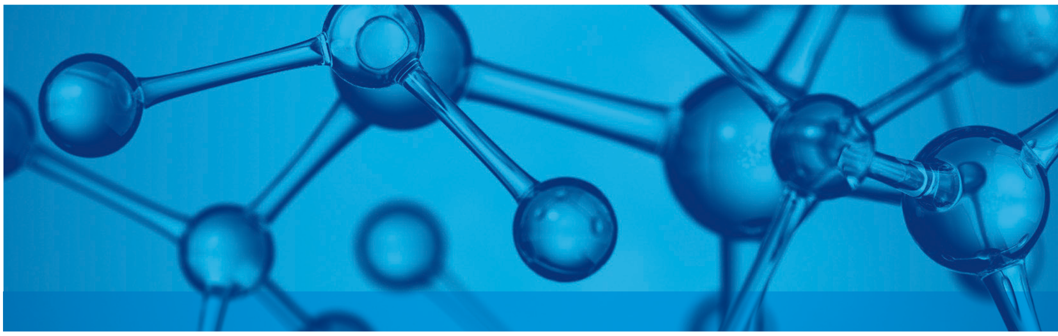


Effects of Machining on the Mechanical Properties of Ixef® PARA

Ixef® polyarylamide (PARA) is one of many high-performance healthcare polymers that Solvay offers for use in medical devices that come in contact with bodily tissues or fluids for less than 24 hours. This material is typically supplied in the form of pellets for injection molding.

Because customers often need to create a prototype of the device prior to molding, there is a need for stock shapes, such as extruded rods and plates, that can be machined and used for functional testing.

Polymer Prototypes

It is common practice to make prototypes from unfilled, amorphous polymers, like Solvay's Radel® polyphenylsulfone (PPSU), because the properties of parts machined from stock shapes closely represent those of the injection molded part.

Conversely, it is generally discouraged to use stock shapes made from highly-filled, semi-crystalline polymers, like Ixef® PARA, to machine prototypes due to several factors, including thermal degradation during the slow extrusion process, lack of fiber orientation in thick cross-sections, and fibers being exposed on the surface of the part.

In order to assist our customers, Solvay conducted a study to evaluate the mechanical effects of extruding and machining Ixef® GS-1022 GY51, a 50 % glass-filled grade that is one of Solvay's standard healthcare grades. The results of this study are presented in this document.

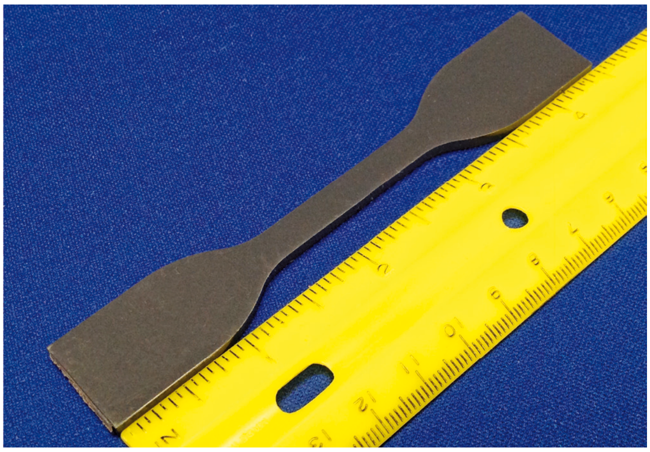
Test Sample Preparation

In order to have a direct, side-by-side comparison, a single lot of Ixef® GS-1022 GY51 was used. Drake Plastics Ltd. extruded circular rods and Solvay molded tensile bars (Figure 1) and test plates using standard published conditions for Ixef® PARA. Dimensions are noted below:

- Circular rod: 3.8 × 1.9 cm (1.5 × 0.75 inches)
- ASTM Type IV tensile bars:
  11.4 × 1.9 × 0.32 cm (4.5 × 0.75 × 0.125 inches)
- Test plates: 15.2 × 15.2 × 0.32 cm (6 × 6 × 0.125 inches)

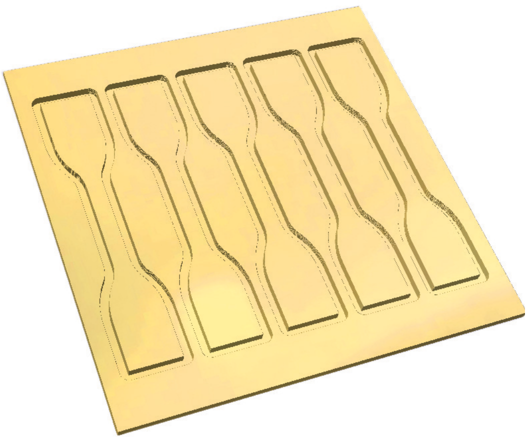
A portion of the Type IV tensile bars were sealed in a vacuum pouch to preserve dry-as-molded conditions, and a portion of the Type IV tensile bars were placed in ambient conditions in a polyethylene (PE) bag to simulate the machined test samples that could not be stored in a vacuum-sealed, moisture-free environment.

Figure 1: ASTM Type IV tensile bar



Molded plates were shaped into ASTM Type IV tensile bars using a CNC machine (Figure 2). Samples cut in the flow and transverse flow directions were stored in ambient conditions in a PE bag until testing.

Figure 2: Cut pattern for molded plates



Rod samples were machined at a local machine shop. Specific machining variables were not recorded. Type IV bars were produced from the 3.8-cm (1.5-inches) diameter bars in 3 locations through the cross-section: outer edge, middle and core. Type IV bars were cut from the 1.9-cm (0.75-inches) diameter bars only from the core of the bar and had a reduced tab width (Figure 3). The edges of all machined samples were lightly sanded with 400 grit sandpaper to remove machining marks from the neck region of the samples to eliminate the possibility of localized failure. The molded and machined Type IV test bars are shown in in Figure 4.

Figure 3: Location of machined rod samples

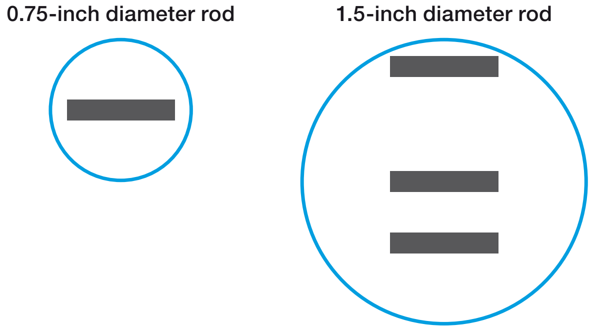
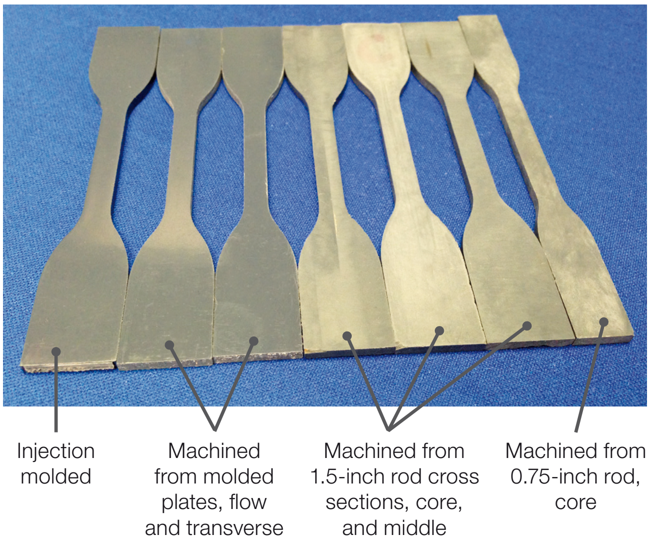


Figure 4: Molded and machined Type IV test bars



Mechanical Properties Testing

All ASTM Type IV tensile bars were tested in accordance with ASTM D693 to measure and calculate tensile strength at break, tensile elongation at break, and tensile modulus using an Instron load frame and Bluehill software. All samples were tested at 5.1 mm/min (0.2 inches/min) using an extensometer.

Table 1: ASTM D693 Type IV tensile bar test results*

Processing Method	Storage Conditions	Tensile Strength at Break [MPA (psi)]	Tensile Elongation at Break [%]	Tensile Modulus [GPA (ksi)]
Injection molded	Vacuum sealed bag	275 ±*2* (39,900 ±*323*)	0.03 (2.0)	20.3 ±*300* (2,950 ±*36*)
Injection molded	Zipper lock bag	265 ±*5* (38,500 ±*660*)	0.09 (1.9)	19.9 ±*1.0* (2,880 ±*145*)
Machined from molded plate, flow direction	Zipper lock bag	196 ±*28* (28,400 ±*4030*)	0.08 (1.8)	16.5 ±*1.9* (2,390 ±*279*)
Machined from molded plate, transverse direction	Zipper lock bag	161 ±*4* (23,400 ±*561*)	0.08 (1.8)	13.9 ±*0.5* (2,010 ±*71*)
Machined from 3.8-cm (1.5-inches) rod, outer edge	Ambient	76 ±*4* (11,000 ±*633*)	0.12 (0.88)	10.1 ±*0.3* (1,460 ±*39*)
Machined from 3.8-cm (1.5-inches) rod, core	Ambient	37.0 ±*14* (5,360 ±*2040*)	0.16 (0.34)	10.6 ±*0.3* (1,540 ±*46*)
Machined from 3.8-cm (1.5-inches) rod, middle	Ambient	46 ±*25* (6,650 ±*3570*)	0.3 (0.52)	9.7 ±*0.5* (1,400 ±*70*)
Machined from 1.9-cm (0.75-inches) rod, core	Ambient	99 ±*9* (14,400 ±*1280*)	0.1 (0.86)	13.3 ±*0.5* (1,930 ±*79*)

**Reported as average (standard deviation)*

Conclusion

As expected, test results show a significant drop in the mechanical properties of machined Ixef® PARA test bars made from either molded plates or extruded rods.

Tensile strength was reduced by 30 % for samples cut from the flow direction of a molded plate and by 40 % for those cut from the transverse flow direction. Parts machined from extruded rod demonstrated an even greater reduction in tensile strength and modulus, decreasing by 80 % and 50 % respectively.

Crystallinity and moisture content measurements show that all samples were fully crystallized and the moisture content was not significantly different between molded and machined test samples stored in ambient conditions.

Although parts machined from Ixef® PARA have acceptable dimensions and appearance, their mechanical properties are impacted significantly due to the lack of fiber orientation in the extruded rod. Subsequently, extruded shapes made from this polymer can be machined for the purpose of general form and fit, but should not be used to evaluate performance.

www.solvay.com

SpecialtyPolymers.EMEA@solvay.com | Europe, Middle East and Africa
SpecialtyPolymers.Americas@solvay.com | Americas
SpecialtyPolymers.Asia@solvay.com | Asia Pacific

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