Barrel Wear and Patching Paper

Occasionally the question comes up, "Is paper abrasive?" The short answer to this is no, not at all. But like most things there is more to the story. Paper is treated with various chemicals during the pulp making process and during the paper making process. Some of the chemicals are left in the paper after processing and some are added to the paper to produce desired effects such as lower cost, higher brightness, or to provide a sharper printed image.

Could it be that these chemicals are harmful to the rifle barrel? The short answer is again, no. Using the rifle will cause barrel wear, that is unavoidable, and shooting paper patched bullets will not accelerate that wear.

But there has been much written and said about this imagined problem on chat rooms, forums, and at the range. Usually the concern is with what is called ash in the paper. Paper does not contain ash. Paper may contain inorganic compounds that, after burning the paper, leave a residue referred to as ash. High grade filter paper and some writing papers will leave little or no ash after burning the paper. Newsprint will typically leave 12% ash. High quality writing or photographic paper may leave as high as 30% ash.

Newsprint is not usually treated to improve the quality of the paper so there is less inorganic material in the paper and less ash after it is burned. High quality paper, known as Fine Paper, leaves more ash because it has been treated to produce sharper print and better images.

To measure the amount of inorganic material a sample of the paper, usually around 2.5 grams (a little less than one ounce) is burned in a highly controlled furnace. The paper is burned at 575 degrees Celsius, 1,075 degrees Fahrenheit, for a certain length of time. Then the residue is weighed and that is expressed as a percentage of the total amount of paper.

Most paper has some amount of inorganic material in it. The percentage of inorganic material can be known because we can weigh the ash left after burning the paper.

What does that mean? Truth is that it means, after burning the paper, there is ash and so there must be some amount of inorganic material in the paper. But of what value is that? Are the inorganic compounds a problem? Will they cause barrel wear, are they abrasive, could they just as well be lubricants, could they be neither good nor bad but just simply there? Without knowing what the material or materials are and what their properties are all that can be said is that there is something in the paper besides wood or cotton pulp.

At this point there are three choices. One is to go ahead and shoot paper patched bullets figuring that barrels are expendable and will wear out no matter what, second is to listen to Old Joe who knows that paper is abrasive because he heard someone say so and they knew it was true because they heard someone say so, and the third choice is to look into a little more deeply.

I will just go on shooting and not sweat wearing out a barrel. If I'm worried about that I'll hang the rifle on the wall and just look at it. If I have to replace a barrel every seven thousand shots, so be it. I can live with that.

But for those who like to worry about things like this a little research into paper can be done.

The concern really is if what-ever is in the paper is abrasive or not. If the inorganic compound is a lubricant wouldn't that really be a plus? If the extra stuff that might be in the paper is softer than the barrel steel is there any point in worrying about it? There are all kinds of abrasives and even the same abrasive material can be more or less aggressive depending on how the abrasive crystal is shaped. Before going on a look at abrasives is needed.

The first thing to consider is hardness of the abrasive grain. Grinding wheels, mounted grinding points, hand stones and other abrasive stones are usually given a hardness rating. That rating refers to the strength, the hardness, of the bond that holds the abrasive stone together and does not apply to the hardness of the abrasive grain itself.

The hardness of the abrasive grain or crystal is critical to an abrasive being able to abrade or wear away other materials. The shape of the abrasive and how quickly it fractures to resharpen itself (friability) are also important but hardness is the main issue.

All minerals, man-made or natural, are rated as to hardness on the Mohs scale. The scale was created in 1812 by Friedrich Mohs and is still in use today. The scale runs from Talc at a Mohs hardness of 1 to diamond with a Mohs hardness of 10. A common natural abrasive, Corundum, is a 9. But using a sclerometer we see that the absolute hardness of Talc is still one, Corundum is 400, and diamond is 1,600. There is a huge increase in absolute hardness as we move up the Mohs scale.

Mohs Mineral Hardness Scale

Mineral	Mohs Hardness	Formula	Absolute Hardness	Knoop	Brinell 500 Kg	Rockwell A scale	Vickers
Talc	1	M S (OH	1	*	*	*	27
Gypsum	2	CaS -2 O	3	*	136	*	61
Calcite	3	CaC	9	169	*	*	157
Fluorite	4	Ca	21	327	*	66	315
Apatite	5	C (P (OH-,CL-,F)	48	564	*	77	535
Feldspar	6	KALS	72	839	*	84	817
Quartz	7	Si	100	*	*	*	1161
Topaz	8	A Si (OH-,F	200	*	*	*	1567
Corundum	9	A	400	*	*	*	2035
Diamond	10	C	1600	*	*	*	*

Additional minerals/materials can be approximated between the standard minerals in the chart. For example copper would have a Mohs hardness of 3.2, window glass would be about 5.5, and a steel file is 6.5 to 7. A pencil "lead" is about 1.5. Hard steel is between 7.5 and 8. Silicon carbide is between 9 and 9.5. Nanocrystalline diamond is greater than 10. Cast iron is roughly a Mohs 4 in hardness.

Since most of us don't use the Mohs scale very often or at all, there is a natural tendency to want to compare a Mohs hardness number to something that we are more familiar with. If the Mohs number could be converted to perhaps Brinell hardness or maybe a Rockwell scale then the Mohs number would be more easily understood. But the Mohs scale cannot be accurately converted to any other hardness scale. At the best there can be some guessing as to how Mohs would compare to Brinell and there are a few charts that list the comparisons. While inaccurate these comparisons do help to understand the hardness of minerals but the charts are mostly educated guesses and should not be used for any serious work.

The hardness conversion chart below compares several hardness scales; three Rockwell scales, three Rockwell Superficial scales, two Brinell scales, one Vickers scale, and the Shore scale. There are other scales that are often used such as the Knoop scale, less well known scales such as Micro-Vickers, and ones not often encountered such as Meyer, Janka, and Barcol. Each hardness testing method is designed for a type of material and purpose. Each hardness testing method uses a different technique and procedure for preparing the test piece. Brinell depends on an optical measurement to determine hardness and the accuracy of the Brinell test requires a very well prepared sample.

On the hardness conversion chart the scales most used by the shooting community would be the Rockwell C, B and the Brinell 500 Kgf (kilograms force) scales. A steel ball with 500 Kgf is used for soft materials like lead while a tungsten ball with 3,000 Kgf is used for harder materials like steel.

For some materials like, mild steel, either a Rockwell C or B scale can be used. The technician needs to determine which testing method will give the more accurate result. If the test result is near the extreme end of the test scale then using a test that will give a more middle-of-the-road reading will usually be better. If the Rc reading is a 12 then using the Rb scale would be better and would give an Rb of 92. The hardness conversion chart below has been shortened to better fit this discussion.

A punch for a bullet swage die could be a 48 Rc. Looking down the Rc column on the chart the 48 Rc can be found. Going across it can be seen that will compare to a 116 Rb, a 451 Bhw (tungsten ball), or a 484 Vickers. If a rifle barrel steel has a specified hardness 104 Rb that will compare to a 28 Rc. A machinist or gunsmith familiar with the Rc scale but not the Rb scale can use the chart to get a feel for how hard the barrel is in terms he is used to.

Hardness Conversions

Rockwell			Rockwell Superficial			Brinell		Vickers	Shore
A	B	C	15-N	30-N	45-N	3,000Kgf	500 Kgf	136	
60kg Brale	100kg 1/16" Ball	150kg Brale	15kg Brale	30kg Brale	45kg Brale	Tungsten ball	10mm Ball Steel	Diamond Pyramid	Sciero-scope
86.5	---	70	94.0	86.0	77.6	---	---	1076	101
82.8	---	63	91.4	80.1	69.9	705	---	772	87
82.3	---	62	91.1	79.3	68.8	688	---	746	85
81.8	---	61	90.7	78.4	67.7	670	---	720	83
81.2	---	60	90.2	77.5	66.6	654	---	697	81
80.1	---	58	89.3	75.7	64.3	615	---	653	78
79.0	---	56	88.3	73.9	62.0	577	---	613	75
78.5	120	55	87.9	73.0	60.9	560	---	595	74
75.9	117	50	85.5	68.5	55.0	475	---	513	67
74.7	116	48	84.5	66.7	52.5	451	---	484	64
73.6	115	46	83.5	64.8	50.3	432	---	458	62
72.5	114	44	82.5	63.1	47.8	409	---	434	58
71.5	113	42	81.5	61.3	45.5	390	---	412	56
70.4	112	40	80.4	59.5	43.1	371	---	392	54
69.4	110	38	79.4	57.7	40.8	353	---	372	51
68.4	109	36	78.3	55.9	38.4	336	---	354	49
67.4	108	34	77.2	54.2	36.1	319	---	336	47
66.3	107	32	76.1	52.1	33.7	301	---	318	44
65.3	105	30	75.0	50.4	31.3	286	---	302	42
64.3	104	28	73.9	48.6	28.9	271	---	286	41
62.4	101	24	71.6	45.0	24.3	247	---	260	37
61.5	99	22	70.5	43.2	22.0	234	195	248	35
60.5	97	20	69.4	41.5	19.6	222	184	238	34
59.0	96	18	---	---	---	216	179	230	33
58.0	95	16	---	---	---	210	175	222	32
56.5	92	12	---	---	---	195	163	204	29
56.0	91	10	---	---	---	190	160	196	28
55.0	89	8	---	---	---	180	154	188	26
53.5	87	6	---	---	---	172	148	180	26
52.5	85	4	---	---	---	165	142	173	25
51.0	83	2	---	---	---	159	137	166	24

Hardness of Common Materials

Material	Use	Hardness Rc	Hardness Rb	Hardness Mohs
Tungsten Carbide	Cutting tools, draw dies	*	*	9
D2 tool steel	Draw dies, cutting tools	64 max.	*	5.8
O6 & A10 tool steel	Bullet swages, gages	63 max.	*	5.8
O6 & A10 tool steel	Tempered	58-55	*	5.4
4140 tempered	Punches	44-40	114-112	4.4
4140 Chrome-Moly	Rifle barrels, tempered	20-27	101-97	3.8-3.6
416R Stainless	Rifle barrels	20-27	101-97	3.8-3.6
Stressproof steel	Rifle barrels	18	96	3.5
C1018 mild steel	low strength, low wear	12	92	3.4
12L14 Steel	.22 RF barrels	3	84	3.2

The chart above lists a few common steels used in tool making and for making rifle barrels. Tungsten Carbide is used to make inserted lathe and milling machine bits, redraw dies, and for other applications where a high degree of hardness is needed. Carbide also resists softening when used at a high temperature so has a "red hardness" that is better than other materials. It can be very brittle and is often shrunk into a steel sleeve to support the die. Tungsten Carbide has about the same hardness as the abrasive Corundum, a natural aluminum oxide.

D2 tool steel will reach a maximum hardness of 64 Rc before being tempered. This puts it at an approximate Mohs hardness of 5.8 as hardened but it is never used without being tempered. D2 is useful for jacket drawing dies but much too brittle for gun barrels.

The steel used for bullet swage dies reaches a maximum hardness of 63 Rc which would still be about a Mohs 5.8. Tools steels are never used without being tempered to relieve brittleness and stress so the swaging dies would be tempered to between a 58 Rc to a 55 Rc.

Punches for bullet swages are often made from a chrome-moly steel which can reach a 51 Rc as hardened but are usually tempered to around a 44 to 40 Rc.

Chrome-Moly barrel steel, often 4140 and sometimes 41L40 because it machines easily, can be hardened to a maximum of a 51 Rc but is usually used at around a 32 to 38 Rc but more often around a 20 to 24 Rc when used for rifle barrels.

One steel that was once commonly used for centerfire barrels is LaSalle Stressproof. It is also known as AISI 1144. It is used as received and not thermally heat treated. Stressproof has a hardness of 217 BHn which is about a 96 Rb. Stressproof was known as "Ordinance Steel" and many barrels were made from it. It has an unfortunate tendency to throw chunks of steel here and there should the barrel burst so it is no longer approved for gun barrels.

Crucible Company 416R stainless steel is a special grade that is often used for centerfire barrels. 416R as annealed has a hardness of 155 BHn, a maximum hardness of 35 Rc, and is most often used at the tempered hardness of 200 BHn. This means that a barrel made from this stainless steel would have a hardness of about a 93 Rb. Excellent barrels can be made from this steel and it is about the same hardness as chrome-moly steels.

Common mild steel like C1018 has too little carbon in it to be hardened. It can be surface hardened in a process known as case hardening or carburizing. This gives a wear resistant surface and a tough core. C1018 has many uses in applications where wear resistance or high strength is not required. It is relatively soft steel and machines fairly easily but tends to make stringy, continuous chips that can be troublesome.

AISI 12L14 is often used for .22 Long Rifle rimfire barrels. This steel has a hardness of 84 Rb. The steel is soft enough that the B scale must be used as the C scale would not be accurate. C12L14 is a low carbon steel and cannot be thermally hardened. It machines very easily and takes a good finish but isn't tough enough to be used for higher pressure cartridges.

Gun barrels, like most things, have various design requirements. If the barrel is too hard it will burst, if it lacks wear resistance it will wear out too soon, if it isn't tough enough it can bulge from the pressure in use, it must be machinable, and it must be a reasonable cost. Toughness, wear resistance, hardness, machinablity, and cost are all separate factors that influence each other. Hardness alone will not necessarily make a long lasting barrel. High wear resistance alone is of little value if the barrel isn't tough enough. If the material cannot be machined at a reasonable speed and cost it won't matter if it is very good otherwise.

The chart below lists some common abrasives use to grind, lap, hone, and polish metals. Green Rouge, and Garnet are not often used on steels but could be however the structure of the abrasive crystal may not be suitable for some uses. Red Rouge can be used to polish steel, even hard steel, to produce a shiny finish. It is very slow cutting. The various types of aluminum oxide are used in many applications. Blocky, hard crystals wear slowly and are used for heavy, rough grinding. Needle shaped crystals of aluminum oxide are very friable and break easily to expose new, sharp cutting edges to permit faster cutting when honing or finish grinding. Silicon carbide is a fast cutting abrasive but when used to hone hard steel it is slower than aluminum-oxide while producing a higher finish. CBN is a man-made abrasive that cuts very hard steel with little effort. When used to hone parts it is usually held in a bronze matrix.

Diamond, usually man-made, is used to lap hard steel or carbide. Diamond will react with iron so it is less desirable for grinding steel than CBN.

There are many other abrasives that are used to grind, lap, hone, and polish metals but those that have a hardness less than about a Mohs 6 aren't of much use on steel. Earlier it was noted that abrasives that are less than a Mohs 4.5 will not scratch steel, as a rule.

Abrasive hardness Chart

Abrasive type	Trade or common name	Mohs Hardness	Comments
Diamond		10	Grinding or lapping very hard materials and carbides.
Cubic Boron Carbide	CBN, Borazon	9.9	Man made abrasive for use on very hard materials.
Boron Carbide	Norbide	9.7	Hexagonal shaped crystal that is used for special operations.
Silicon Carbide	Crystolon	9.5	Fast cutting on softer materials leaving a frosted finish. Slower cutting on hard materials but leaves a bright finish.
Aluminum Oxide	Alundum	9	Blocky, stong crystal useful for heavy grinding.
Natural Aluminum Oxide	Corundum	9	Has many uses. Man-made has often replaced it.
Chromium Oxide	Green Rouge	8.5	Used to polish and lap stainless steel.
Garnet	Garnet	7	Excellent for fast cutting sandpaper for wood. Used to lap bronze and cast irons. Also for sandblasting.
Ferric Oxide	Red Rouge	6.5	Used for polishing soft materials.

All of the preceding has been to lay a bit of ground-work before looking at the chemicals used in the making of pulp and paper. With a little understanding of the Mohs scale, the hardness of abrasives, and the hardness of common steels used in gun barrels it is now possible to consider the chemicals used in paper making. The last chart below lists some of the many chemicals used to produce paper.

There are other chemicals that are used which I have left off of the chart. Oxygen and Hydrogen-Peroxide are both used but clearly there is little about them that would cause any barrel wear. Other chemicals are used to control the build-up of slime or to prevent foaming as the paper is processed. Many of these chemicals are only used in pulp processing and then removed from the pulp before the paper is made.

Some chemicals, inorganic compounds, are added to the paper to reduce its cost, to improve whiteness, stiffness, glossiness, or to produce a sharper image. While paper does not contain ash one chemical, sodium carbonate, is called Soda Ash. The name comes from an old process where chemicals are combined and then burned to produce an ash. The ash is then processed to make sodium carbonate. This process is no longer used because of the air and water pollution it caused.

But the old name has stuck so sodium carbonate or Washing Soda will often be called Soda Ash. It is used in the pulping process of paper making.

Most of the processing chemicals are not abrasive but a few might be. Soda Ash, sodium carbonate, is a very mild abrasive having an approximate Mohs number of 2. Since a Mohs 4 or higher is required to scratch steel clearly Sodium Carbonate in paper would be of no consequence.

Where a chemical in the chart is not abrasive or is not used in the finished paper the letters n/a (not applicable) are used instead of a Mohs number. A glance through the list will show that almost all of the potential abrasive materials are much softer than barrel steel and pose no risk to the barrel. Only Titanium Oxide, Titania, is of sufficient hardness to wear the rifle barrel. Titanium Oxide is a little less hard than Red Rouge which is used for light polishing of steel. Titanium Oxide at the worse would make a barrel shiny but do little more than that.

Chemicals Used in Pulp & Paper Making

Common Name	Chemical Name	Chemical Formula	Used For	Other Characteristics	Mohs Hardness
Agalite or Talc	Silicate of Magnesia	MgO-32%, SiO_2-62%	Enables paper to take a high finish.	A natural fibrous form of talc	1
AKD	Alkyl Ketene Dimer		Sizing		n/a
Alum	Sulfate of Alumina	$Al_2(SO4)_3.18H_2O$	For alkaline sizing along with Rosin		Less than 3.5
Albarine	Natural Sulfate of Lime	$CaSO_4.2H_2O$ - 100%	Calcium salt used for a variety of purposes		1.5 to 2
Ammonium Zirconium Carbonate	Ammonium Zirconium Carbonate	$CH_2O_3NH_3Zr$	In-solubilizer, crosslinker & hardener	AZC is a clear, usually colorless solution	2.5 to 3
Anthraquinone	Anthraquinone	$C_{14}H_8O_2$	Added to to improve pulp yield.	yellow crystalline powder	n/a
Asbestine	Silicate of Magnesia	MgO-32%, SiO_2-62%	Used in manufacture of blotting papers and board.	Fibrous magnesium silicate. Physical characteristics of talc	1
APE	Alkylphenol Ethoxylates	$CH_3(CH_2)_n(C_6H_4)(OCH_2CH_2)_m$-OH	Used as cleaning agents		n/a
ASA	Alkenyl Succinic Anhydride		Sizing		n/a
Barium Sulfate	Barium Sulfate	$BaSO_4$ - 100%	Used as a pigment & filler	White insoluble powder.	3
Casein	A milk phosphoprotein		Binder or adhesive		n/a
CMC	Carboxy Methyl Cellulose		Sizing		n/a
Caustic Lye or Caustic Soda	Sodium Hydroxide	NaOH	Pulping and to maintain pH		n/a
Chalk (Precipitated)	Precipitated Calcium Carbonate	$CaCO_3$ - 100%	Filler	High Brightness & Opacity	3

Chalk (French or Spanish)	Silicate of Magnesia	$4MgO+5SiO2+H_2O$; MgO - 33%; SiO_2 62%		A soft white compact talc	1.5
China Clay, Kaolin	Hydrated Silicate of Alumina	Al_2O_3-40%; SiO_2-46%; H_2O-13%	Filler, Coating		1
Dolomite	Calcium Magnesium Carbonate	$CaMg(CO_3)_2$	Filler, Coating		3.5
DTPA	Diethylene Triamine Penta Acetate		Used for chelation		n/a
EDTA	Ethylene Diamine Tetra acetic Acid		Used for chelation		n/a
Guar Gum	Natural Polymer		Dry Strength Additive	cationic derivative	n/a
Gypsum	Natural Sulfate of Lime	$CaSO_4.2H_2O$	Gypsum board		2
Lime	Calcium Oxide	CaO	Alkaline Pulping, Bleaching		3 to 3.5
Magnesite	Magnesium Carbonate	MgCO3 -100%			3
Rosin	Abietic Acid	$C_{19}H_{29}COOH$	Sizing		n/a
Rosin Soap	Sodium Abietate	$C_{19}H_{29}COONa$	Sizing		n/a
Salt Cake	Sodium Sulfate	$Na_2SO_{4.}\ 10H_2O$	sulfate pulping recovery		2.5
Sodium Dithionite	Sodium Hydrosulfite	$Na_2\ O_4\ S_2$	Bleaching	White crystalline powder	n/a
Sodium Silicate	Sodium Silicate	Na_2SiO_3	Waste paper deinking		n/a
Starch		Glucose units linked together by oxygen bridges	Wet and dry end additive		n/a
Sulfur	Sulfur	S	To make HSO_3 for bi-sulfite pulping		2
Titania	Titanium Dioxide	TiO_2	Increase the opacity & brightness		5.5 to 6

The issue of barrel wear caused by inorganic materials in paper is simply not true and probably based on anecdotal evidence, hearsay, and little science. Chat rooms and forums spread a wealth of mis-information, bad data, incorrect conclusions, personal opinions, and are often outdated or just plain wrong. Forums and chat rooms can be useful but only if a person is extremely careful of what is stated and tries to verify the information. Information that something is good or bad, harmful or not without knowing that the information presented comes from George who heard it from Bill who heard it from Oscar who heard it from George is of little value or use.

Hearing that paper contains China Clay, Kaolin, and that it is abrasive might cause some concern about wearing out a barrel if that paper is used to patch bullets. But China Clay has a hardness of a Mohs 1 and materials softer than a Mohs 4 or 4.5 won't scratch or damage steel, even soft steel, so the Kaolin in the paper is of no concern. Now if paper contained silicon carbide, Mohs hardness of 9.5, that would be cause for alarm and it would be wise to use a different paper.

The charts in this discussion allow the reader to determine if a material would really cause barrel wear or not.

It should also be remembered that some of the materials such as China Clay and Titania are used to make paper whiter, brighter, and glossier. The more coatings or additives added to the paper the less suitable it will be for patching bullets not because the paper might harm the barrel but because the paper is too costly, too slick, too stiff, or not able to absorb patch lubricant. The qualities that make some paper better for sharp print or photographic images are not the qualities that make for good patching paper.

It must also be remembered that barrels will wear out. That is just a normal process caused by using the rifle. Smokeless powder is more harmful to a barrel than patching paper could ever be and blackpowder will ruin a barrel overnight, if not cleaned correctly.

Wear caused by patching paper is a non-issue. It would be much better to spend time shooting and less time worrying about barrel wear.

Additional Data

Since this was written I have had the opportunity to run hardness tests on several barrel samples. A few of these tests included a stainless steel Winchester M70 barrel in .300 Win Mag caliber, a Ruger stainless barrel in .223 Rem. Caliber, a Douglas Premium barrel in .300 Weatherby caliber, and a Remington barrel in .22-250 caliber.

The tests were done on a bench or lab type of Rockwell tester using the C scale. The samples were cut from the barrels so that they were a uniform diameter and length. The ends were squared and smooth. Testing was done on the diameter of the barrel samples as well as on the ends of the samples. It was expected that the tests on the diameter of the barrels would result in lower readings than tests on the ends of the samples but this was not so.

The Winchester stainless barrel is a hammer forged barrel. It gave a hardness of 20 to 24 Rc. The stainless Ruger barrel gave a hardness of 23 to 25 Rc. The Douglass barrel gave a hardness of 20 to 21 Rc and the Remington barrel gave a hardness of 23 to 24 Rc. Interestingly the hardness of the stainless and chrome-moly barrels was virtually the same.

As noted earlier hardness is only one consideration. Toughness and wear resistance are two more factors to be considered but as far as barrel wear caused by patching paper it remains a non-issue. All of the materials in paper that might cause barrel wear are so much softer than the barrel that they cannot wear the barrel.