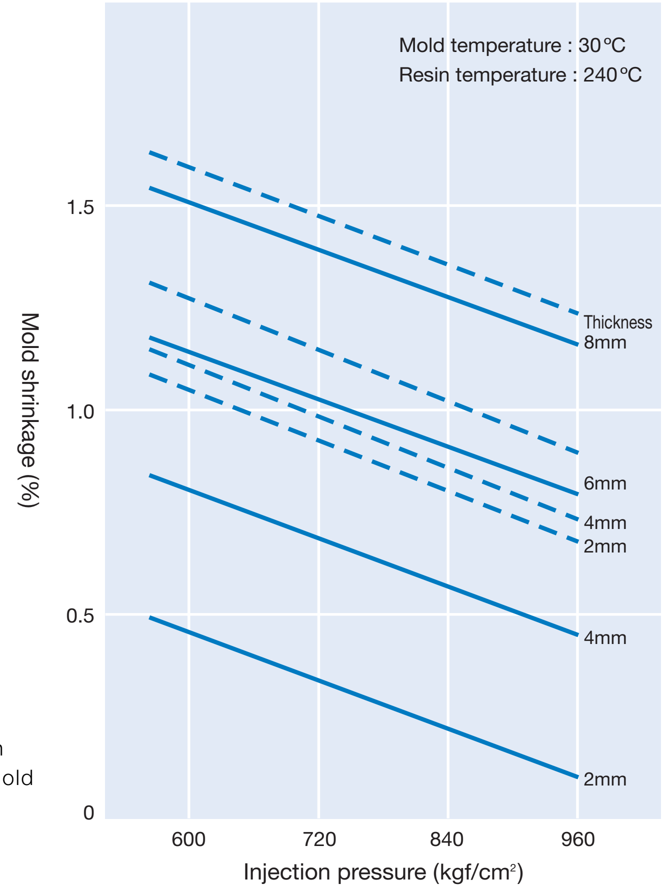


Figure 12. Dependency on Injection Pressure of L1940 Mold Shrinkage Rate

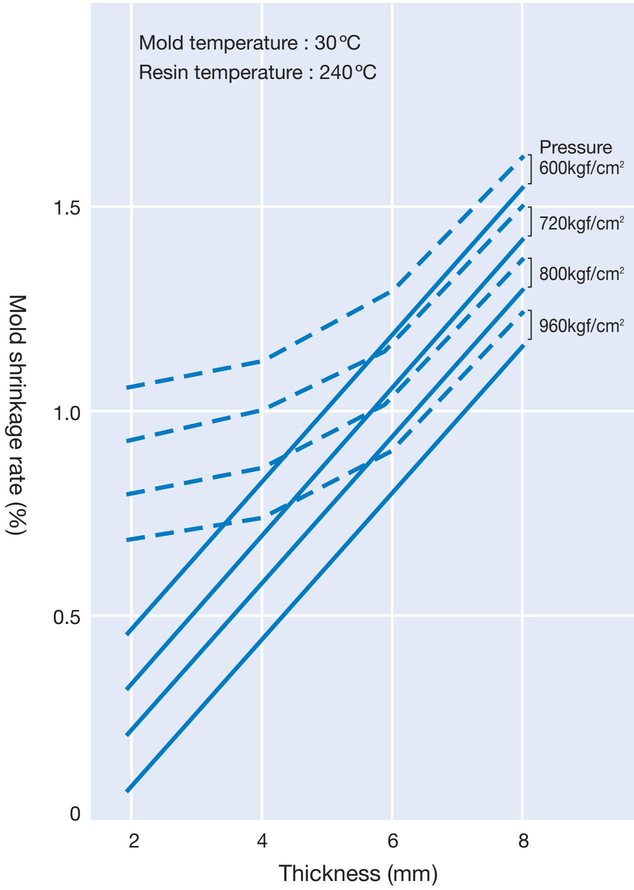
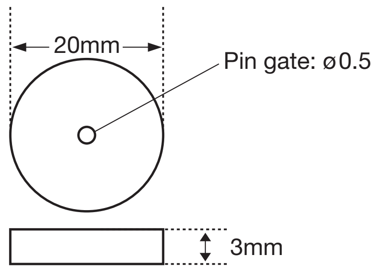


Figure 13. Dependency on Thickness of L1940 Mold Shrinkage Rate

Pin gate

The graphs below show the respective mold shrinkage rates of DAIAMID/VESTAMID measured on a disc with a pin gate, as illustrated below.



Molding conditions

Cylinder temperature	190~280ºC	
Mold temperature	30ºC	
Injection speed	3 m/sec. (cylinder)	
Holding pressure	20, 40, 60, 80, 100, 120MPa	
Cycle	Pressure holding	7sec
	Cooling	10sec
	Middle	3sec

The average diameter of the molded disc was calculated after keeping the disc for 24 hours in an air-conditioned room set at 25ºC and 65%RH.

Figure 14. High-CycleGrades (220ºC)

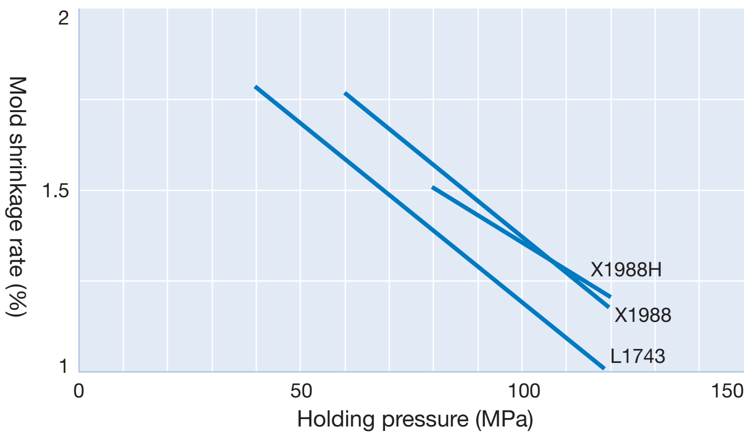


Figure 15. High-Cycle Grades (240ºC)

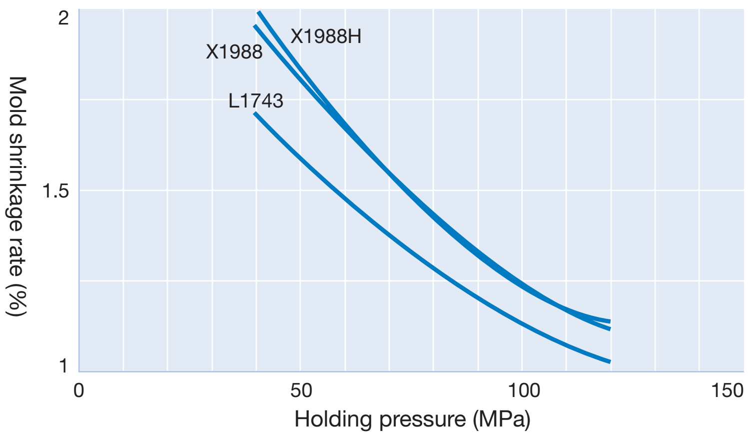


Figure 16. High-Cycle Grades (60MPa)

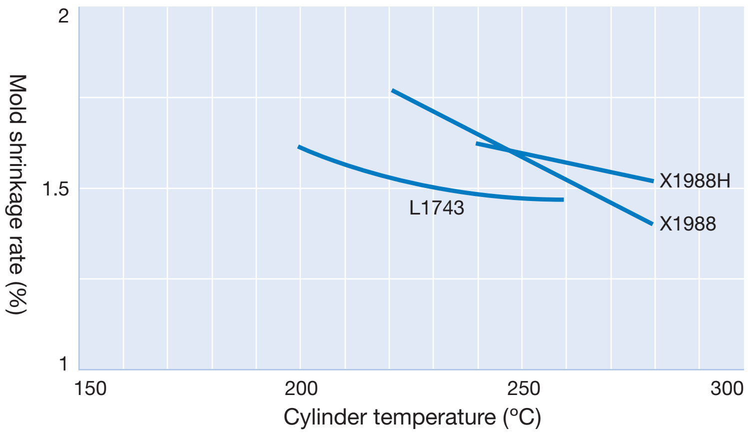
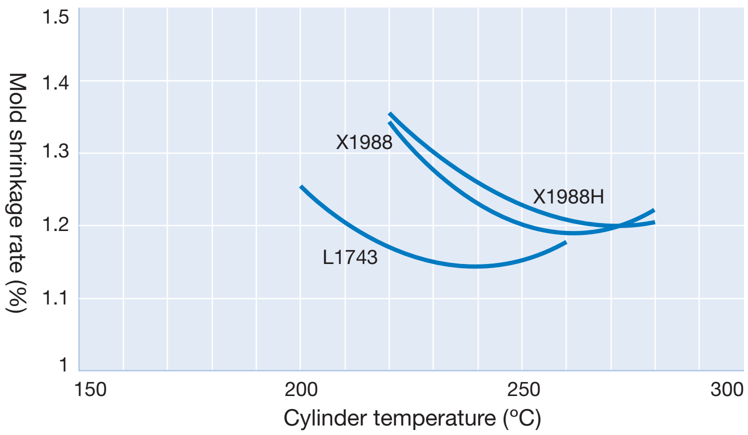


Figure 17. High-Cycle Grades (100MPa)



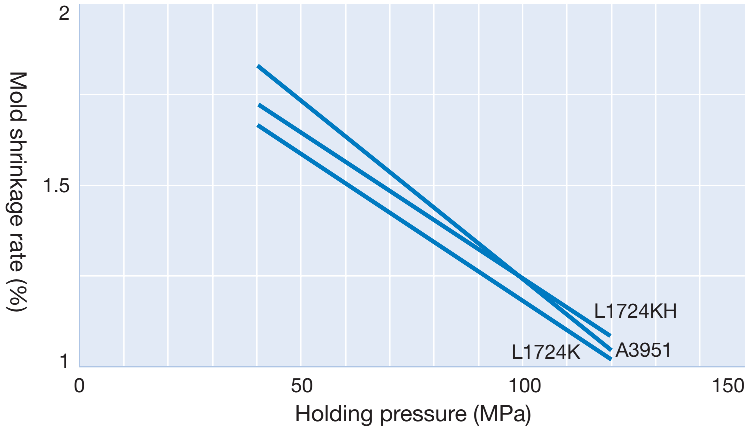


Figure 18. Plasticized High-Cycle Grades (220ºC)

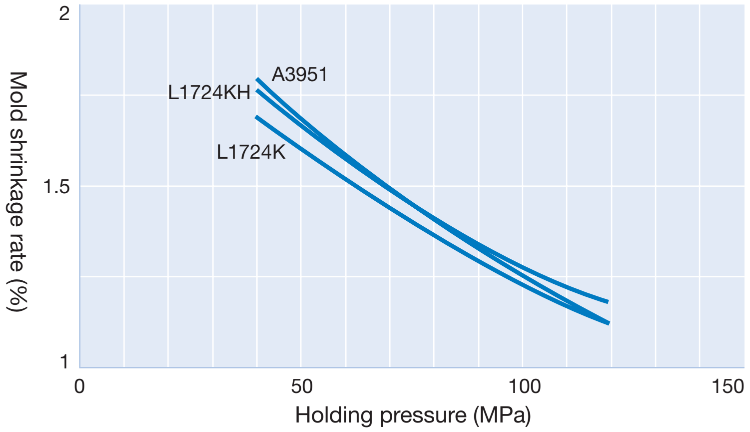


Figure 19. Plasticized High-Cycle Grades (240ºC)

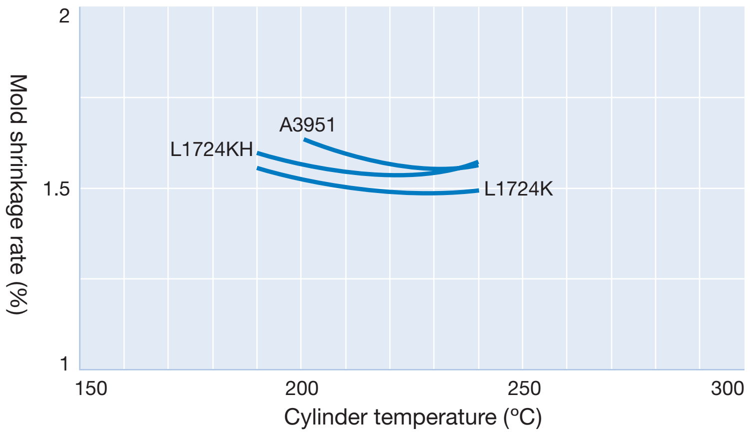


Figure 20. Plasticized High-Cycle Grades (60MPa)

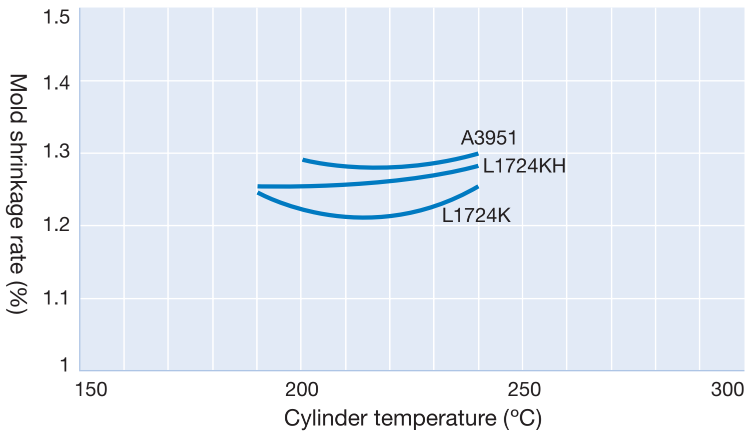


Figure 21. Plasticized High-Cycle Grades (100MPa)

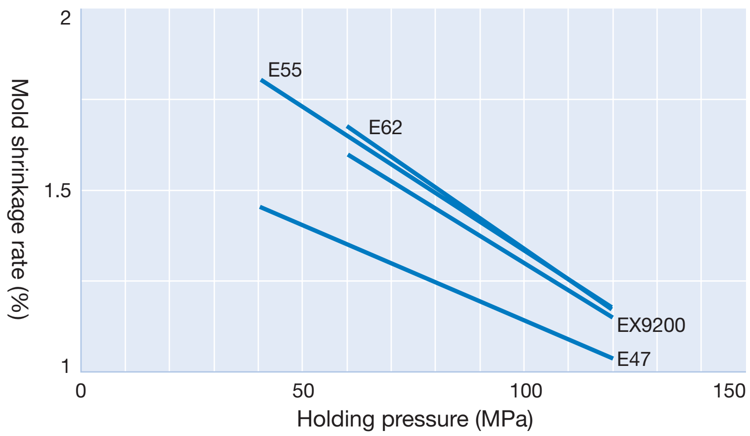


Figure 22. PAE (220ºC)

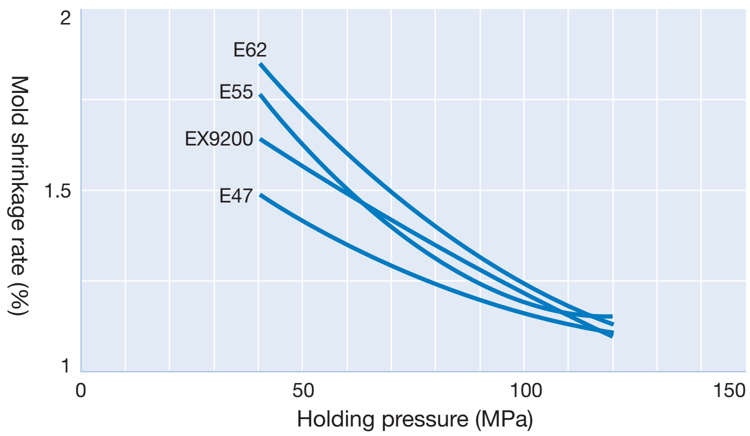


Figure 23. PAE (240ºC)

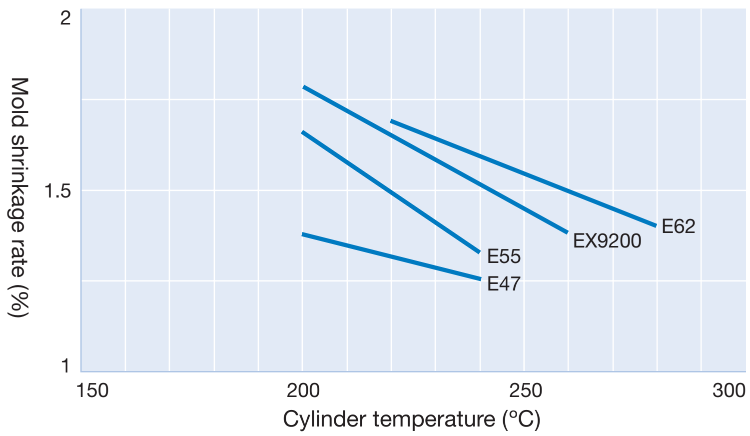


Figure 24. PAE (60MPa)

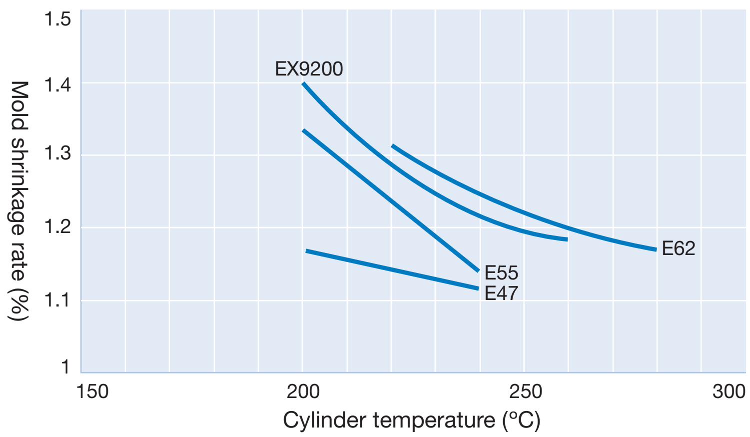


Figure 25. PAE (100MPa)

Figure 26. Reinforced Grades (240ºC)

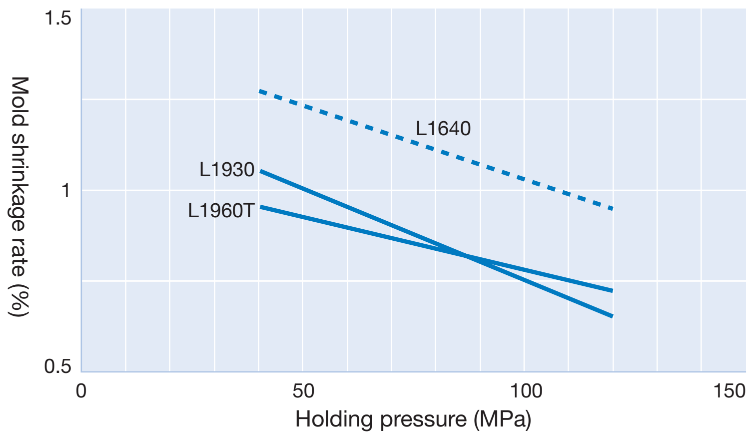


Figure 27. Reinforced Grades (260ºC)

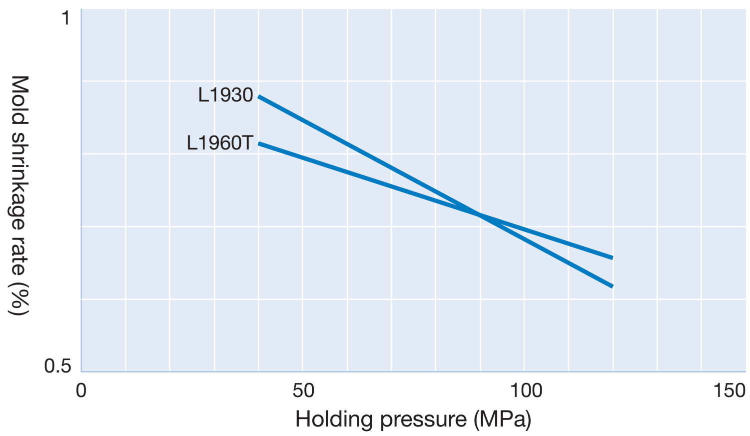


Figure 28. Reinforced Grades (60MPa)

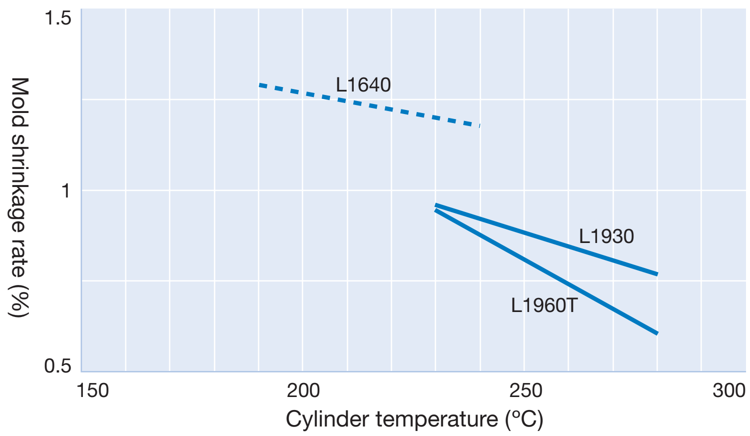
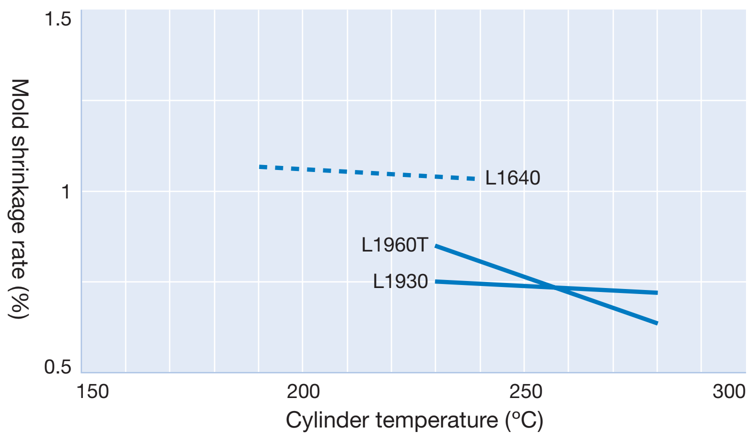


Figure 29. Reinforced Grades (100MPa)



*L1640, as shown in the graphs, is not a reinforced grade but is included for comparison.

3. Countermeasures to Defects

<table>
<tr><th colspan="2"></th><th>Shink mark</th><th>Void</th><th>Short short</th><th>Burr</th><th>Warpage</th></tr>
<tr><td rowspan="8">Cause</td><td>Cylinder temperature</td><td>High</td><td>High</td><td>Low</td><td>High</td><td>Low</td></tr>
<tr><td>Injection pressure</td><td>Low</td><td>Low</td><td>Low</td><td>High</td><td>High</td></tr>
<tr><td>Injection speed</td><td>Fast</td><td>Fast</td><td>Slow</td><td>Fast</td><td>Fast</td></tr>
<tr><td>Mold temperature</td><td>High</td><td>Low</td><td>Low</td><td>High</td><td>Low</td></tr>
<tr><td>Gate size</td><td>Small</td><td>Small</td><td>Small</td><td></td><td></td></tr>
<tr><td>Sprue, Runner</td><td>Thin</td><td>Thin</td><td>Thin</td><td></td><td></td></tr>
<tr><td>Molding cycle</td><td>Short</td><td>Short</td><td></td><td></td><td>Short</td></tr>
<tr><td>Other</td><td>● Non-uniform shrinkage
● Insufficient holding pressure</td><td>● Insufficient drying
● Air holding at metering process</td><td>● High-viscosity material</td><td>● Low-viscosity material
● Insufficient clamping pressure
● Deformation of parting line</td><td>● High-viscosity material
● Inappropriate reinforcing agent
● Non-uniform wall thickness distribution over molded product
● Large L/D of molded product
● Poor gate position</td></tr>
<tr><td colspan="2" rowspan="3">Countermeasures (Points)</td><td colspan="3">● Increase the gate size and apply sufficient holding pressure.</td><td rowspan="3">● Select a grade of higher melt viscosity.
● Select a high-cycle grade and reduce the solidification time.
● Lower the mold temperature and apply sufficient clamping pressure.
● Modify the mold-parting line.</td><td rowspan="3">● Select a grade of lower melt viscosity to reduce the residual strain resulting from molecular orientation.
● Select a high-cycle grade to ensure uniform shrinkage.
● Make the wall thickness of the molded product uniform.
● Add ribs to the molded product to make its shape more resistant to strain.
● Prolong the molding cycle.</td></tr>
<tr><td colspan="2">● Select a material of lower melt viscosity to reduce the resin temperature and raise the injection pressure, thus increasing the amount of resin filled into the mold.
● Select a high-cycle grade material to ensure uniform shrinkage during solidification.</td><td rowspan="2">● Select a grade of lower melt viscosity.
● Increase the resin temperature and injection pressure.
● Enlarge sprue runner.</td></tr>
<tr><td>● Homogenize mold cooling.</td><td>● Decrease the cylinder temperature on the hopper side to prevent air holding at metering process
● Dry the material sufficiently.</td></tr>
</table>

Table 2. Countermeasures to Molding Defects

<table>
<tr><th></th><th>Weld line</th><th>Bad mold release</th><th>Gate release</th><th>Burn</th><th>Silver streak</th><th>Gas</th></tr>
<tr><td></td><td>Low</td><td>High</td><td></td><td>High</td><td>High</td><td>High</td></tr>
<tr><td></td><td>Low</td><td>High</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Slow</td><td></td><td>Fast</td><td>Fast</td><td>Fast</td><td>Fast</td></tr>
<tr><td></td><td>Low</td><td>High</td><td>High</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Small</td><td>Large</td><td>Large</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Thin</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Short</td><td>Short</td><td>Long</td><td></td><td></td></tr>
<tr><td></td><td>• High-viscosity material
• Poor gate position
• Excessive use of mold-release agent</td><td>• Excessive filling
• Little taper angle of the mold
• Insufficient polishing of mold</td><td>• Poor gate shape
• Abnormal heat generation from material</td><td>• Insufficient cleaning of molding machine
• Excessive cylinder capacity, resulting in long residence time</td><td>• Insufficient drying
• Contamination of different resin</td><td>• Insufficient degassing from the mold</td></tr>
<tr><td rowspan="2"></td><td rowspan="2">• Select a grade of lower melt viscosity and set a sufficient injection pressure.
• Review the gate position.
• Reduce quantity of mold-release agent.</td><td rowspan="2">• Select a high-cycle grade and increase mold shrinkage.
• Lower the mold temperature.
• Polish the mold sufficiently.
• Increase the draft angle.
• Use lubricant.
• Prolong the molding cycle.</td><td rowspan="2">• Select a grade of lower melt viscosity and reduce the gate size.
• Select a high-cycle grade.
• Reduce the injection speed to prevent abnormal heat generation from the resin at the gate.
• Lower the mold temperature.</td><td colspan="3">• Perform idle run for a sufficient duration before molding to thoroughly remove the residual resin or different resin.
• When the same machine is used for molding with different resins, purge the machine sufficiently to remove the residual resin before a molding session. (High viscosity PP or PE is recommended.)</td></tr>
<tr><td>• Select a grade of lower melt viscosity to reduce the resin temperature.
• Lower the cylinder temperature on the hopper side to prevent the resin from oxidizing.
• Shorten the molding cycle.</td><td>• Perform sufficient drying.
• Keep the water content to 0.1% or less, since silver streaks often occur when the water content increases to 0.3% or above. (See "Preparation for Molding" on p. 4.)</td><td>• Select a grade of lower melt viscosity to reduce the resin temperature.
• Perform sufficient degassing.</td></tr>
</table>

4. Recycle

There is a growing demand for the recycling of resins as a means to reduce environmental loading and production costs. DAIAMID and VESTAMID, thanks to their outstanding heat stability, are very easy to recycle. As shown in the graphs below, the tensile strengths of DAIAMID and VESTAMID do not change much after repeating a 100% recycling process five times.

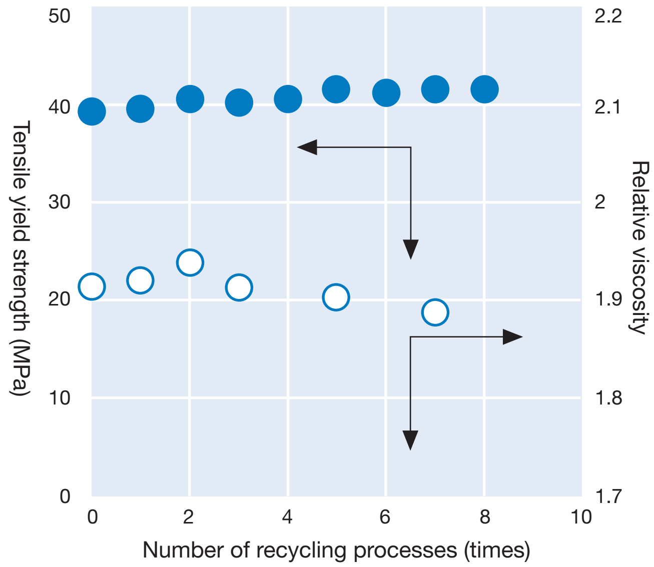


Figure 30. Recycle Test of L1940

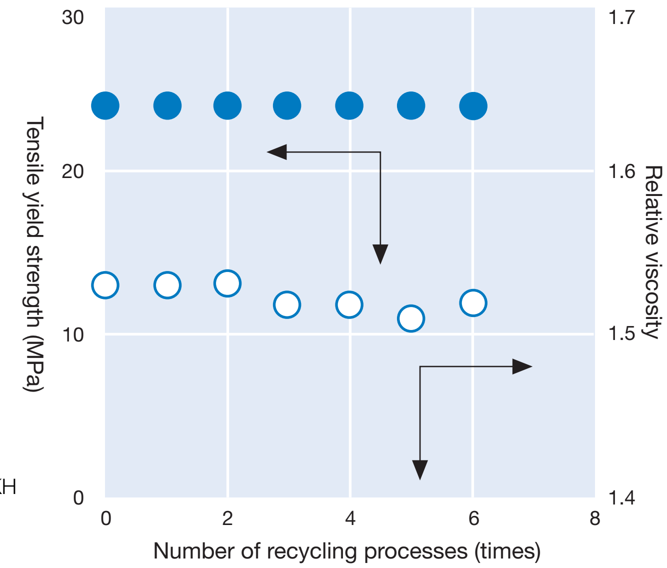


Figure 31. Recycle Test of L1724KH

DAIAMID and VESTAMID, as shown above, generally offer excellent recyclability. However, the incorrect recycling of these materials may result in unexpected problems. Please be aware of the following precautions so that recycling problems can be avoided.

1) **Sufficiently dry the material before recycling**

A high water in the resin can cause appearance defects such as voids and a rough surface on the molded product. If the molding temperature is high, water content may even sever the molecular chain of polyamide, resulting in invisible problems such as reduced molecular weight or even lower mechanical strength. Therefore, when recycling DAIAMID/VESTAMID that has been left standing for a long time, the material must be dried at 80ºC to 100ºC for around four hours. Preferably, confirm before use that the water content of the recycled product is 0.1% or less.

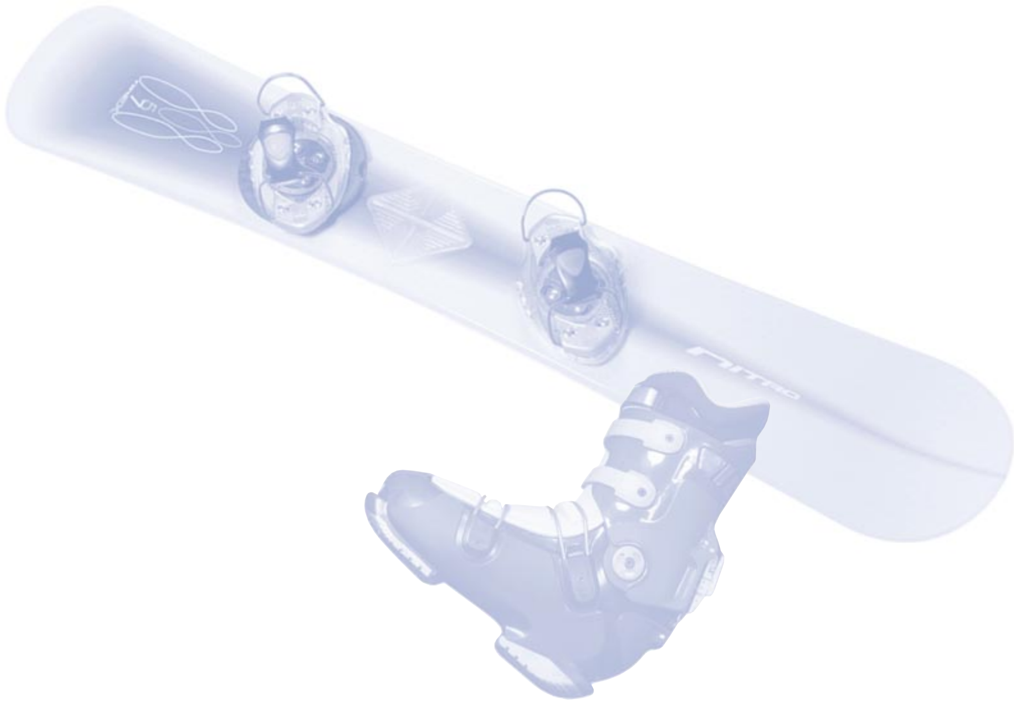
2) Be certain the material is free from contaminations of different resins or foreign matter

DAIAMID, because of its excellent ductility, sometimes picks up fine powders of polyacetal, ABS and other brittle resins that have been left in the crusher. Even though they're in the same polyamide group, Polyamide 6 and Polyamide 66 can reduce the properties of DAIAMID if they're allowed to intermix with it. Prevent other resins comprising the sprue or runner from mixing into the DAIAMID, and thoroughly clean the crusher before crushing a recycling product. If possible, use a dedicated crusher.

3) We recommend the blending of recycled material with virgin material

As shown in the graph, property changes in DAIAMID are limited even after it has been recycled 100 %. However, repeated exposure to heat may produce discolorations and other immeasurable changes. To minimize such effects, it is recommended that recycled DAIAMID be diluted with virgin material to minimize the content of recycled DAIAMID. The ratio of recycled DAIAMID should ideally be kept to around 20 to 30 %. If the ratio must be raised beyond that level, verify through a practical test, etc., that it won't cause a problem.

Although DAIAMID offers excellent recyclability, as explained above, problems can happen depending on the control level during the recycling process. If you have any questions regarding the recycling of DAIAMID/ VESTAMID, please contact your Daicel-Degussa sales representative. We will study your specific application and give you the proper advice.



III. Lubricated Properties of DAIAMID and VESTAMID

DAIAMID and VESTAMID, thanks to their excellent dimensional stability and noise reduction properties, have been used for many years in the production of silent gears for AV equipment, OA equipment, and so on. However, resins used as gear materials face a constant need for improvement in order to offer better sliding characteristics and abrasion resistance as a means to ensure higher durability, allow the elimination of grease, etc. The following explains the test results on a Suzuki friction & wear tester (thrust type wear tester) of the standard gear grade and lubricated grades (note that A3951 is considered a special lubricated grades, as indicated by the suffix "H" in the part number), as developed by applying a special process to improve lubricated properties.

1) Friction coefficients and abrasion ratio in major gear-grades
2) Relationship of load pressure and limit sliding speed
3) Relationship of sliding speed and friction coefficient

1) Friction coefficients and abrasion ratio in main gear-grade materials

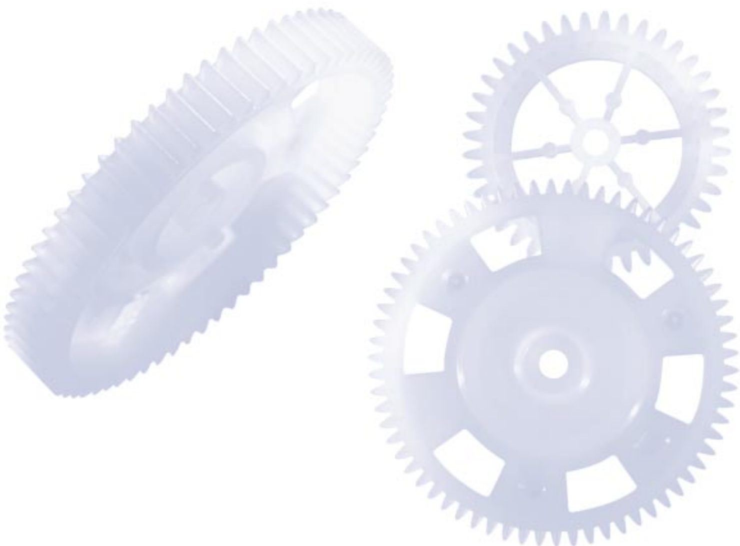
Test method:

Measurement was performed in conformance with JIS K7218.
Against material: Polyoxymethylene (POM)
Sliding area: 2 cm^2
Test conditions:

Measuring condition	Sliding speed(mm/sec)	Load pressure(kgf/cm^2)	PV value(kgf/cm/sec)
1	250	0.460	11.5
2	500	0.322	16.1
3	1000	0.138	13.8

Results:

The relationship of measuring condition and friction coefficient and that of PV value and abrasion ratio are shown in the accompanying graphs.



Relationship of measuring condition and friction coefficient

The friction coefficients of L1724K, X1988 and E62 are all at approximately 0.4, so there isn't much difference between these grades. The friction coefficients of these materials are roughly the same as the friction coefficient of POM. On the other hand, the friction coefficients of lubricated grades such as L1724KH, X1988H and E62H are approximately 0.2. It is therefore shown that the lubricated grades offer significantly lower friction coefficients.

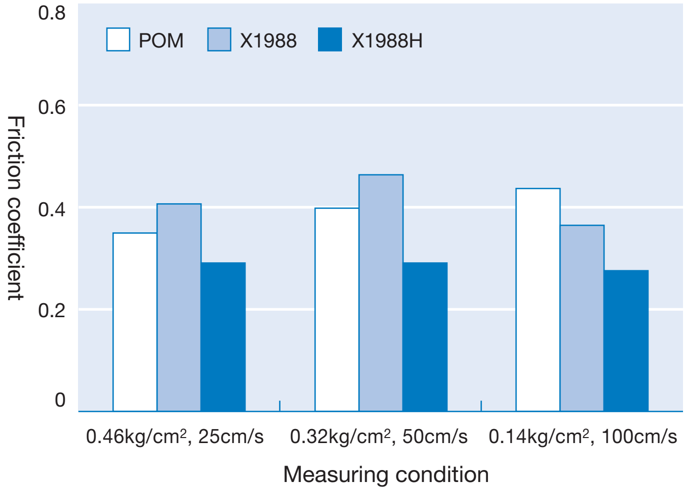


Figure 32. Friction Coefficients of X1988(H)

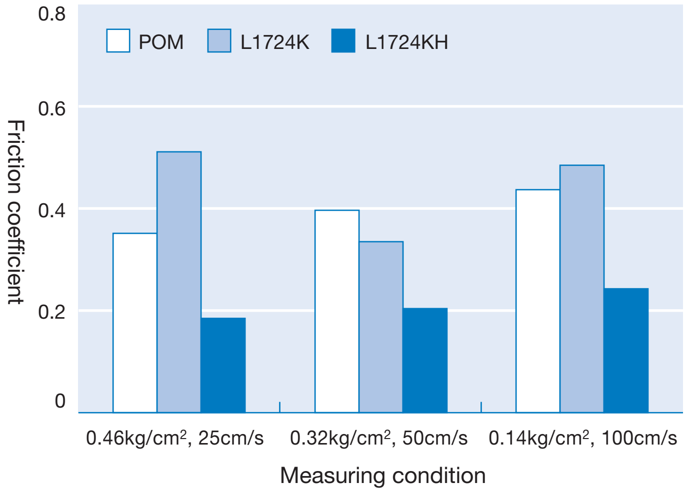


Figure 33. Friction Coefficients of L1724K (H)

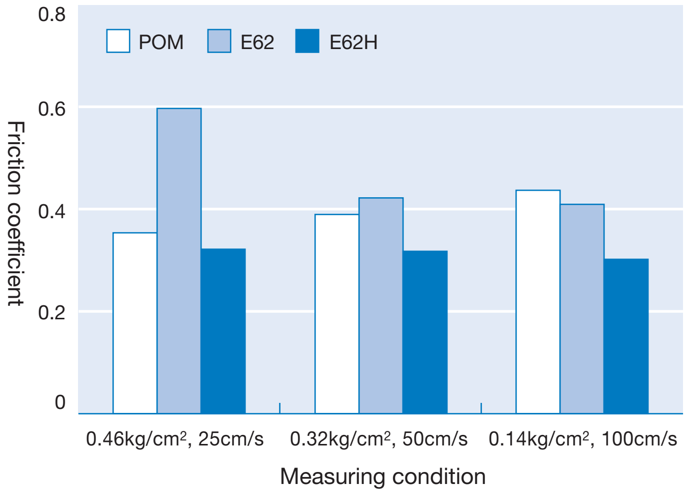


Figure 34. Friction Coefficients of E62 (H)

Relationship of PV value and abrasion

The comparison data of abrasion ("abrasion" indicating how much the resin has abraded with respect to a specific sliding distance) shows slight differences in terms of the resin's flexibility, shear strength and other mechanical characteristics. Specifically, a hard grade like X1988 has a small amount of abrasion, while soft grade like L1724K and E62 exhibit large amounts of abrasion. In comparison E62 with the lubricated grade of E62, there is not much improvement on the abrasion ratio between them. However, the abrasion is shown to improve significantly with the lubricated grades of L1724K and X1988.

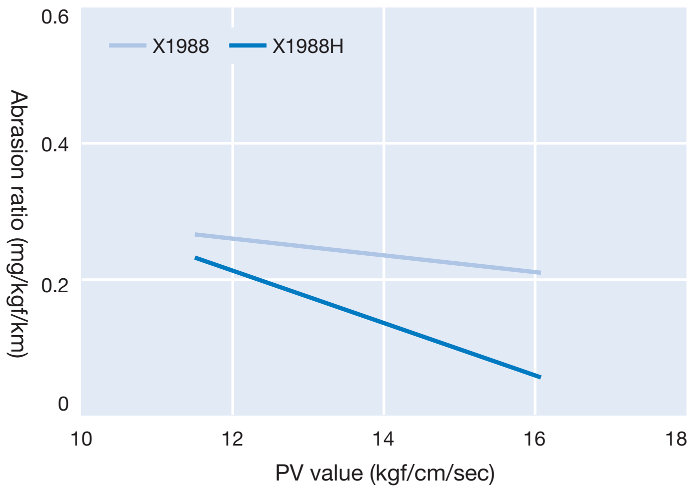


Figure 35. Abrasion Ratio of X1988(H)

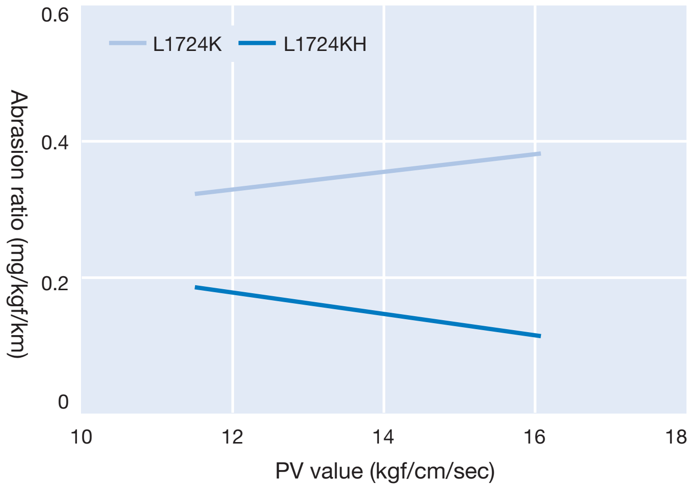


Figure 36. Abrasion Ratio of L1724K(H)

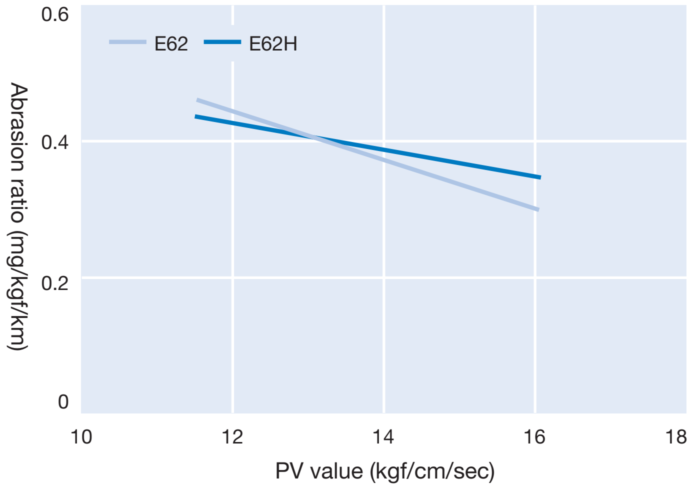


Figure 37. Abrasion Ratio of E62(H)

2) Relationship of load pressure and limit sliding speed

In a friction test, raising the sliding speed continuously will reach a point where the resin surface starts to melt due to friction heat generated on the interface between two materials and the gear begins to lose its functionality. This speed is referred to as the "limit sliding speed." The load pressure has a significant influence on limit sliding speed. The graph below shows the relationship of load pressure and limit sliding speed with E62 and E62H against POM.

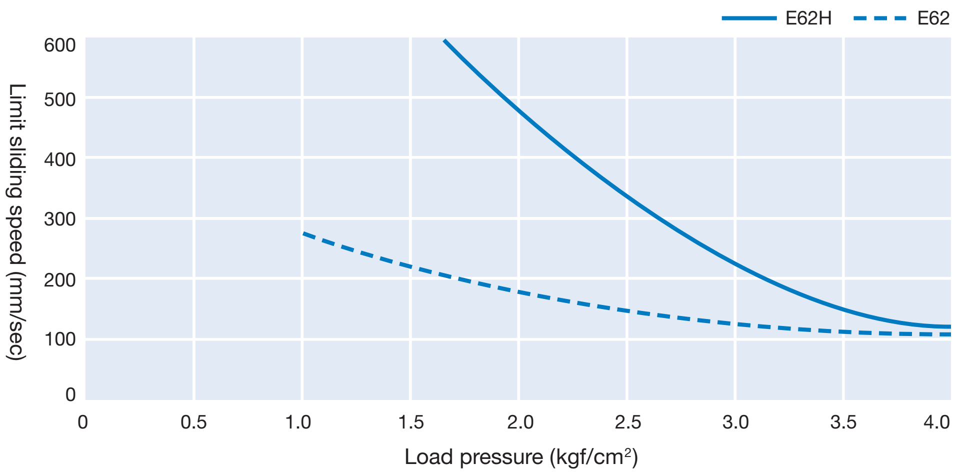


Figure 38. Limit Sliding Speed of E62 (against POM)

The limit sliding speed decreases as the load pressure increases. One way to increase the limit sliding speed is to reduce the friction resistance and thereby suppress the generation of friction heat. Generally, from this perspective, a lubricant, etc., is applied to the gear surface. From the above data, our lubricated grade is as effective as when lubrication is applied to the gear made of a standard resin.

3) Relationship of sliding speed and friction coefficient

The graph below shows the relationship of sliding speed and friction coefficient with E62 and E62H against S45C, general grade of carbon steel (load pressure: 1 kgf/cm^2).

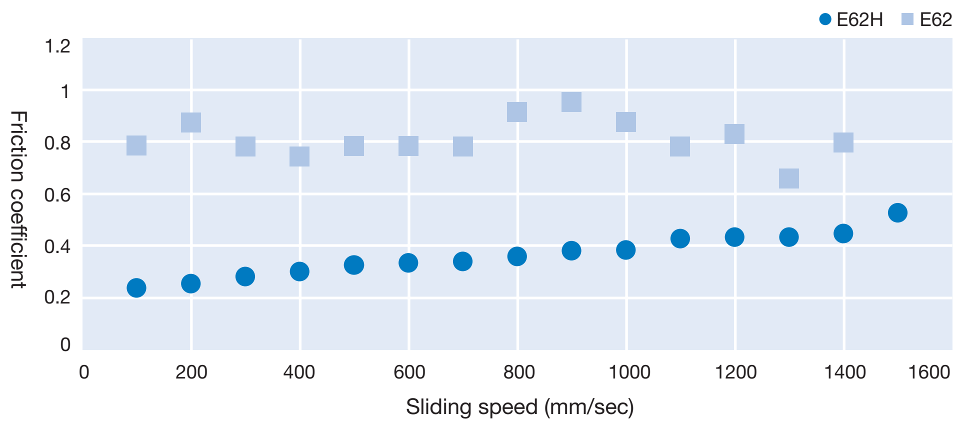


Figure 39. Relationship of Sliding Speed and Friction Coefficient (against S45C; Load pressure: 1 kgf/cm^2)

By using the lubricated grade E62H instead of the standard E62, the friction coefficient decreases over a wide range of sliding speeds.

IV. Appendix Graph

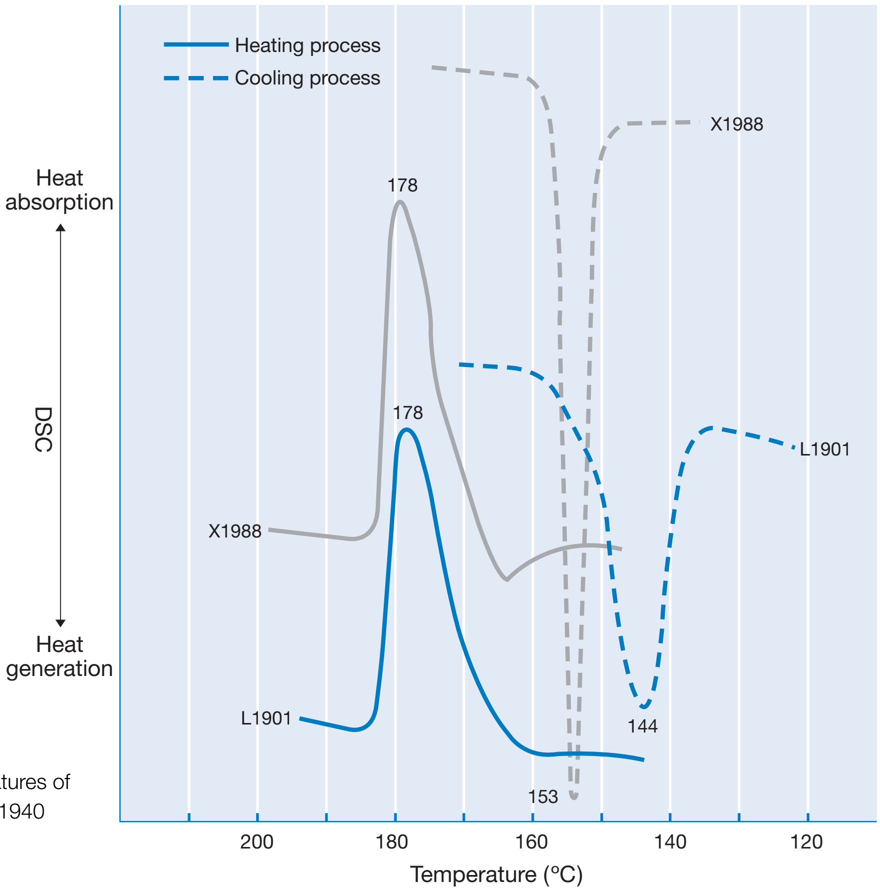


Figure 40. Melting Points and Crystallization Temperatures of DAIAMID X1988 and L1940

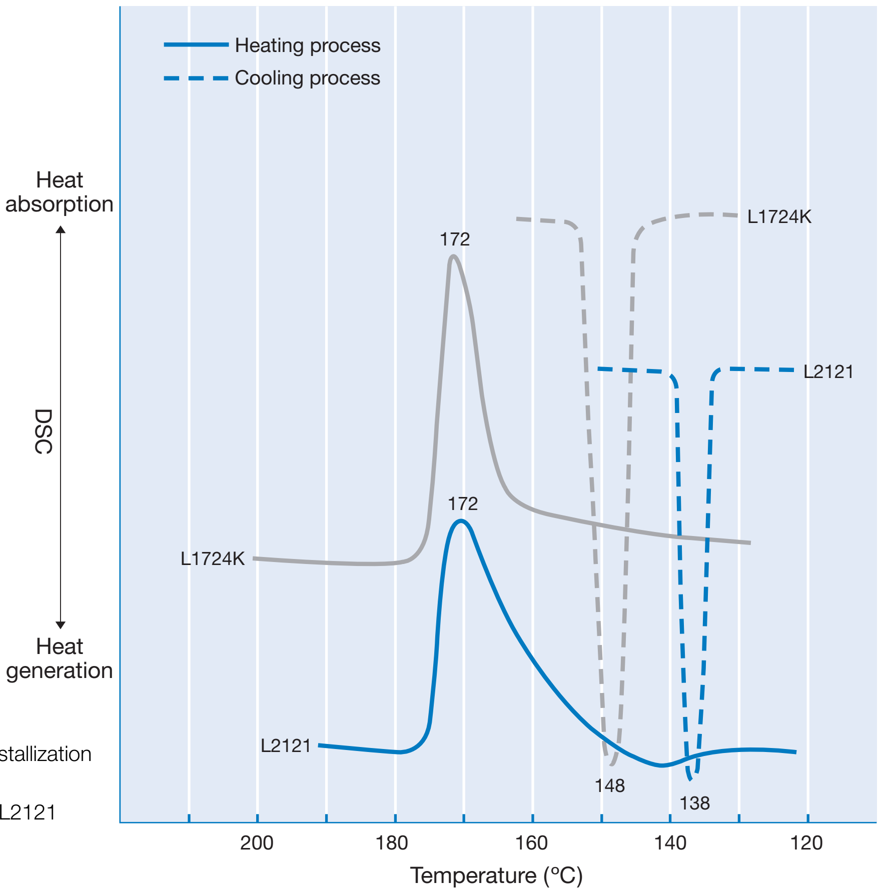


Figure 41. Melting Points and Crystallization Temperatures of DAIAMID L1724K and L2121

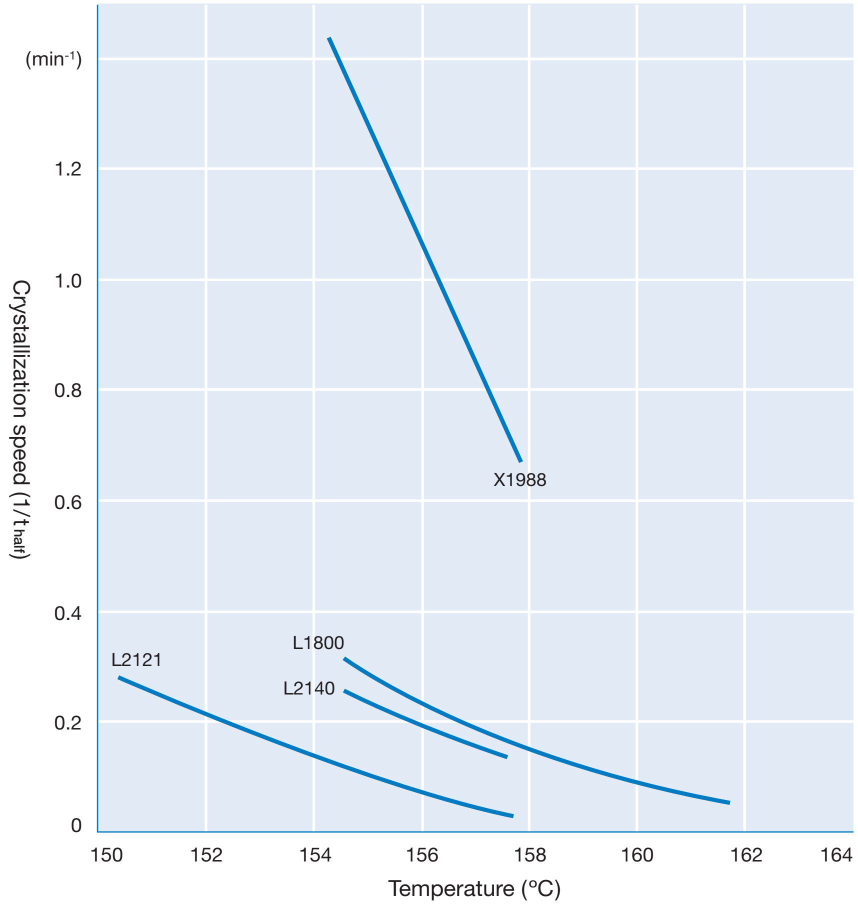


Figure 42. Isothermal Crystallization Speeds of DAIAMID/VESTAMID

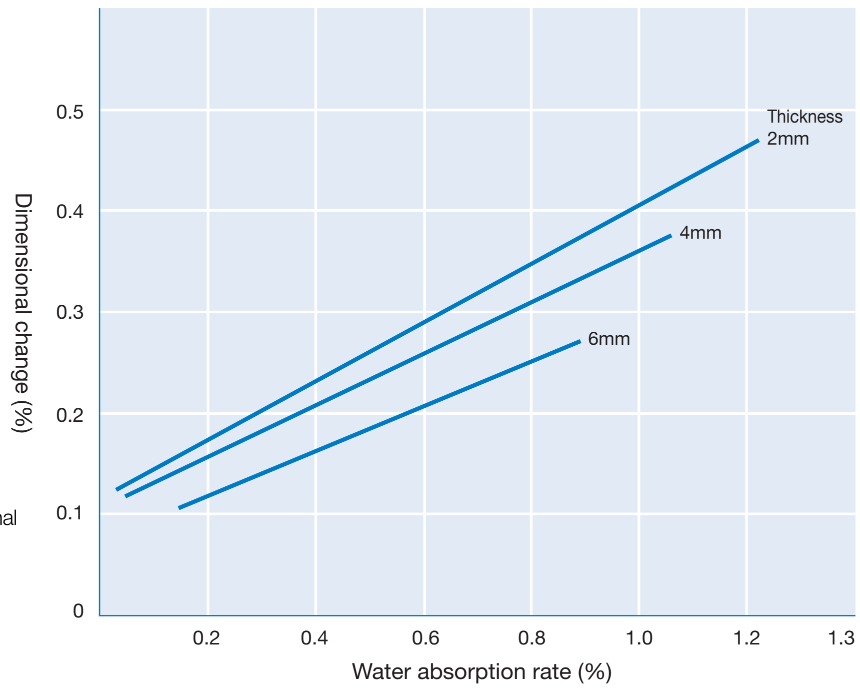


Figure 43. Relationship of Water Absorption and Dimensional Change with DAIAMID/VESTAMID (Basic Grade)

* The figures stated in this catalog represent average values measured on DAIAMID and VESTAMID in conformance with ISO and other applicable standards. These values may not be directly applicable under conditions other than those described. Neither do these figures guarantee the safety or conformance of a given application. Please verify the safety and conformance of DAIAMID/VESTAMID in your specific application.

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