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(54) Abrasive bodies such as grinding wheels.

(57) Relatively hard grade, high structure cold-formed organic-bonded abrasive bodies such as metal grinding, snagging and cut-off wheels have abrading portions of improved life and efficiency comprising, by volume, 30 to 44% of 12 to 100 grit size abrasive particles, 24 to 36% thermosetting resin, 14-29% active filler material and 5-18% pores and, wherein the active filler replaces reductions in abrasive content when going to a higher structure and thereby increasing the volume ratio of filler to both the abrasive and resin content. The preferred ratios are in the range of 1 volume of filler to .8 to 2.6 volumes of resin and 1.0 to 3.2 volumes of abrasive.

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The invention relates to a high structure, organic bonded abrasive body and particularly to high structure cold-pressed, resin-bonded, abrasive grinding, snagging and cut-off wheels of exceptionally high efficiency.

The invention concerns itself with abrasive wheel compositions for making what are known in the art as relatively hard grade high structure non-reinforced and reinforced organic-bonded thin disc and peripheral type grinding wheels. In particular, the cold-pressed wheels are for grinding, snagging and/or cutting off metal from welds, gates and risers from castings and cutting bars or rods of carbon and stainless steels.

Various methods are known to vary the grinding performance (life, cut-rate, etc) of cold-pressed organic bonded grinding wheels. These methods typically include: controlled porosity variations in the wheel structure, variations in resin cure by baking at different temperatures, and variations in the filler to resin ratio of the bond.

Another method that is not as commonly used to vary grinding performance is to vary the ratio of bond (resin and filler) to abrasive in the wheel structure. It is commonly known, especially in medium to dense cold pressed grinding wheels, that if the abrasive content is reduced to provide a more open structure and is replaced by an equivalent volume of bond, the grinding wheel would act softer, i.e., the metal removal rate would increase and the wheel life (grinding G-ratio) would decrease in constant pressure grinding. The common explanation of this phenomenon is that as the structure becomes more open as abrasive content is reduced, interference in chip formation is likewise reduced and the wheel becomes freer cutting with a significant increase in metal removal rate. However, due to the higher forces exerted on the individual abrasive particles, the wheel life or G-ratio is significantly decreased.

Conventionally, for each and every grade of wheel, an increase from a lower to a higher structure number the pore volume remains constant, volume of abrasive decreases by a specific amount and replaced by an equal volume of premixed bond which includes a fixed ratio of resin to filler content. Also, for any structure number, an increase from a softer to a harder grade of wheel, the volume of abrasive remains constant, pore volume decreases by a specific amount and replaced by an equal volume of the premixed bond that includes a fixed ratio of resin to filler content. Thus in each case the premixed bond compensated for either the decrease in pore volume and/or volume of abrasive and regardless of the number of changes in structure the ratio of resin to filler remained constant.

In contrast the Applicant's concept is to vary the ratio of resin to filler for each change in structure by replacing each reduction in abrasive content with an equal volume of an active filler material. Thus, the higher the structure the greater ratio of filler to resin in the wheel.

U.S. Patent 4,253,850 unexpectedly discovered an improvement in grinding performance and achieved higher grinding ratios and metal removal rates with relatively dense low abrasive, higher filler and substantially lower constant resin content, hot-pressed steel conditioning wheels under relatively constant force grinding conditions.

In contrast the Applicant has discovered that if the filler portion of the bond is an active grinding aid, i.e., the filler portion consisting of one or more finely divided materials that enhance and improve the grinding quality and efficiency, when the abrasive content is reduced and replaced by an equal volume of bond as previously described but with the exception that now only the active filler in the bond is increased to compensate for the reduction in abrasive and thus the resin content remaining unchanged, an unexpected improvement in grinding performance occurs.

Additionally, it has been found that medium density cold-molded wheels of improved grinding quality and efficiency can be made with reduced abrasive content and correspondingly increased active filler content and differing from U.S. Patent 4,253,850 in that the resin content is higher. This increased resin content is necessary for cold molding and extends the range of usefulness to higher porosity and less dense grinding wheels.

In accordance with the present invention there is provided organic bonded cold formed or pressed and post-cured abrasive bodies of relatively high structures, grinding efficiency, performance and life, such as disc and peripheral metal grinding and cut-off wheels have abrading portions comprising a greater and equal volume of active filler replacing the reduction in abrasive content whereby a high structure wheel has a greater ratio of filler to resin than a lower structure wheel.

The abrading portion of the abrasive body or wheel may comprise 30 to 44% by volume of 12-100 grit size abrasive particles suitable for removing metal, 24 to 36% by volume of an organic thermosetting resin, 14 to 29% by volume of an active filler material and 5-18% by volume pores. Additionally the abrading portion may contain 0 to 5% by volume of one or more suitable wetting agents which are deemed to be part of the resin content. If desired the abrasive bodies may be reinforced with suitable and conventional discs of open mesh fiber glass cloth, glass or other fibers and/or with a strong non-abrading backing or center portion adjoining the abrading portion. For some applications, the abrasive bodies may have, what are known in the art as "rough sides" to enhance grinding, quality of finish and prevent burning of the metal workpiece being ground or cut.

The organic bonded abrasive bodies of the invention are preferably high structure cold formed or pressed and post cured grinding wheels of medium to low porosity normally utilized in grinding, removing or snagging metal from various types of workpieces, weldments, castings and cutting-off metal rods, bars or strip stock to shorter length.

In most instances the abrasive bodies are relatively hard grade, high structure cold pressed grinding wheels in which the porosity is in the range of from 5-18% by volume of the abrading portion.

It has been discovered that the grinding performance, efficiency and life of the cold pressed wheels can be improved by replacing abrasive in the abrading portion with an active filler without jeopardizing the strength and safety factor of the wheel.

Thus, without sacrificing strength and safety, the cold pressed wheels of the invention have varying greater ratio of filler to resin content and thus substantially much more active filler than that normally provided in conventional prior art cold pressed wheels of comparable size, volume, grade and structure.

Abrasive bodies of the instant invention have an abrading portion comprising from 30 to 44% by volume of any suitable well known conventional abrasive material selected from the group consisting of fused aluminum oxide, fused alumina-zirconia, sintered alumina-zirconia, sintered alumina, sintered bauxite, silicon carbide and mixtures thereof.

Preferably, the abrasive material employed in the abrading portion has a particle size in a range of from 12 to 100 grit size or an average particle size of 2550 to 173 microns

A conventional resinoid binder mixed with at least one active filler material is utilized to bind the abrading composition together. The organic binder is preferably a thermosettable mixture of both liquid phenolic and powdered phenolic novalac resin including 9% of the cross linking aid hexamethylenetetramine. A suitable powered resin is Varcum 29344 standard thermosetting epoxy modified phenolic novalac resin available from Reichold Chemical Inc. Varcum Div., Niagara Falls, N.Y. However, other formulations of thermosetting phenolic novalac resin with 6% to 16% hexamethylenetetramine may be employed.

Other suitable thermosetting resins include phenoxy, phenol-furfural, aniline formaldehyde, urea formaldehyde, epoxy, cresol aldehyde, resorcinal aldehyde, urea aldehyde, melamine formaldehyde and mixtures thereof.

Small amounts of various resinous material may be utilized to modify the thermosetting resins. They include epoxy, vinyl resins, vinyl chloride, vinyl butyral, vinyl formal, vinyl acetate, cross linking aids, such as, para formaldehyde or hexamethylenetetramine and suitable plasticizers or solvents such as furfuryl alcohol and mixtures thereof.

Preferably the resin content in the abrading portions of the wheels of varying abrasive content and comparable size will range from 24 to 36% by volume.

There are various organic and inorganic fillers and mixtures of fillers which may be put in abrasive bodies for improving strength, reducing cost and most importantly for improving grinding efficiency.

Fillers are usually considered to be part of the bond and are in a finely divided state. They may include organic and inorganic materials of various particle sizes well below and much smaller than the primary grinding abrasive particles.

Suitable conventional and well known chemically active fillers are cryolite, fluorospar, magnesia, lead oxide, sodium chloride, iron pyrites (di-sulfide), iron sulfide, potassium sulfate, potassium fluoborate, potassium aluminum fluoride, potassium magnesium sulfate, alkali metal chloro ferrate, alkali metal chloro-fluoro ferrate, copolymer of vinylidene chloride and vinyl chloride (Saran B), polyvinylidene chloride, polyvinyl chloride, other sulfides, sulfates, halides, chlorides, fluorides, and mixtures thereof.

A preferred active filler material is a mixture of 50% by volume of -200 mesh size potassium sulfate, and 50% by volume of -325 mesh size iron disulfide also known as iron pyrites.

Also, abrasive bodies of the invention may be safety reinforced with various conventional chopped glass fiber up to 1/4" (6mm) long, inorganic fibers of short or long continuous length and/or open mesh fiber glass cloth discs. The fiber glass cloth may be of known twisted or of substantially untwisted strands or rovings of continuous glass filaments.

Other means of reinforcing the wheel may be used. For example, it is well known to provide a high speed grinding wheel with, what is known in the art, as a reinforced center to increase the safety factor, and its resistance to bursting apart and thereby allow the wheel to operate safely at higher speeds.

The reinforced center usually comprises reinforcing a central non-abrading portion about the axis or an inner annular non-abrading portion extending around a spindle mounting aperture and normally engaged by the clamping flanges of the drive spindle.

Adjoining and extending around the reinforced center portion is an outer annular abrading portion comprised of an abrading composition of the invention. Thus, it is the composition of the abrading portion of the wheel to which the invention is directed.

To evaluate the grinding effect of going from 7 to 15 higher structure wheels by replacing abrasive with active fillers, a first large batch of 16" (406 mm) diameter x 5/32" (3.96 mm) thick x 1" (25.4 mm) diameter hole cut-off wheels were made, including duplicates, of each of ten different formulations and compositions shown in Table I and tested by cutting off 1 1/2" (3.81cm) diameter bars of 304 stainless and C1018 carbon steels.

TABLE I

Composition % by Volume Excluding Wetting Agents (Furfural and Carbosota and Chlorinated Paraffin)

Wheel composition	1	2	3	4	5	6	7	8	9	10
Grade/structure	T7	V7	V9	V11	V13	V15	V9	V11	V13	V13
50% 24 grit and 50% 30 grit size Aluminum Oxide Abrasive	50	50	46	42	38	34	46	42	38	38
VARCUM V29344 Powder and 18% Liquid Phenolic Resins	27	30	30	30	30	30	33	36	39	34.5
Active Fillers 50% -325 mesh Iron di-sulfide (FeS_2) and 50% -200 mesh Potassium Sulfate (K_2SO_4)	9	10	14	18	22	26	11	12	13	17.5
Pores	14	10	10	10	10	10	10	10	10	10

All of the cut-off wheels were made with the same 50% 24 and 50% 30 grit size (1035 - 930 microns) aluminum oxide abrasive particles in the volumes specified for each particular structure number. As the abrasive content is reduced, in increments of 4% by volume as conventional when going to a higher structure, it was replaced by an equal volume of the active filler. Also, when going from a T7 to the higher V7 grade wheel of the same structure number, the pore volume decreases 4% by volume and is replaced by an increase in bond which includes about 3% by volume of resin and about 1% by volume of the filler material. Note, with the exception of the wheel compositions 7-10 that regardless of structure number, wheels of the same grade have the same volume of resin and pore volume.

A first group of wheels 1 and 2 are conventional T and V grade 7 structure wheels which are considered to be up to this discovery, the standard, most efficient, and most widely commercially used cold pressed cut-off wheel.

The prior state of the art standard cold pressed wheels 1 and 2 have a relatively higher 50% by volume of abrasive, a lower 9% and 10% by volume of filler than the other wheels, 27% and 30% by volume of resin and 10% and 14% by volume of pores. Heretofore, it was believed that the higher volume of abrasive was for the most part responsible for increasing the grinding efficiency of cold pressed grinding wheels.

The second group of wheels 3 to 6 includes a first series of V9-V15 grade and structure wheels made to evaluate the effect of replacing abrasive with an equal volume of active filler in accordance with the invention while maintaining a constant volume of resin for a particular grade of wheel.

A third 7 to 9 group and second series of V9 to V13 grade and structure wheels were made to evaluate the grinding effect of replacing abrasive with high resin and lower filler content and compare their performance with the second group 3 to 6 and first group of T7 and V7 wheels.

The last wheel 10 is a third V13 grade and structure wheel made to evaluate the effect of further varying the volume of filler and resin to a point intermediate that of the other V13 wheels 5 and 9.

In preparing each composition for molding into wheels the ingredients of the bond comprising the active fillers and VARCUM V29344 powdered phenolic resin were blended together dry and then wetted with CARBOSOTA (20cc/lb dry resin). The abrasive was wetted by and mixed with a compatible liquid phenolic resin comprising about 18% of the total volume of resin in the composition. The bond was then mixed with the wetted abrasive and further dampened with from 3 to 6 cc mixture of furfural and CL40 (chlorinated parafin) brand per lb. (6.6 to 13.2 cc/kg) of the mixed composition. CARBOSOTA is a registered trademark for a refined coal tar cresote oil wetting or dampening agent sold by Allied Chemical and Dye Corporation.

Preferredly the wetting or dampening agents furfural CL40 and CARBOSOTA comprise less than 3% by volume of the abrading portion of the wheel and may be considered part of the cured resin content thereof.

However, the abrading portion of the wheels may contain 0 to 5% by volume of suitable wetting agents selected from furfural, furfuryl alcohol, liquid resin, CARBOSOTA, CL40 (Chlorinated Parafin) and mixtures thereof.

Each of the various prepared mixtures of abrasive and bond was placed in a suitable mold and cold pressed at from 600 to 900 tons (544.3 - 826.4 metric T) total pressure. Wheels 2 through 6 required essentially the same molding pressure of 800 - 900 tons (725.7 - 826.4 metric T) total pressure and wheels 1 and 7 through 10 were molded at about 600 tons (544.3 metric T) total pressure.

The wheels were stripped from the molds and baked or post cured for 17 hrs. at 175°C. With the exception of wheel 6 (V15) all the other wheels 1 through 7 with 27 - 33% volume resin content cured well while wheels 8 through 10 of higher resin content exhibited signs of excessive flow during the bake and thus wheel 9 of (V13) with the higher 39% by volume resin content did not cure as well and therefor was not tested.

With the exception of the defective wheel 9 all other wheels were tested by mounting them on a Stone M150 Hydraulic chop cut off machine and dry cutting 1-1/2" (3.81 cm) diameter 304 stainless steel and C1018 carbon steel rods at both constant feed rates and constant pressure with the wheel speed maintained at 12,000 sfpm (61.0 SMPS).

On the 304 stainless steel bars each wheel made 20 cuts at each of the constant feed rates of 2.5, 4, and 6 seconds per cut, 30 cuts each at 55 and 70 lb. (121.25 - 154.3 kg) of constant pressure and 30 cuts each at 2.5 seconds per cut through the C1018 carbon steel.

To determine wheel wear and G-ratio the thickness of each wheel was measured before and after each test and its diameter measured before and after each series of 10 cuts and compared with the amount of metal removed. Additionally the average peak KW of power consumption and of time/per cut was measured and recorded for each series of 10 cuts. Lastly, the range in % of work piece burn was observed and recorded for each series of the 10 cuts.

The results of the comparative grinding tests are shown in the following Tables II, III and IV and wherein G-Ratio represents the volume of metal removed per unit volume of wheel and is a frequently used measure by which wheel consumers determine the efficiency and life of the wheel.

TABLE II

Average Relative Test Results Dry Cutting 1 1/2" (3.81 cm) Diameter
304 Stainless Steel at 2.5, 4 and 6 sec/cut Constant Feed Rates. (20 cuts)

Wheel Composition #	Gde/Str.	Average Wheel Thickness IN.	(mm)	G - RATIO		Power Consumption Peak KW	%
1	T7	.156"	(3.962)	4.578	92%	15.7	98%
2	V7	.156	(3.962)	4.975	100%	16.1	100%
3	V9	.155	(3.937)	5.136	103%	15.4	96%
4	V11	.156	(3.962)	5.543	111%	14.6	91%
5	V13	.155	(3.937)	5.39	108%	15.3	95%
6	V15	.157	(3.988)	4.756	96%	14.7	92%
7	V9	.154	(3.91)	5.153	104%	15.3	95%
8	V11	.150	(3.81)	5.01	101%	15.04	94%
9	V13	---	--	--	--	---	-
10	V13	.150	(3.81)	4.696	94%	14.7	92%

TABLE III

Average of Relative Test Results Dry Cutting 1 1/2" (3.81 cm) Diameter

304 Stainless Steel at 55 and 70 lb. Constant Pressure (30 cuts).

Wheel Composition #	Gde/Str.	Time Sec/Cut	G - R A T I O		Power Consumption Peak KW	%
1	T7	5.2	4.97	105%	10.6	98%
2	V7	5	4.74	100%	10.8	100%
3	V9	4.7	4.55	96%	11	102%
4	V11	4.7	5.68	120%	10.8	100%
5	V13	4.2	4.16	88%	11.8	109%
6	V15	4.1	3.43	72%	13	120%
7	V9	4.5	4.68	99%	11	102%
8	V11	4.3	4.22	89%	11.6	107%
9	V13	--	--	--	--	--
10	V13	4	3.90	82%	11.8	109%

TABLE IV

Average Relative Test Results Dry Cutting 1 1/2" (3.81 cm) Diameter

C1018 Carbon Steel at 2.5 sec/cut Constant Feed Rate

Wheel Composition #	Gde/Str.	No. Cuts	G - R A T I O		P O W E R Peak KW	%	% Burn
1	T7	30	3.59	100%	25.2	101%	0-30%
2	V7	30	3.59	100%	24.8	100%	0-30%
3	V9	17	4.04	112%	28	113%	0-50%
4	V11	20	3.96	110%	26	104%	10-80%
5	V13	8	4.05	113%	24.8	100%	0-5 % Trace
6	V15	20	3.40	94%	26.5	106%	0-80%
7	V9	14	3.32	92%	25.6	103%	0-80%
8	V11	12	3.85	107%	29	117%	0-80%
9	V13	--	--	--	--	--	--
10	V13	5	2.95	82%	26.4	105%	--

The unexpected results of the tests reveal that going from 7 to 15 higher structure and increasing the ratio of active filler to resin content to replace abrasive does significantly increase the performance and quality of grinding wheels of the same grade containing less amounts of abrasive.

For example in dry cutting of 304 stainless steel at a constant rate the #4, V11 composition wheel produced 11% greater G-ratio and wheel life with 9% less power and at constant pressure, cut 6% faster with 20% better life and G-Ratio than the conventional standard #2, V7 wheel composition of the same porosity and resin content but containing 8% more abrasive and less filler.

The data also shows that the performance of the second series of wheels V9, V11 and V13 of the wheel compositions 7, 8 and 10 with higher resin and lower active filler content was, with the exception of #7, V9, below that of the first series 3 to 5 of V9, V11 and V13 wheel compositions, but better than the performance of both the standard #2, V7 and #1, T7 wheel compositions with greater volumes of abrasive taught to be necessary for increasing the grinding efficiency.

Thus, the most efficient of the high structure V grade wheels tested cutting 304 stainless steel appears to be the #4, V11 composition followed in order of performance by #5, V13, #7, V9, #3, V9, #8, V11, #2, V7, #6, V15 and #10, V13 wheels all of which performed better than the standard #1, T7 grade/structure wheel with less resin and filler.

The results of cutting 304 stainless at constant 55 and 70 lb. head force as previously shown in Table III indicates that the highest structure V13 and V15 wheel compositions cut up to 25% faster than the standard #2, V7 and #1, T7 structure wheels, but had a relatively lower G-Ratio and hence wheel life. Again the #4, V11 wheel composition demonstrated better grinding quality, 20% better G-Ratio and wheel life and 6% faster cut rate than the standard #2, V7 structure wheel composition.

However, the data shown in table IV reveals that

TABLE V

Average Centrifugal Burst Strength

Wheel Composition #	Gde/Str.	VOLUME % Abr.	Resin	Filler	Pores	Centrifugal Burst Speed (sfpm)	(smps)
1	T7	50	27	9	14	25310	128.57
2	V7	50	30	10	10	25230	128.16
3	V9	46	30	14	10	22810	115.87
4	V11	42	30	18	10	23650	120.14
5	V13	38	30	22	10	23940	121.6
6	V15	34	30	26	10	21960	111.55
7	V9	46	33	11	10	26170	122.94
8	V11	42	36	12	10	25630	130.2
9	--	--	--	--	--	--	--
10	V13	38	34.5	17.5	10	24190	122.88

in cutting the C1018 carbon steel the high structure wheels did not perform as well and had a greater tendency to burn the work. This was attributed to the nature of carbon steels and the relatively smooth sides of the wheels creating unusually high friction and heat.

A number of wheels of each of the compositions were speed tested to destruction and the average results thereof are shown in Table V.

The bursting speeds shown in Table V reflect the strength and safety factor of the wheels tested.

The data indicates that wheel strength and hence the safety factor is reduced slightly from that of the standard #2, V7 composition wheel by replacing reductions in abrasive solely with active filler. However, the surface speeds and hence strength and safety factor are still well above that required and almost twice the usual 12000 (sfpm) (61.0 smps) at which the wheels are rotated. A slight addition in resin content of the second series of #7, V9, #8, V11 and #10, V13 wheel compositions appears to maintain strength and hence the safety factor thereof to the level of the #2, V7 wheel.

A second larger batch of 16" (406 mm) diameter x 1/8" (3.17 mm) thick x 1" (25.4 mm) dia. hole; R, T and V grade 7-13 structure cut-off wheels were made and provided with rough sides to alleviate the burning problem encountered previously in cutting C 1018 carbon steel.

The various wheel compositions were prepared as before and depending on grade were cold pressed at about 450 tons (408.2 metric T) for R grade, 600 tons (544.3 metric T) for T grade and 700 - 850 tons (630.9 - 771.1 metric T) for V grade in rubber lined molds adapted to produce the rough sides.

Table VI reveals the various grade and structure compositions and formulations 11 to 23 to which the second batch of wheels were made and tested.

TABLE VI

Compositions % by Volume Excluding Wetting Agents

(Furfural and Carbosota and Chlorinated Paraffin)

Wheel Composition (Rough Sides)	Std 11	12	13	14	Std 15	16	17	18	Std 19	20	21	22	23
Grde/Structure	Std R7	R9	R9	R10	Std T7	T9	T11	T11	Std V7	V11	V11	V12	V13
50% 24 grit and 50% 30 grit Aluminum Oxide Abrasive	46	46	44	50	46	42	42	42	50	42	42	40	38
Varcum V29344 Powder and 18% Liquid Resins	24	24	26	27	27	27	27	30	30	30	33	33	33
Active Fillers 50% -325 mesh Iron di-Sulfide (FeS_2) and 50% -200 mesh Potassium Sulfate (K_2SO_4)	8	12	10	11	9	13	17	14	10	18	15	17	19
Pores	18	18	18	18	14	14	14	14	10	10	10	10	10

It is also known that the theorical density of a green uncured cold pressed cut-off wheel may be less than the actual measured density of the wheel after it is baked and cured. The increase in density can vary and depends upon how the green cold pressed wheel is supported, and arranged during the bake and cure.

Table VII gives the actual measured cured volume, grade and structure for each of the theoretical R,T and V grade, 7-13 structure green cold pressed wheels, stacked together and separated by polytetrafluoroethylene (PTFE) coated glass cloth and clamped under 460 lbs. (208.kg) of pressure.

The data for the cured wheels given in Table VII indicates significant density increases for all wheels relative to theoretical or green molded values. The standard clamping (460 lb) caused 1.4, 2.2 and 3.9% density increases in the standard V7, T7, and R7 wheels 19, 15 and 11 respectively. Rough side retention during the bake was good in all grades for the standard 7 structure wheels.

High structure wheels exhibited significantly higher densification during the bake especially the higher porosity R-grade wheels 11 to 14. The R10 wheel 14, achieved the greatest densification of 9.8% relative to the theoretical density to a V8 grade/structure. Rough side retention was observed to be excellent for all R-grade wheels. The higher structure V11 - V13 wheels 20 to 23 were more structurally stable during the bake achieving more moderate density increases of approximately 4% but still significantly greater than the 1.4% increase of the standard V7 wheel 19. For example, wheel 20, a theoretical V11 achieved a cured grade/structure of X10 (6% porosity).

The higher structure wheels 19 to 23 exhibited varying degrees of rough side loss depending on the ratio of resin to abrasive. The 12 and 13 structure V-grade wheels 22 and 23 exhibited a 65% loss in side roughness, in fact the V13 wheel 23 conformed almost entirely to the pattern of the interlayer material use to separate the wheels during the bake and cure.

TABLE VII

Wheel Composition		Gde/Str.		Abr.	VOLUME % Resin	Filler	Pores	(Wax-Water Method) Wheel Density g/cc	% Theor. Density
11	Theor.	Std.	R7	50	24	8	18	2.58	
	Meas.		S-T6	51.9	24.9	8.3	14.9	2.68	103.9%
12	Theor.		R9	46	24	12	18	2.57	
	Meas.		U7	49.7	25.9	13.0	11.4	2.78	108.0%
13	Theor.		R9	46	26	10	18	2.52	
	Meas.		U7	49.6	28.0	10.8	11.6	2.72	107.8%
14	Theor.		R10	44	27	11	18	2.49	
	Meas.		V8	48.3	29.6	12.1	10.0	2.74	109.8%
15	Theor.	Std.	T7	50	27	9	14	2.66	
	Meas.		U6-7	51.0	27.5	9.2	12.3	2.72	102.2%
16	Theor.		T9	46	27	13	14	2.64	
	Meas.		V-W8	48.5	28.5	13.7	9.3	2.79	105.5%
17	Theor.		T11	42	27	17	14	2.64	
	Meas.		W-X9	45.4	29.2	18.4	7.0	2.85	108.1%
18	Theor.		T11	42	30	14	14	2.56	
	Meas.		W-X9	45.5	32.5	15.2	6.8	2.78	108.4%

TABLE VII (Continued)

19	Theor.	Std. V7	50	30	10	10	2.73	101.4%
	Meas.	V-W6-7	50.7	30.4	10.2	8.7	2.77	
20	Theor.	V11	42	30	18	10	2.71	104.4%
	Meas.	X10	43.9	31.3	18.8	6.0	2.83	
21	Theor.	V11	42	33	15	10	2.64	103.9%
	Meas.	X10	43.6	34.3	15.6	6.5	2.74	
22	Theor.	V12	40	33	17	10	2.63	104.2%
	Meas.	X11	41.7	34.4	17.7	6.2	2.74	
23	Theor.	V13	38	33	19	10	2.63	103.8%
	Meas.	X12	39.5	34.3	19.7	6.5	2.73	

The average results of dry cutting 1-1/2" (3.81 cm) diameter 304 stainless steel with each of the wheels 11 to 23 mounted on a Stone M150 Hydraulic Chop Machine and rotated at 12,000 sfpm (61.0 smps), 2.5, 4, and 6 second/cut for 20 cuts each wheel are given in TABLE VIII.

TABLE VIII

Average Relative Results Dry Cutting 1 1/2" (3.81 cm) Diameter 304 Stainless Steel at 2.5, 4. and 6 second/cut Constant Feed Rates (20 cuts/wheel)

Rough Sided Wheel Composition	Gde./Str.	Average Wheel Thickness IN.	(mm)	G - RATIO		Power Consumption Peak KW	%
11	Std. R7	.124	3.15	2.87	100%	12.8	100%
12	R9	.119	3.023	4.04	141%	12.9	101%
13	R9	.122	3.099	3.90	136%	12.67	99%
14	R10	.118	2.997	4.36	152%	12.28	96%
15	Std. T7	.126	3.175	3.77	100%	13.63	100%
16	T9	.122	3.099	4.71	125%	13.35	98%
17	T11	.116	2.946	5.58	148%	12.9	95%
18	T11	.116	2.946	5.39	143%	12.6	93%
19	Std. V7	.127	3.226	4.21	100%	13.6	100%
20	V11	.120	3.048	5.68	135%	12.24	90%
21	V11	.118	2.997	5.47	130%	12.37	91%
22	V12	.118	2.997	5.30	126%	12.1	89%
23	V13	.117	2.972	5.22	124%	11.8	87%

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The average relative performance of each rough sided wheel cutting 304 stainless steel is readily comparable to the standard rough sided R7, T7, V7 wheels 11, 15 and 19 respectively rated at 100%. As shown the higher structure wheels of each grade group, generally consumed less power, outperformed and have 24 to 52% better G-ratio and wheel life than the standard R7, T7, and V7. The best performing high structure #14, R10 and #20, V11 wheel achieved 52% and 35% better life and G-ratio than the standard #11, R7 and #19, V7 wheels.

The average relative performance of each of the same rough sided cut-off wheel compositions 11 to 23 rotated at 12,000 sfpm (61.0 smps) and dry cutting 1-1/2" (3.81 cm) diameter C1018 carbon steel bars at 3, 4 and 5 sec/cut for R grade wheels 11-14 and at 2.5, 3 and 4 sec/cut for T and V grade wheels 15 - 23 (30 cuts per wheel) is shown in the following TABLE IX.

TABLE IX

Average Relative Performance Dry Cutting 1 1/2" (3.81 cm) Diameter C1018 Carbon Steel At Constant Feed Rates of 3, 4, and 5 sec/cut R Grade Wheels 11-14; 2.5, 3, and 4 sec/cut T & V Grade Wheels 15-23 (30 cuts/Wheel)

Rough Sided Wheel Composition	Gde/Str.	G - RATIO		POWER Peak KW.	POWER %	% Burned At # Sec/Cut
11	R7	2.95	100%	14.5	100%	0-80 at 5 sec
12	R9	3.846	130%	16.8	116%	0-60 at 4 sec 0-100 at 5 sec
13	R9	3.62	122%	15.8	109%	0-40% at 4 sec 0-100 at 5 sec
14	R10	4.02	137%	14.9	103%	0-100% at 5 sec
15	T7	2.94	100%	17.46	100%	0
16	T9	4.01	136%	18.15	104%	0-100% at 4 sec
17	T11	4.79	163%	16.76	96%	0
18	T11	4.53	154%	16.5	95%	0-80% at 4 sec
19	V7	3.84	100%	18	100%	0-60% at 4 sec
20	V11	4.76	124%	16.1	89%	0
21	V11	4.45	116%	16.2	90%	0-60% at 4 sec
22	V12	4.45	116%	16.1	89%	0
23	V13	4.14	108%	16.3	91%	0-100% at 4 sec

The overall results cutting burn sensitive C1018 carbon steel indicate that grinding quality and versatility are greatly improved by going to high structure/high active filler with rough sided wheels. For examples, wheel #14, an R10 (cured to V8) with high active filler achieved 37% overall greater wheel life relative to the standard #11, R7 wheel but with equal versatility. Wheel #17, a T11 (cured to W-X9) achieved 63% better life with equal freeness-of-cut and versatility relative to the standard #15 - T7 wheel. Wheel #20, a V11 (cured to X10) achieved 24% better life relative to the standard #19 - V7 wheel, but was also significantly freer cutting and delivering burn free cuts at the 4 sec/cut feed rate. It was expected that the #22, V13 might have demonstrated better performance than the results indicate, however, significant loss in rough side definition may have adversely affected the results.

Also, the grinding quality is increased significantly especially for V grade high structure wheels which have the highest concentrations of active fillers. This is the first time a high structure V grade has been able to achieve burn-free cuts at a feed rate of 4 sec/cut on 1-1/2" - C1018 Carbon Steel and at the same time producing a phenomenally high average G-ratio of 4.76 (wheel #20, V11).

In TABLE X there is disclosed the results of speed testing to destruction wheels made to each of the grade and high structure wheels composition 11, and 13 to 20. Wheel #12 was not tested due to a shortage of available test wheels.

TABLE X

Average Centrifigal Burst Strength

Rough Sided Wheel Composition #	Gde/Str.	VOLUME % Abr.	Resin	Filler	Pores	Centrifugal Burst sfpm	smps
11	R7	50	24	8	18	26330	133.75
12	R9	46	24	12	18	NOT AVAILABLE	
13	R9	46	26	10	18	28820	146.4
14	R10	44	27	11	18	28270	143.6
15	T7	50	27	9	14	27200	149.8
16	T9	46	27	13	14	27790	141.17
17	T11	42	27	17	14	29450	149.6
18	T11	42	30	14	14	29690	150.8
19	V7	50	30	10	10	27720	140.8
20	V11	42	30	18	10	29100	147.8
21	V11	42	33	15	10	29970	152.2
22	V12	40	33	17	10	29670	150.7
23	V13	38	33	19	10	30010	152.45

Table X indicates higher centrifugal burst strength for high structure wheels relative to standard 7 structure wheels. The higher strength in the high structure wheels is attributable to higher densification during the bake and curing, relative to 7 structure wheels 11, 15 and 20.

By referring to Tables I, VI, and VII one can calculate and determine from the data given that when going to a higher structure in each of the particular grades the volume ratio of filler increases relative to both resin and abrasive due primarily to replacing the reduction in abrasive with filler and maintaining substantially constant volumes of resin and pores.

As calculated the ratios for all wheel compositions above the standard 7 structures are in the range of 1 volume of filler to 1.15 to 3 volumes of resin and to 1.3 to 4.1 volumes of abrasive.

However, in accordance with the invention the ratios are preferably in the range of 1 volume filler to .8 to 2.6 volumes resin and to 1.0 to 3.2 volumes of abrasive in the abrading portion of the wheel composition. In contrast, the standard 7 structure wheels contain 5 to 6.25 volumes of abrasive and no less than 3 volumes resin to 1 volume of filler.

Thus, the test data reveals conclusively that the performance and life of relatively hard grades, high structure grinding wheels is greatly improved by replacing reductions in abrasive content with active filler and thereby increasing the volume ratio of filler relative to both the abrasive and the resin in the wheel.

The invention can be utilized in other various forms of cold formed organic bonded abrasive bodies. Especially in medium to coarse grit size abrading portions of abrasive bodies such as unitary cylindrical peripheral and radial face or disk wheels and abrasive segments for both cylindrical and radial segmental wheels usually mounted in rotary chucks adapted for attachment to the drive spindle of a machine.

1. A high structure, organic-bonded abrasive body having an abrading portion comprising:

30 to 44% by volume of from 12 to 100 grit size abrasive particles of fused aluminum oxide, fused alumina-zirconia, sintered alumina, sintered bauxite, sintered alumina-zirconia, silicon carbide or a mixture thereof;
24 to 36% by volume of thermosetting resin;
14 to 29% by volume of active filler; and
5 to 18% by volume pores.

2. A high structure organic bonded abrasive body according to claim 1, wherein the volume of resin and filler are in a ratio of .8 to 2.6 volumes resin to 1 volume filler.

3. An abrasive body according to claim 1, wherein the volume of abrasive and filler are in a ratio of 1.0 to 3.2 volumes abrasive to 1 volume filler.

4. An abrasive body according to any one of the preceding claims, wherein the thermosetting resin is a phenol-formaldehyde, phenol furfural, aniline formaldehyde, urea-formaldehyde, cresol aldehyde, resorcinal aldehyde, urea aldehyde, melamine formaldehyde, phenoxy, or epoxy resin or a mixture thereof.

5. An abrasive body according to any one of claims 1-4, wherein the active filler material is an inorganic sulfides, inorganic sulfates, organic or inorganic halides, metal oxide or a mixture thereof.

6. An abrasive body according to any one of the preceding claims, wherein the active filler comprises potassium fluoborate, potassium sulfate, potassium aluminum fluoride, potassium magnesium sulfate, iron sulfide, cryolite, fluorospar, magnesia, lead oxide, sodium chloride, iron pyrites, iron disulfide, alkali metal

chloro ferrate, alkali metal chloro-fluoro ferrate, a co-polymer of vinylidene chloride and vinyl chloride, polyvinylidene chloride, polyvinyl chloride or a mixture thereof.

7. An abrasive body according to any one of claims 1-3, wherein the active filler comprises a mixture of potassium sulfate and iron di-sulfide, and the thermosetting resin is phenolic resin.

8. An abrasive body according to any one of the preceding claims, wherein the abrading portion further comprises at least one rough side of sufficient predetermined depth and spacing between peaks of abrasive particles and valleys therebetween to enhance the cutting efficiency of the abrading portion and substantially reduce burning of a workpiece thereby.

9. An abrasive body according to any one of the preceding claims, in the form of a rotatable grinding wheel.

10. An abrasive body according to claim 9, which is a rotatable cut-off grinding wheel.