WHITE PAPER:

Breaking the (injection) mold

Comparing the wear rates of 3D printed components vs injection molded components

igus®

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Abstract

Since its creation in the 1980s, 3D printing has evolved tremendously, with more printing technologies and material types available. Research shows that engineers in North America are optimistic about the future of 3D printing and believe new materials will help advance the industry. This white paper details a new plastic material solution that allows engineers and product developers to print parts with wear rates comparable to certain injection-molded components.

Introduction

Injection molding is the most widely used processing technology for plastics (Guevara-Morales & Figueroa-López, 2014); however, it does have its limitations. For example, parts with hollow walls or other complex geometries cannot be produced (Styles, 2018), and small production runs can be very expensive. Luckily, additive manufacturing – also known as 3D printing – can be used as an alternative manufacturing method.

3D printing was once perceived as a process that was only suitable for rapid prototyping, but that is no longer true. In 2019, a French 3D printing company called sculpteo surveyed more than 1,300 people from around the world – 64% of which had an engineering background – to determine the current state of the 3D printing industry. The study found that 51% of respondents use 3D printing for production, up from 38% in 2018. Additionally, nearly 60% of respondents believe the industry needs new materials to grow.

This white paper examines a new engineered composite plastic material solution for the 3D printing industry: powders and filaments capable of producing plastic parts that are nearly as durable as certain injection-molded components.

Thermoplastics

Injection molds can process most commodity and engineering-grade thermoplastics (Holtz, 2018). Engineering plastics, such as acrylonitrile butadiene styrene (ABS) and nylon, exhibit superior mechanical and thermal properties compared to the more widely used commodity plastics, such as polyethylene (PE) and polystyrene (PS) (Guevara-Morales & Figueroa-López, 2014). They are typically used in applications that require exceptional properties like stiffness, toughness, and heat and chemical resistance (Guevara-Morales & Figueroa-López, 2014). Different additives, fillers and modifiers can be added to improve certain properties of engineering plastics like ABS (Midstate Mold, 2017), but these additives can affect the behavior of the polymer melt (Guevara-Morales & Figueroa-López, 2014).

Some 3D printing processes, such as Fused Deposition Modeling (FDM) and Selective Laser Sintering (SLS), also use thermoplastics for production; however, each process requires the materials to come in different forms. FDM, for example, requires thermoplastic filaments, whereas SLS requires thermoplastic powders. A wide range of materials are available for FDM printing, including commodity plastics, engineering plastics and high-performance plastics, such as polyether ether ketone (PEEK) and polyetherimide (PEI). The two most common materials used are ABS and polylactic acid (PLA). ABS is characterized with good strength and good temperature resistance, and PLA has excellent visual quality and is easy to print with (Bournias Varotsis, n.d.). FDM is ideal for concept models, functional prototypes, manufacturing aids and low-volume end-use parts (Solid Concepts, 2013). SLS prints lightweight, highly durable, and heat and chemical resistant parts mostly out of polyamide 12 (PA12, or Nylon 12), making it an ideal process for creating production parts without the expense of injection mold tooling (Solid Concepts, 2013). Other SLS materials include nylon 6, nylon 11 and glass-filled nylon. Materials filled with additives are usually more brittle and can have highly anisotropic behavior (Bournias Varotsis, n.d.).

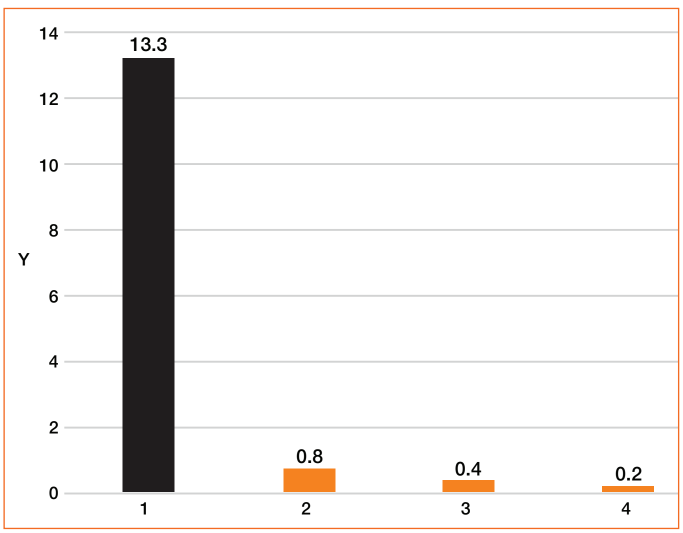
A new alternative to these standard plastic printing materials is high-performance plastic iglide® filaments and powders. Test results show iglide® is more wear resistant than ABS, PA12 and PA12-GF (plastic reinforced with glass) and has comparable wear rates to injection-molded iglide® components. iglide® is a tribologically-optimized polymer blend composed of base materials for wear resistance, reinforcing fibers for high forces, and solid lubricants to eliminate the need for external oil and grease. In addition to being self-lubricating, all iglide® materials are maintenance-free, lighter than metal, and resistant to dirt, dust and chemicals. igus® engineers rigorously test our self-lubricating plastics inside our 41,000-square-foot lab at our headquarters in Cologne, Germany.
igus® has conducted numerous wear tests on our FDM filaments and SLS powders based on DIN ISO 7148-2, including linear long and short strokes, pivoting, and rotating. Results show that iglide® filaments last up to 50 times longer inside moving applications than standard printing materials, and iglide® powders last up to three times longer.

Wear-resistant 3D-printing materials

Linear : long stroke

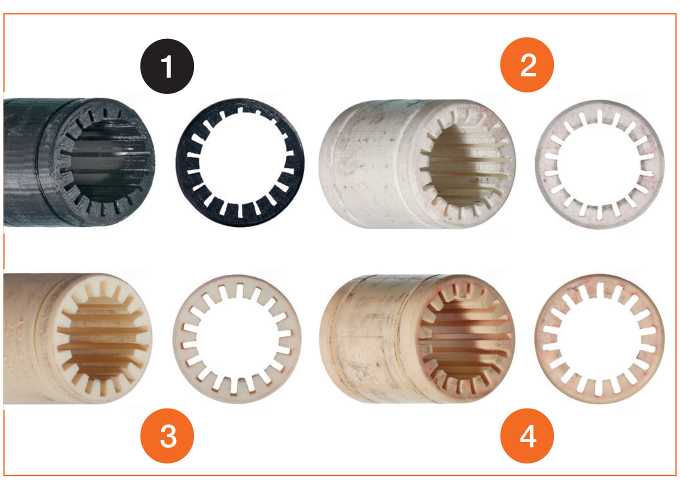
For the linear long stroke test, we compared the wear resistance of an FDM-printed ABS linear bearing to three other linear bearings made from different types of iglide® materials and manufacturing methods. They include FDM-printed iglide® I180, SLS-printed iglide® I3 and injection-molded iglide® J linear bearings. Test parameters were as follows:

- Surface pressure: 15 psi
- Surface speed: 66.93 ft/min
- Stroke: 370mm
- Shaft materials: alu hc
- Duration: 3 weeks



Y = wear rate [mg/km]

1. ABS (FDM)
2. iglide® I180 (FDM)
3. iglide® I3 (SLS)
4. iglide® J (injection molded)



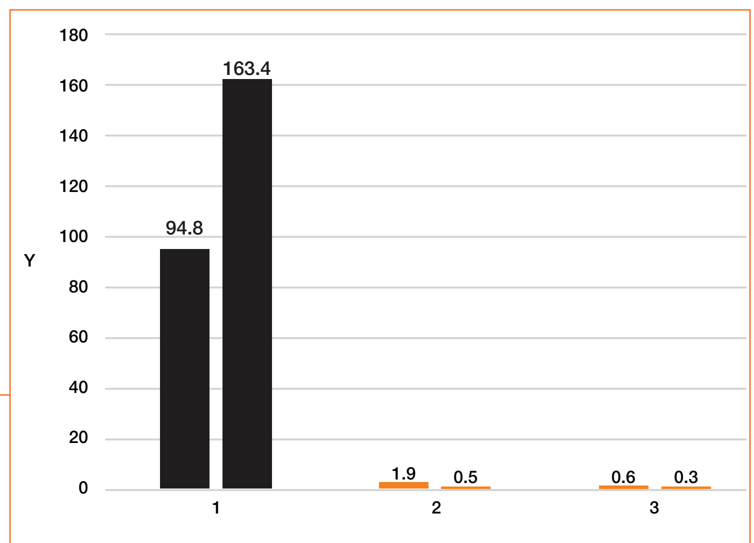
The long stroke test shows that the iglide® I180 linear bearing offers a lower coefficient of wear by factor 15 compared to the ABS bearing. As depicted in the wear chart, I3 is only twice the amount of wear compared to an injection-molded part.

We compared the wear resistance of FDM-printed ABS plain bearings to FDM-printed iglide® J260 and injection-molded iglide® J260 plain bearings during the linear short stroke test. The test parameters were as follows:

- Surface pressure: 145 psi
- Surface speed: 59.06 ft/min
- Stroke: 5mm
- Shaft materials: CF53 (left bar) and 304 SS (right bar)
- Duration: 1 week

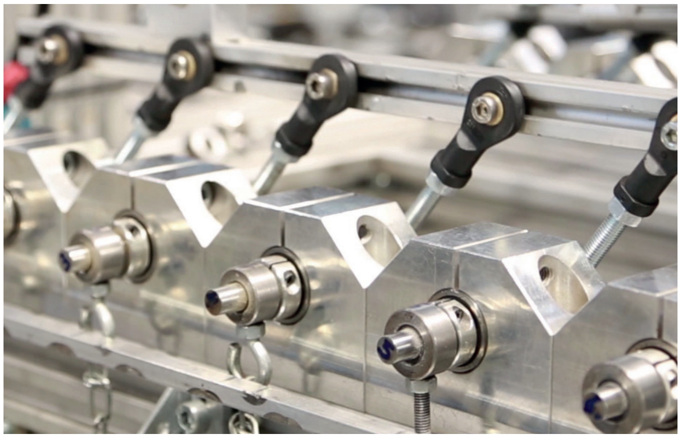
The injection-molded and 3D-printed iglide® J260 plain bearings were tested with the same load and surface speeds. Results show that both bearings have similar wear rates, regardless of manufacturing method. The test also shows that our material's coefficient of friction and wear rates are much lower than standard ABS materials.

1. ABS (FDM)
2. iglide® J260 (FDM)
3. iglide® J260 (injection molded)



Y = wear rate [mg/km]

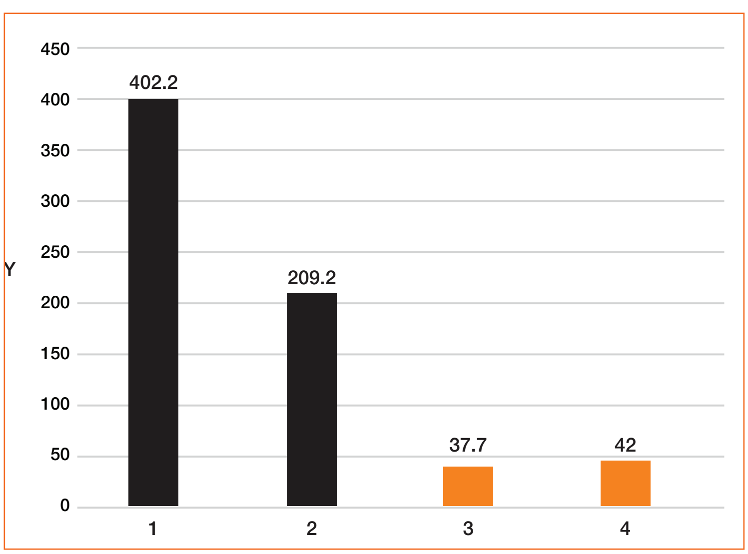
Pivoting



During our pivoting test, we compared the wear resistance of a SLS-printed PA12 plain bearing, a SLS-printed PA12-GF plain bearing, a SLS-printed iglide® I3 plain bearing and an injection-molded iglide® L280 plain bearing. The test parameters were as follows:

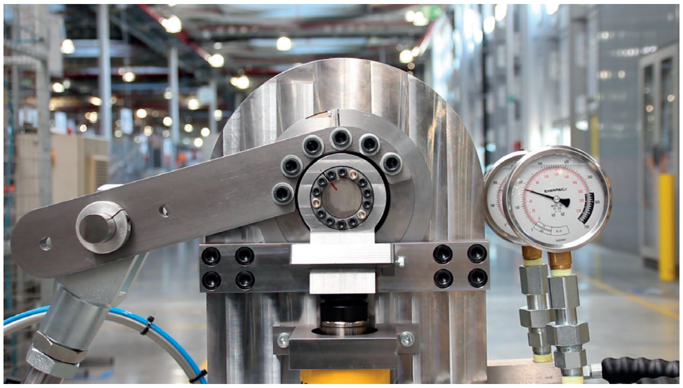
- Surface pressure: 2900 psi
- Surface speed: 1.97 ft/min
- Pivoting angle: 60°
- Shaft materials: 304 SS
- Duration: 4 weeks

The swivel test shows that the triboloigcal properties of iglide® SLS materials offer 10 times more abrasion resistance than that of standard 3D printing materials, such as PA12, and offer a much longer service life.



❶ PA12 (SLS)
❷ PA12-GF (SLS)
❸ iglide® I3 (SLS)
❹ iglide® L280 (injection molded)

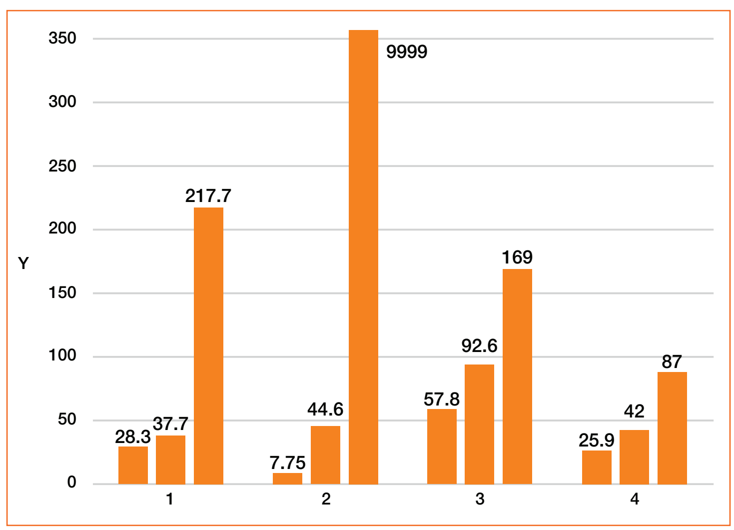
Pivoting : heavy load



We compared the wear rates of plain bearings made from different iglide® materials and manufacturing methods during our pivoting heavy load test. The first was an SLS-printed iglide® I3 bearing; the second was a FDM-printed iglide® I180 bearing; the third was an injection-molded iglide® G300 bearing; and the fourth was an injection-molded iglide® L280 bearing. Each bearing had a diameter and length of 20mm (i.e., the 3D-printed plain bearing was loaded with 1800kg), and the test parameters were as follows:

- Surface pressure: 1450, 2900 and 6526 psi
- Surface speed: 1.97 ft/min
- Pivoting angle: 60°
- Duration: 1 week

Results show that our SLS-printed plain bearings can withstand loads of up to 6526 psi surface pressure – making them suitable for heavy-duty applications – and that their tribological properties are just as good as our injection-molded bearings.



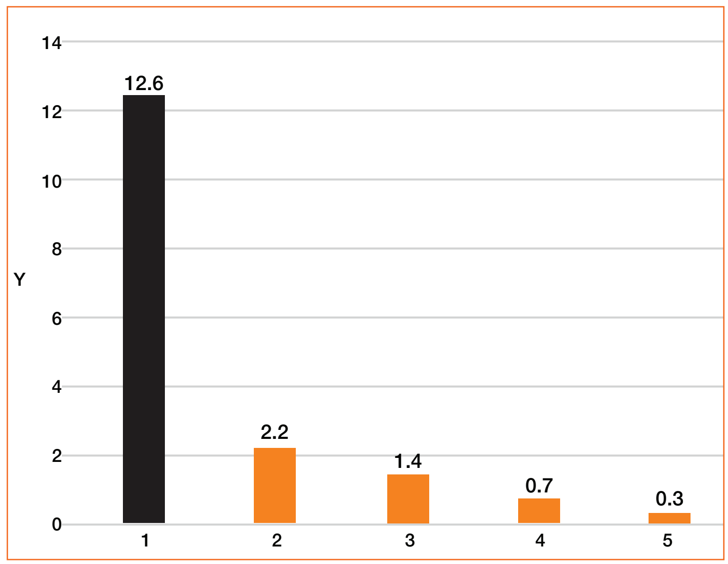
1. iglide® I3 (SLS)
2. iglide® I180 (FDM)
3. iglide® G300 (injection molded)
4. iglide® L280 (injection molded)

Lead screw nut

During the lead screw nut test, we compared the wear resistance of FDM-printed ABS, iglide® I180 and iglide® J260 lead screw nuts to a SLS-printed iglide® I3 nut and an injection-molded iglide® J nut. Test parameters were as follows:

- Torque: 95.15 ft/lbs
- Stroke: 370mm
- Speed: 290 [rpm]
- Duration: 2 weeks

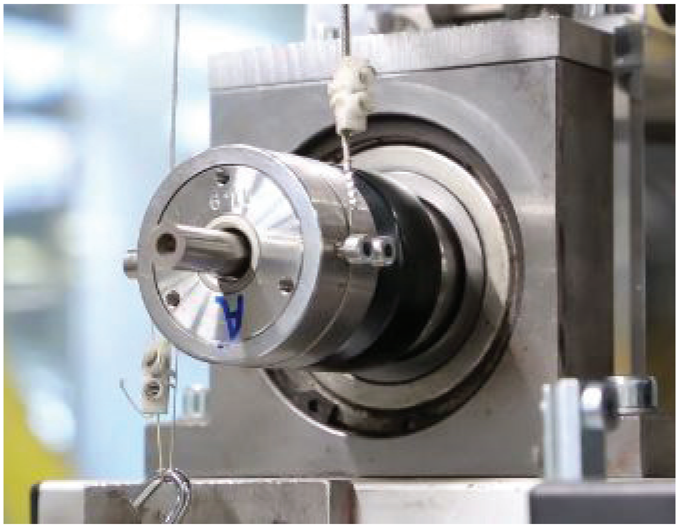
The results show that depending on which 3D-printing material and method are used, iglide® offers higher wear resistance by factor 6 to factor 18 compared to ABS material. Printing lead screw nuts in low quantities is a cost-effective alternative to injection molding since the thread can be produced directly in the 3D printer without expensive tooling.



Y = wear rate [mg/km]

❶ ABS (FDM)
❷ iglide® I180 (FDM)
❸ iglide® J260 (FDM)
❹ iglide® I3 (SLS)
❺ iglide® J (injection molded)

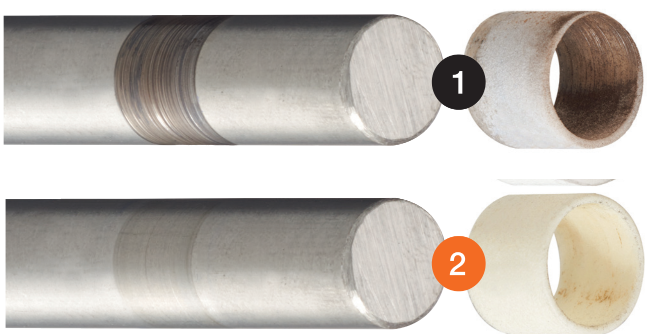
Rotating



For this test, we compared the coefficient of friction of a SLS-printed PA12 plain bearing to a SLS-printed iglide® plain bearing. Test parameters were as follows:

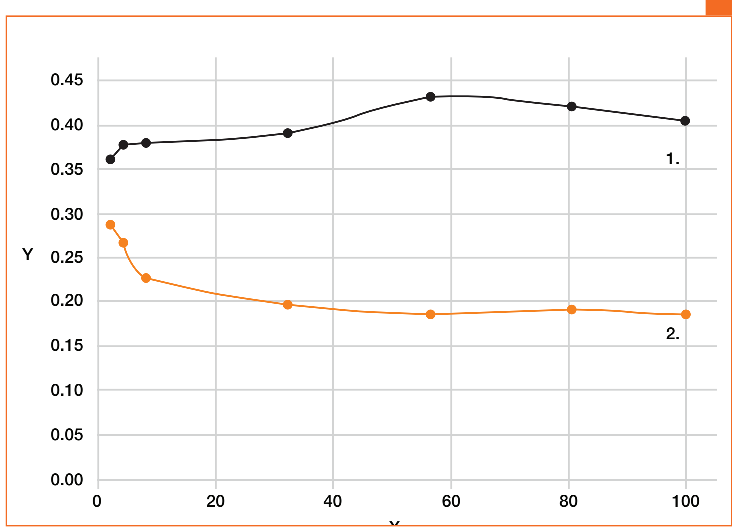
- Surface pressure: 145 psi
- Surface speed: 19.7 ft/min
- Shaft material: Cf5

The results show the tribological properties of iglide® I3 are better than standard 3D-printing materials by factor 2. That is due to the solid lubricants that are embedded in iglide® materials, which lower the coefficient of friction and significantly increase wear resistance. The tribological properties of iglide® polymers are beneficial for designing motors and drive forces, as half the friction only requires half the drive force.



Y = coefficient of friction [-]
X = duration [h]

❶ PA12 (SLS)
❷ iglide® I3 (SLS)

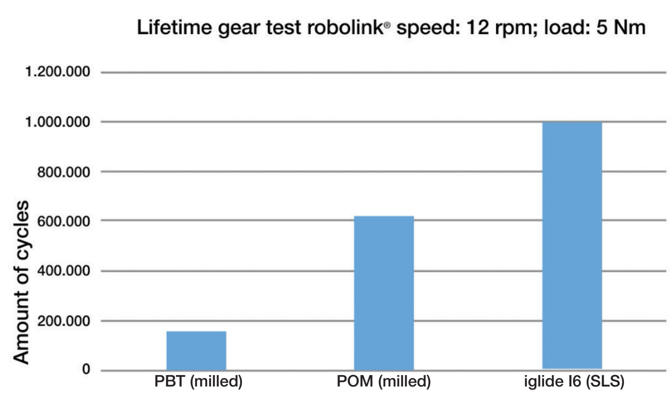


Worm gears

The objective of the worm gear test was to see how many cycles a milled polyoxymethylene (POM) worm gear and a SLS-printed iglide® I6 worm gear could withstand before failing. Test parameters were as follows:

- Torque: 3.61 ft/lbs
- Speed: 12 [rpm]
- Mating gear: hard anodized aluminum
- Duration: 2 months

Results show the POM gear failed after 621,000 cycles, whereas the iglide® gear sustained only minor wear after 1 million cycles.



iglide® I6: only minor wear after 1 million cycles

POM: failure after 621,000 cycles

PBT: failure after 155,000 cycles

Conclusion

Engineering-grade thermoplastics like ABS, PA12 and PA12-GF are capable of producing parts with exceptional properties; however, SLS and FDM-printed iglide® components have been proven to last three to 50 times longer inside moving applications. Additionally, our 3D-printed plastics exhibit wear rates that are comparable to our injection-molded components, making them ideal for use during small production runs.

It is clear that the 3D-printing industry is continuing to grow and evolve and that the perception of the manufacturing method has drastically changed. Therefore, it is more critical now than ever before for manufacturers to adapt and offer wear-resistant 3D-printing materials that have been tested and proven to offer an extended service life. Visit www.igus.com/info/3d-printing-service for more information on iglide® filaments and powders, to place an order for prototypes or small production runs, or to contact an igus® expert.

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