Advances in Grinding Technology for Woodworkers

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Now that Shaun Sampson has taken orders for some Norton Global Force wheels, this is a good time to put these wheels in perspective.

Grey grinding wheels and sharpening stones have served us very well to date. They are cost effective and multi-purpose. The ubiquitous grey grinding wheel works very well for a multitude of sharpening tasks. There are variations of the grey wheel, so-called white wheels, pink wheels, ruby wheels, etc that have different formulations of grits and binders. Basically, the grits used in these wheels are all aluminium oxide (Al_2O_3) called Corundum, held together with ceramic binders.

Norton's Global Force wheel that Lionel likes so much is also basically aluminium oxide, with the grain size and characteristics optimised for grinding. Norton claim that the grit is a microcrystalline grit composed of scores of tiny crystals sintered together. These grains are designed to fracture in use to expose fresh sharp edges, so that the wheel remains sharp and "cool" grinding. This helps to avoid overheating of the edges of heat sensitive tools, such as those made from plain carbon steels.

There are a number of other grinding options available. There are some grinding and sharpening tasks that the grey wheels and stones cannot do well, so it is worth a look at what is available in the market.

To understand how minerals compare in hardness, we can look at the Mohs scale.
(See http://en.wikipedia.org/wiki/Mohs_scale_of_mineral_hardness)

The Mohs scale was defined in for use in the field for identifying minerals by Friedrich Mohs in 1812. The Mohs scale ranges from 1 to 10. Talc is defined as 1 and Diamond as 10. It is very practical, so sample minerals can be carried in the field, to see what scratches what. As we are only interested in the harder minerals, I have only shown the range from 7 to 10. Visit the above link to see the whole table.

Mohs hardness	Mineral	Chemical formula	Absolute hardness	Image
7	Quartz	SiO_2	100	
8	Topaz	$Al_2SiO_4(OH–,F–)_2$	200	
9	Corundum	Al_2O_3	400	
10	Diamond	C	1600	

Quartz is the mineral found in old fashioned glass paper – relatively speaking, it is not very hard, which is why glass paper is not used much these days – it goes blunt too quickly. Corundum is much more effective. It is very cheap and can be made in all grit sizes.

Here is an excerpt from another useful table (also from Wikipedia) that contains most of the minerals we are interested in:

Mohs Scale	Substance or mineral
4 to 4.5	platinum, mild steel
5	apatite, cobalt, zirconium, palladium, tooth enamel, obsidian (volcanic glass)
5.5	beryllium, molybdenum, hafnium
6	orthoclase, titanium, manganese, germanium, niobium, rhodium, uranium
6 to 7	glass, fused quartz, iron pyrite, silicon, ruthenium, iridium, tantalum, opal
7	quartz, vanadium, osmium, rhenium
7.5 to 8	hardened steel, tungsten, emerald, spinel
8	topaz, cubic zirconia
8.5	chrysoberyl, chromium, silicon nitride
9-9.5	corundum(Al_2O_3), silicon carbide (carborundum - SiC), tungsten carbide (WC), titanium carbide (TiC), stishovite
9.5–10	rhenium diboride, tantalum carbide, titanium diboride, cubic boron nitride (cBN), boron
10	diamond
>10	nanocrystalline diamond (hyperdiamond, ultrahard fullerite)

Remember this is only a ranking scale, not a measure of absolute hardness. It is useful, because if you want to sharpen a blade, the edge must be softer than the sharpening stone. Conversely, if you wish to cut something, the blade must be harder than the work piece.

The turners will sometimes complain that a particular wood blunts tools rather quickly. This may be because the wood contains silica. Silica has a hardness range of 6 to 7 on the Mohs scale, which is not much below the hardness range for the tools, which are from 7.5 to 8.

Aluminium oxide (Al_2O_3), found in the grey wheels mentioned above, is suitable for grinding most steels including High Speed Steels (HSS) that are popular with wood-turners. Tungsten carbide (WC) is a little too hard to be ground with Al_2O_3 You can see why – they are of similar hardness. You can touch up a WC edge such as a masonry bit on an Al_2O_3 wheel, but if you have one, a Silicon Carbide (SiC) wheel is a better bet in practise.

Flat grey stones for hand sharpening in their cheapest form are grey Al_2O_3 and are quite effective, albeit usually a little coarse for a fine edge for a plane blade or a carving gouge.

The disadvantage of Al_2O_3 wheels and stones is that they wear down significantly. The wheels develop grooves and reduce in diameter, and sharpening stones dish in the middle. For a wheel, to straighten the grinding face, a dressing tool is used, ranging from the crudest – another piece of the same grey stone material or a star wheel dresser to the best – a diamond dresser. A star wheel dresser will de-glaze a wheel, and open up the grit, but it is not very precise, and rapidly wears away the wheel. A diamond dresser, which could be single point or multiple point tool, is capable of trimming the wheel to a very fine, accurate surface, suitable for the finest work.

When a flat stone is no longer flat, it has to be dressed manually, which is hard work. A glass plate with grit such as SiC (valve grinding paste) can be used. If you have one, a diamond plate can be used to grind away the high spots, until you have a uniformly flat surface.

Alternatives to Grey Stones

Variations on Aluminium Oxide (Al_2O_3) – white, pink, red, and blue wheels. Different formulations of Al_2O_3 in different colours have different advantages. These are small differences, and you may not notice the differences in practise.
White wheels are Al_2O_3 with very little ceramic binder, so they are very friable, which means they wear away rapidly with use, and are not inclined to glaze up. They are "cool" grinding, and less liable to burn edges. They do need more frequent dressing.
Pink and red wheels have chromium oxide blended in to increase the toughness of the grains, so they wear less than white.
Blue wheels such as the Norton Globalforce (SG) wheels are so-called micro-crystalline wheels. These were mentioned last month – they are also available from other sources such as www.peterchild.co.uk They are claimed to be cooler cutting than white wheels and last up to 5 times longer

Silicon Carbide. SiC wheels have the same structure as Al_2O_3 wheels – an open ceramic bonded matrix of SiC grains. The main difference is that the SiC grains are harder. Known by the Norton trade name of Carborundum, These wheels are usually green. Even though they are shown on the same line as Aluminium oxide (Al_2O_3) in the Mohs table, in practise, SiC is sufficiently harder to make a difference. SiC wheels tend to glaze up when grinding softer materials such as steels because the lower pressures do not displace the worn grit. Wet/dry or so-called water papers are made with SiC grits to make them harder wearing than Al_2O_3.

Diamond.
Diamond is the hardest natural material known and is positioned at 10 on the Mohs hardness scale. This means that only diamond will scratch diamond, and diamond will scratch everything else. Diamond wheels and plates consist of a grit bonded to a metal base using an electroplated metal such as nickel. The size of the grit determines the grade. These products are expensive, but given the extreme hardness of the diamond grits, have a very long life, if used correctly.
Diamond plates can be used to flatten Al_2O_3 stones. Grades of diamond plates offered are typically Coarse (220 grit, 60µm), Medium (325 grit, 45µm), Fine (600 grit, 25 µm) and Extra Fine (1200 grit, 9 µm). The extra fine grit gives a high quality edge that will satisfy most people. The next stage is 2000 grit equivalent abrasive, which is available on special order. 2000 grit can also be had as a ceramic stone, Wet and Dry paper, or a Japanese Waterstone, if you need it but most people won't need to go this fine.

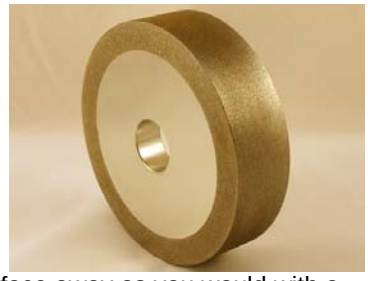
A variety of smaller diamond plates and files are offered for sharpening bits such as Tungsten Carbide (WC) router bits. Diamond coated bits are also offered for Dremel type tools, discs for angle grinders and core hole cutters for masonry, at very reasonable prices these days.
Diamonds can be used cutting or grinding almost any material, including tungsten carbide. There is one exception – high speed cutting or grinding of steel. Because the carbon in diamond is soluble in iron at the high temperatures and pressures found right at the cutting edges at high speeds, the carbon in the tool dissolves into the iron substrate of the work-piece, so abrasive wear becomes unacceptably high. So don't use diamond for high speed machining of steel, use cBN (see below).
(Despite advertising by the jewellery trade, diamonds are not forever – they are extremely durable – but there are conditions when they deteriorate rapidly – high temperatures – above 400ºC should be avoided.)

The 200mm diameter wheel on the right is suited for fitting to a Tormek, which is a slow speed grinder. Its selling point is that it does not require truing or dressing. One example is from T&J Tools (See http://www.mamut.net/controls/shop/shops/12/8/default.asp?wwwalias=TJTOOLS&gid=47) at £165-. Peter Child also offer one.

In the early days, diamond dust left over from cutting and polishing of natural diamonds was used for abrasives, but these days, most of the grits used are of synthetic origin. Synthetic diamond grits have more consistent properties and sizes and are readily available. The grits are attached to the substrate, such as a cutting disc by electroplating, such as with nickel. The nickel is relatively soft, so it wears away exposing the diamond grits to do the cutting.

CBN

Just below diamond on the Mohs scale, we find cubic Boron Nitride between 9.5 and 10. cubic Boron Nitride (cBN) describes the crystalline form of Boron Nitride. With hardness just below diamond and with superior heat resistance properties, cBN is able to machine ferrous metals, without the wear problems that diamond has. For this reason, cBN wheels are being offered for high speed grinders for machining steel. The cBN grit is embedded in a plastic substrate – a so-called resin wheel or electroplated onto the surface like diamond wheels. The example on the right is offered by T&J tools (See http://www.mamut.net/controls/shop/shops/12/8/default.asp?wwwalias=TJTOOLS&gid=47) at £117-. It is 150mm diam x 25mm wide and suitable for direct fitting to a "high-speed" grinder. High speed means 2800 rpm. Peter Child offer a similar product in 150 x 40 and 150 x 20 sizes at £110- and £81- respectively. (See www.peterchild.co.uk)



The cBN wheels have the advantages of extreme wear resistance and dimensional stability of diamond wheels, but they are intended for machining hard ferrous metals. They have a flat face on the side as well as the circumferential surface. They are made very precisely, so the exact bush to fit your grinder shaft must be ordered. There is only a single layer of cBN crystals, so you can't true up the wheel by dressing it like you can with a conventional wheel! Apparently, because they are so accurately made and balanced, there is almost no vibration. cBN wheels are not recommended for materials other than hard steels. Softer materials such as mild steel and some stainless steels can be problematic, as they can be inclined to clog up the gaps in the grit and removing them is almost impossible. You can't dress the glazed surface away as you would with a grey wheel, because you would remove the single layer of grit. Grind these materials with an ordinary grey wheel, as they are unlikely to be heat sensitive. Because the grit layer on a cBN wheel is very thin, rough treatment with a sharp edge can remove the grit layer, so gently does it.

Acknowledgements: www.peterchild.co.uk www.norton.com www.wikipedia.org