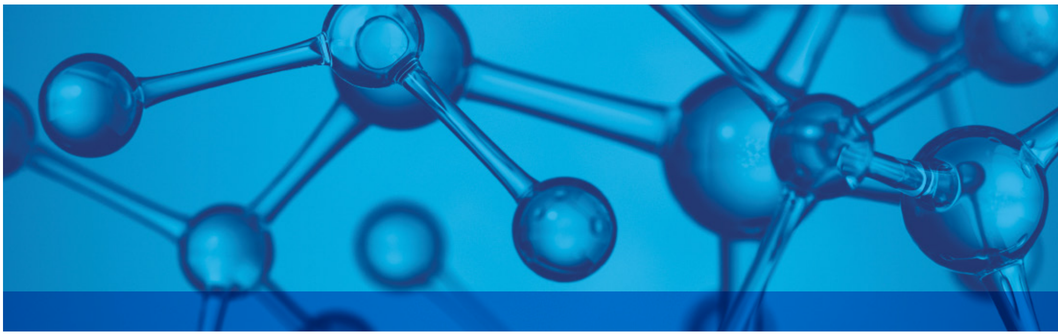


Extending Tool Life through Abrasion Resistant Steels and Surface Treatments

Introduction

Like all glass reinforced and/or highly filled engineering plastics, Ryton® PPS (polyphenylene sulfide) injection molding compounds cause wear in injection molds. This wear is primarily due to abrasion by the glass fibers and/or mineral fillers in the plastic compound. The severity of abrasive wear is dependent on the formulation of the compound. The greater the filler content, the more severe will be the abrasive wear, and harder fillers will be more abrasive than softer fillers. Most Ryton® PPS compounds contain a high percentage of glass fiber reinforcement, alone or with mineral fillers, which is particularly abrasive.

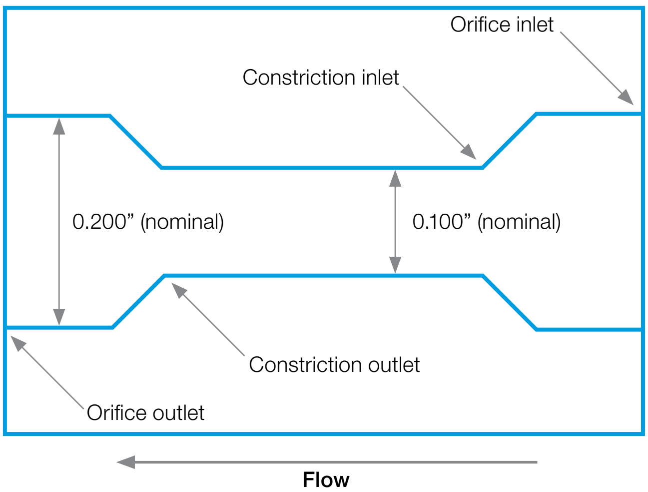
The compositions of the filler systems of Ryton® PPS compounds are critical to providing the performance attributes desired by design engineers. It is not generally practical to mitigate tool wear by altering or reducing the filler content of the material, but still attain adequate performance characteristics. While it is possible to reduce wear effects to some degree by altering processing conditions, that approach may adversely affect mold filling and packing, and thereby compromise part performance. It is most practical to extend tool life by the proper selection of tool steels and surface treatments to resist abrasive wear. This information has been compiled in response to customer inquiries regarding what tool steels and surface treatments are most effective for prolonging tool life when processing Ryton® PPS compounds.

Wear Resistance Testing

To evaluate the relative wear resistance of different tool steels and surface treatments, an accelerated test method was developed that involved injecting a measured amount of plastic compound, at a high shear rate, through a small, removable orifice in the nozzle of an injection molding machine. Each specially machined test orifice was designed to fit within a chamber in a specially designed nozzle tip. A sketch depicting an orifice cross section is shown in Figure 1. The inlet and exit diameters of each orifice were machined to a nominal 5.08 mm (0.200 inches). In the mid-section of each orifice was a constriction where the diameter was reduced to a nominal 2.54 mm (0.100 inches). Before use and at predetermined intervals, based on quantity of material processed, measurements of the orifice diameters and/or weight were recorded. When an orifice was reinserted in the nozzle after making measurements, it was always replaced in the same orientation to ensure that material would always flow through it in the same direction.

The orifice diameter measurements were obtained using a calibrated coordinate measuring machine (CMM), with a microscopic video camera, accurate to 0.00025 mm (0.00001 inch). Measurements were taken at four different diameter positions as indicated in Figure 1: the orifice inlet, the constriction inlet, the constriction outlet, and the orifice outlet. Three separate diameter measurements per diameter position were calculated on the CMM using eight perimeter points. Wear rates were determined by linear regression of the diameter measurements versus the weight of material processed, and are reported in mils of wall erosion per 100 pounds of material processed.

Figure 1: Wear resistance test orifice



The orifice weight measurements were determined using a calibrated electronic lab balance accurate to 0.001 g, and are reported in percent weight reduction of the orifice after processing 50 or 100 pounds of material. Some wear studies were conducted before the CMM equipment was available, so only weight loss data are reported in those cases.

The measurements obtained by this accelerated test method can not be used to predict absolute tool life, but only serve to provide a relative indication of how much tool life may be improved by using certain tool steels or surface treatment methods. Actual tool life is very dependent on the geometry of the tool, the material being molded, and the processing conditions used.

Tool Steels

A number of tool steels have been evaluated using the wear resistance test described herein, and results indicate that tremendous improvements in tool life can be realized through selection of more abrasion resistant tool steels. The data in Table 1 show the results of wear resistance testing using orifices machined from a variety of metals, with and without hardening. This data illustrates the improvement that can be achieved through the selection of abrasion resistant steels such as A-2 or D-2. The results indicate that A-2 will provide four times the tool life of P-20, and D-2 will provide twenty-five times the tool life of P-20. The usefulness of D-2 is somewhat limited, however, due to the difficulty of machining the material and the possibility of cracking during heat treatment of large or very intricate components. Ferro-Tic® is a dispersion of carbide in a tool steel matrix that can be machined before hardening, but after hardening suffered no measurable degree of wear in this test (see Appendix I for supplier information).

Table 1: Wear resistance test results
After processing 22.7 kg (50 pounds) of 65 % glass/ mineral filled PPS

Orifice Material		Weight Loss
A-2	as machined	1.83 %
A-2	hardened	1.76 %
D-2	as machined	0.51 %
D-2	hardened	0.16 %
H-13	as machined	5.15 %
H-13	hardened	1.19 %
P-20	as machined	8.77 %
P-20	hardened	6.95 %
Ferro-Tic®	as machined	2.52 %
Ferro-Tic®	hardened	0.00 %[1]
D-2	hardened, nitrided	0.03 %
D-2	hardened, Borofuse®	0.02 %
D-2	hardened, Crystallon® II	0.00 %[1]
D-2	hardened, LSR-1	0.00 %[1]

[1] *No measurable weight loss after processing 45.4 kg (100 pounds) of 65 % glass/mineral filled PPS*

Surface Treatments

The abrasion resistance of tool steels can be substantially enhanced by the application of various platings or surface treatments. Typical chrome or electroless nickel plating processes provide good mold release characteristics and fairly long tool life. The wear resistance test described herein has shown that dramatic improvements in wear resistance may be realized through the use of some more exotic treatments and platings. Although some of the surface treatment contractors used in these studies may no longer provide these services, they may be able to recommend suitable alternative surface treatment methods or vendors.

In one evaluation of surface treatments, identical D-2 steel orifices were sent to three different contractors for application of four different surface treatments. Contact information for the contractors is provided in Appendix I. The results are included in Table 1. Nitriding and Borofuse® case hardening treatments increased the wear resistance of D-2 steel up to five times that of the untreated metal. Two carbide plating methods have also been evaluated: Crystallon® II, a hard plating containing carbide particles, and LSR-1, a vapor deposition process for applying carbide to steel. These carbide containing platings showed no measurable degree of wear in this test.

In another evaluation of surface treatments, identical H-13 steel orifices were sent to four different contractors for application of five different surface treatments. Contact information for the contractors is provided in Appendix I. The weight loss data from these surface treatment evaluations is shown in Table 2. This data indicates that chromium nitride or titanium carbonitride will provide three times the tool life of Nicklon® and up to twice the tool life of Electrolyzing® or ion nitriding. The wear rate data shown in Table 3 provide a slightly different impression though, indicating overall that ion nitriding and titanium carbonitride provided the best wear resistance, chromium nitride and Electrolyzing® only slightly less wear resistance, and Nicklon® the least wear resistance. There appeared to be considerable variation in the degree of wear resistance imparted by different surface treatments in different regions of the orifice. In general though, all of these surface treatments were very effective at reducing wear, with titanium carbonitride appearing to be the best of the group and Nicklon® not quite as good as the others.

Table 2: Wear resistance test results
After processing 45.4 kg (100 pounds) of 40 % glass filled PPS

Orifice Material		Weight Loss
H-13	hardened, Nicklon®	0.54 %
H-13	hardened, chromium nitride	0.15 %
H-13	hardened, Electrolyzing®	0.31 %
H-13	hardened, ion nitriding	0.26 %
H-13	hardened, titanium carbonitride	0.18 %

Table 3: Wear Resistance Test Results
After processing 45.4 kg (100 pounds) of 40% glass filled PPS

Surface Treatment[1]	Wear Rates, mils/100 pounds			
	Orifice Inlet	Constr. Inlet	Constr. Outlet	Orifice Outlet
Nicklon	1.74	2.03	1.28	1.48
Chromium nitride	1.21	1.34	0.86	1.80
Electrolyzing	2.16	0.68	0.92	1.72
Ion nitriding	2.01	0.98	0.81	1.01
Titanium carbonitride	0.83	1.04	1.23	1.45

[1] *H-13 steel, hardened*

Conclusion

By far the greatest reduction in tool wear can be realized by the proper selection of tool steels. A good, hard tool steel, such as A-2 or D-2, will provide good tool life when hardened to Rc 60 or better. The application of a dense chrome or electroless nickel plating will enhance the abrasion resistance of these tool steels to some degree. Various other surface treatments and case hardening processes can dramatically enhance tool life. The ultimate in abrasion resistance of tool steels can be achieved by any of the methods of incorporating carbides in the tool steel surface. In particularly high shear areas, such as small gates, it may be desirable to use replaceable blocks and/or an even more abrasion resistant material such as solid tungsten carbide.

Appendix I

Surface Treatment Contractors

Alloy Technology International
West Nyack NY
1-800-431-1854
845-358-5900
www.alloytechnology.com
- Ferro-Tic®

Balzers
Amherst NY
716-564-8557
www.btc.balzers.com
- Chromium Nitride (not used herein)
- Titanium Carbonitride

Electrolizing®
Providence RI
401-861-5900
www.electrolizing.com
- Electrolizing®
- Slow Deposition Chrome Plating

Materials Development Corporation
Medford MA
781-391-0400
www.vbcgroup.com/vbc/borofuse.htm
- Borofuse®

Microsurface Corporation
Morris IL
1-800-248-4221
www.microsurfacecorp.com
- Chromium Nitride (used herein)
- Nicklon®

Praxair Surface Technologies
Indianapolis IN
317-240-2500
www.praxairsurfacetechnologies.com
- LSR-1

Sun Steel Treating
South Lyon MI
1-877-471-0844
www.sunsteeltreating.com
- Ion Nitriding

W-J Incorporated
Cleveland OH
1-800-331-1321
216-248-8282
www.w-jinc.com
- Crystallon® II
- Nitriding