Performance Punched Parts

A Penn Fibre Company

Fluid handling

Die cut or punched parts are well known and widely used in the plumbing and fluid handling industry, but punching materials are typically not designed specifically for use in these applications. Acetal has good water resistance but is degraded by acids and bases and has marginal performance in chlorine solutions, especially at elevated temperature. Nylon hydrolizes in hot water, and is especially sensitive to acids, but these are the two most common polymers produced for strip for punching.

In order to meet the demanding requirements for plumbing, pumps, apertures etc, Performance Punched Parts division of Penn Fibre has developed a range of thin sheet materials especially well suited for these applications. We have available materials for either aqueous environments or harsh hydrocarbon environments.

Figure 1 is a bubble chart in which we compare the chemical resistance of various polymeric punching materials vs. their UL relative temperature index (RTI). The bubbles are the general chemical resistance to hydrocarbon environments such as gas, oil, benzene, toluene, xylene etc.. To determine actual performance in a specific reagent it is necessary to get data directly from each polymer producer, but this is a summary from various sources. In Figure 2, the same polymers are shown relative to aqueous reagents such as HCL, H_2SO_4, steam, brine, detergents etc. It is quite apparent that many polymers may that are good in hydrocarbons are bad in hot water and visa versa.

Before continuing, is it worth reviewing how an RTI is developed. First it is an ageing process

Figure 1 Resistance to hydrocarbons solutions/vapor

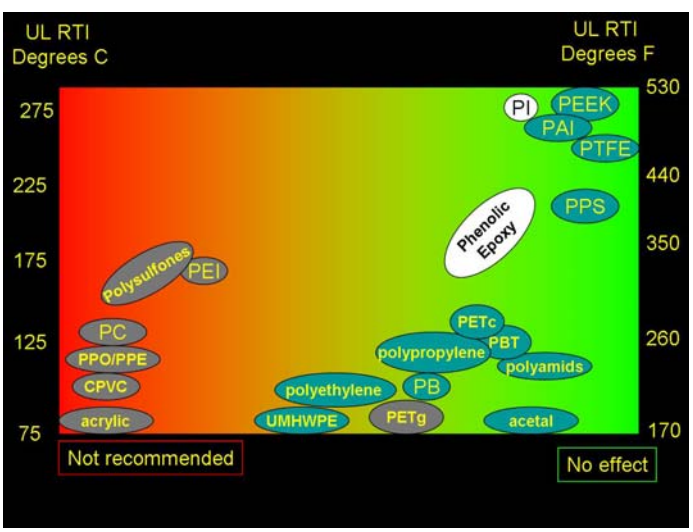
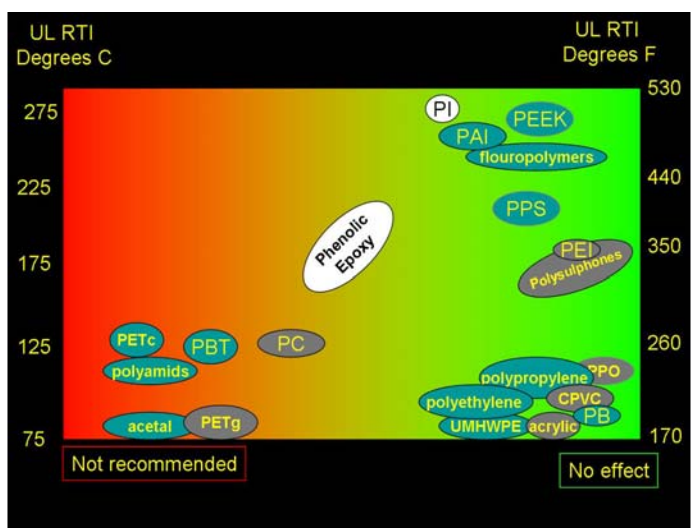


Figure 2 Resistance to aqueous solutions/vapor



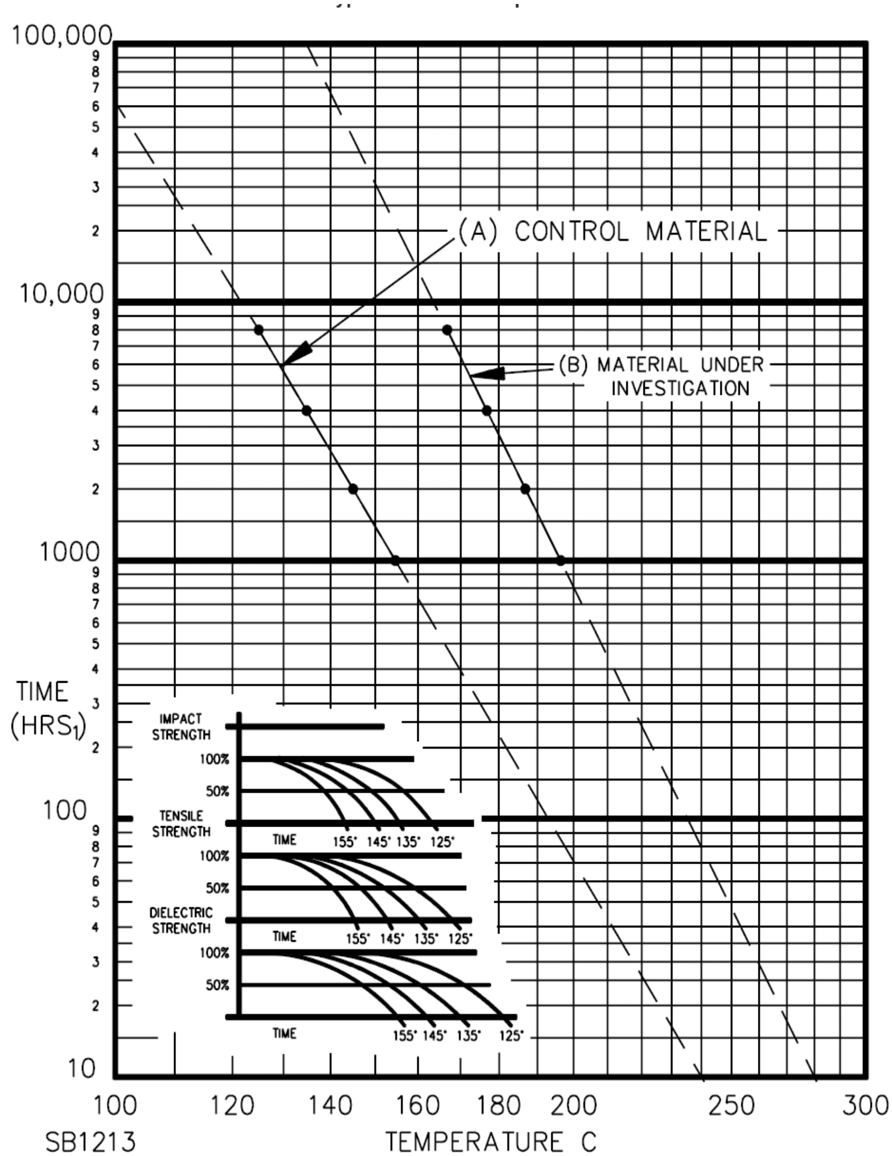
in hot air only. It should not be construed that the part will perform long term while in contact with a chemical reagent. Other chemical reactions may be occurring that significantly impact the material's performance. However, it is indicative of how well a material handles oxidation. In the UL test, an attempt is made to predict how long a material will survive to 100,000 hours or about 11.4 years. It is done by predicting at what temperature a material will lose half its original properties at 100 K hours. It should be noted that this is dependant on the property being tested as well as the material thickness. When considering RTI, the number must be evaluated with both the critical property and part thickness in mind. Thicker parts will last longer

As polymer degradation is a chemical reaction it occurs at a rate inversely proportional to the log of time due to free energy of a reaction. Several samples are tested at different temperatures until they lose 50% of their properties (considered failure). In figure 3, material A is a control material with a long history of actual performance at various temperatures. This material actually has a UL rating of 100C, even though predictive testing with the four data points tested at 125, 135, 145, and 155C would suggest that at 100C the material will lose 50% of its properties at 60,000 hours. Sample B is a higher performance polymer and is tested at higher temperature to achieve failures in reasonable testing periods. This material was given a rating of 140C (where the extrapolation crosses the 100,000 hour time line. Note that for every 10C decrease in temperature the part lasts roughly twice as long. This is very important for using the index in a predictive manner.

If a material is going to operate above its RTI, it does not necessarily mean it will fail in the application. While a car may have a design life of 15 years, it is not operating continuously during that period. If one assumes it will drive 200K miles at an average of 25 mph, parts under the hood need to last 8000 hours. A material like nylon with a 105 deg C RTI will last about 50000 hours (50% decrease due to 10C increase in temperature) at 115C, at 125C it should last 25,000 hours, and 12,500 hours at 135C and so on. Under hood temperatures are far above nylons RTI, yet it is a standard material of choice, and handles direct contact with fuel, oil, even hot ethylene glycol in radiator end caps. While it uses a special hydrolytically stabilized formula, this is an unlikely application for a material known to degrade in hot water. Likewise polypropylene has a 105 C rating, but it is the only material used for battery housings, and operates with hot sulfuric acid.

So while RTI can not be assumed to be unaffected by chemical environment it is not a bad starting point in screening materials for an application, and always consider how many hours the application will really be at design temperature.

Figure 3 Testing data used to develop an RTI



So, in reconsidering the bubble charts in Figure 1 and 2 there are several polymer types shown; the blue bubbles are crystalline resins, the gray bubbles are amorphous resins and the white are thermosetting or non melting polymers. All can be punched into parts.

It should be apparent from the charts that crystalline resin generally have better resistance to aliphatic or aromatic hydrocarbons then their amorphous counterparts. However, in aqueous solutions the amorphous material in most cases tend to be better then crystalline polymers. Some crystalline resins that are made by condensation polymerization may hydrolyze or be attacked by acids.

Catalyzed olephinic materials like Polypropylene (PP), Polyethylene (PE), ultra high molecular weight polyethylene (UHMWPE), polybutylene (PB1), 1-4 Methyl Pentene copolymers etc. are not attacked by hydrocarbons (other then chlorinated hydrocarbons) but absorb them and soften and swell. The effect is akin to plasticizing, and similar to water’s effect on nylon.

As it is difficult to know what is the key performance criteria without knowing a parts function, we will discuss these physical properties in general terms, and simply highlight a few materials that may be of interest for stamped parts in fluid management.

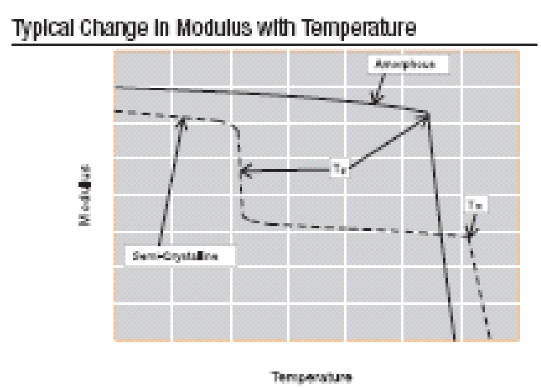
Amorphous resins:

These materials do not melt, but soften and flow above their glass transition temperatures (Tg). While below their Tg, they tend to have better creep resistance then crystalline materials, and they maintain stiffness at elevated temperature close to their Tg as illustrated in Figure 4. As shown in table 1, their tribological properties (wear resistance) is generally not as good as a crystalline material.

Table 1 weight loss in Al_2O_3 slurry 1750 rpm 7.5 hr as percent of loss of carbon steel

UHMW-PE	44	MDPE	125
Abrasion Resistant Steel	52	Phosphor Bronze	190
PB-1	**56**	PP	190
TFE	72	Phenolic Laminate L.E.	200
304 Stainless Steel	84	Polysulfone	300
Polycarbonate	96	Yellow Brass	400
Carbon Steel	100	LDPE	530
HDPE	109	Maple Wood	690
Polyacetal	110	Hard Neoprene	800

Figure 4 modulus vs temperature curves



Polysulfones:

Of the sulfone polymers Polyphenylsulfone (PPSU) has the best high temperature capability as well as resistance to organic solvents and hydrolytic stability followed by polyethersulfone (PESU) and polysulfone. The Tg of Polysulfone is 185C and 220 C for both PPSU and PESU. Grades are available that meet NSF standard 51 (food) up to 191C and standard 61 (plumbing) up to 85C. Other global plumbing standards are available for some products as well. These products have become widely accepted in molded plumbing parts in recent years. The products have shown virtually no loss in properties after 16000 hours at 194 F in water, and PPSU has been autoclaved for 1000 cycles without crazing at 270F. Resistance to specific chemicals should be addressed to resin suppliers, but in general they are gaining wide recognition in fluid management.

Ultem™ Polyetherimide PEI:

With a Tg of 216 C and an RTI of 180C PEI is one of the highest temperature capable amorphous polymers available. It is used in reusable food service applications and has been tested to 1000 dishwasher cycles. It is also used in hot water exchangers, pump impellors, and water reservoirs. It is NSF approved to 90C.

Noryl™ Polyphenylene oxide (PPO) and CPVC:

These resins are both widely used in hot water plumbing applications. Both can be punched, and are well accepted for molding. They are much lower in cost then the other amorphous resins discussed above.

Crystalline resins:

PEEK is the highest temperature thermoplastic available in strip stock for punching. While it is very expensive, it has exceptional chemical resistance at high temperature combined with extremely good wear properties as can be seen from data below from Victrex.

Figure 27: Wear Factor at 200°C (390°F), with 3 m s^{-1} (600 ft min^{-1}) and 20 kg (44 lb) Load for some of the Highest Tribological Performance Materials

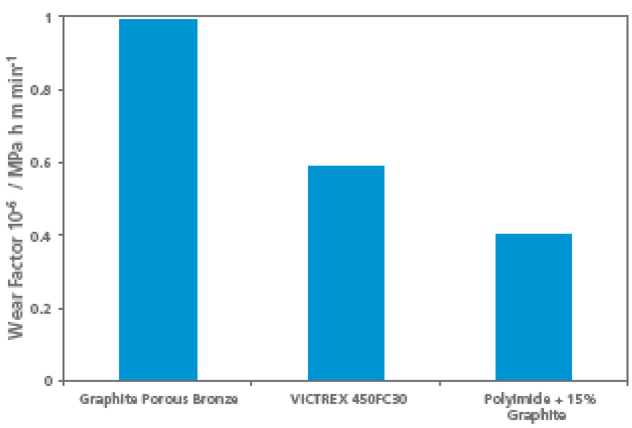
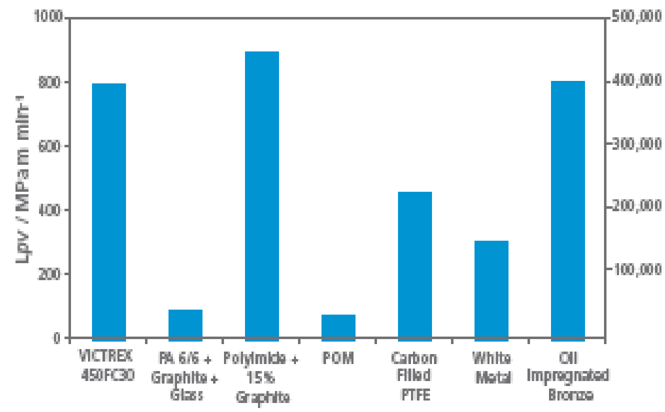


Figure 30: Lpv for a Range of Bearing Materials at 20°C (68°F), with v = 3 m s^{-1} (600 ft min^{-1})



At over 40$/lb PEEK washers (shown at left) are too costly for plumbing applications, but may make senses in high temperature fuel systems, engine componentry or hydraulic applications. As discussed in our article on costing, injection molding may be a lower cost process if the application will consume more then 15-20K parts year.

Olefins:

PE is used extensively in cool or cold water application. However at elevated temperatures and harsh environments it needs cross-linking to improve creep and stress crack resistance. These products are available in sheet via radiation or ethylene vinyl silane grafted moisture cure technology.

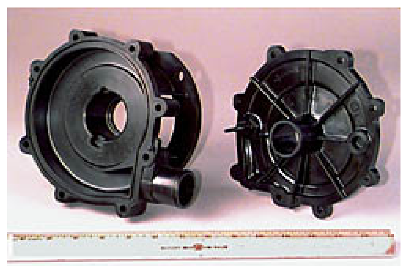
Finally anyone who knows plumbing is familiar with Polybutylene (aka Polybutene-1 or PB1). Shell, DuPont, Celanese and pipe producers paid large awards for failures in PB plumbing systems, and pay outs continue today. While not available for plumbing pipe in NA, the product is still widely used

outside of the US where there were little to no failures. The systems have operated successfully for 50 years vindicating the materials performance and claims that the issues were design related.

The unique feature of he material is its great creep behavior while still being flexible. In fact it has a compression set method B of 50% at 23C and 74% at 75C, which rivals many cross linked elastomers. Its abrasion resistance in slurry type abrasion testing is comparable to UHMW. This extrudes well as a strip material as well.

Finally, one material we have extruded but not punched to date is polyphenylene sulfide (PPS). This may be an overlooked candidate for the market, as it has chemically resistance comparable to PEEK at a fraction of the cost. It is finding a home in the oil patch, and may be a good candidate for gasketing and other cut parts competing with materials like polyamide imides (AKA Nomex™ or Kapton™ fabric or film)

Figure 5, Ryton™ PPS Pump parts



Have another material of interest or want to know more?

Contact us at sales@performancepunchedparts.com

Or call us toll free at 877-445-PART (7278)

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