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(54) A METHOD FOR PREPARING SCARFER SPITTINGS AND A METHOD FOR BENEFICIATING A WASTE PRODUCT TO PRODUCE A SIZE-GRADED ABRASIVE PRODUCT

(71) We, BETHLEHEM STEEL CORPORATION, a corporation of the state of Delaware having its offices at Bethlehem, Pennsylvania 18016, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention is directed to a method for preparing scarfer spittings and a method for beneficiating a waste product to produce a size-graded abrasive steel material.

Scarfer spittings are produced during scarfing of the surface of semi-finished steel products such as blooms, slabs, billets and bars to remove defects. During scarfing, the surface of the steel is heated to a molten temperature by gas torches in order to eliminate surface defects. The molten metal thus produced is customarily removed by high pressure water jets which impinge upon the surface of the workpiece immediately following passage of the gas torches. The molten metal removed from the surface of the product solidifies in the form of generally spherical-like particles having a wide range of sizes, for example larger than 2 inches (50.8 mm) to less than #100 sieve size. The solidified particles, or scarfer spittings, are comprised of metallic cores having substantially the same chemical composition as the steel which had been scarfed, enclosed in brittle shells which are substantially iron oxides. The scarfer spittings are usually collected in a water bath. Scarfer spittings have been used in the past as a portion of the charge to sintering strands to reclaim the iron which they contain. However, only the larger particles can be used in this manner. Therefore a large portion of finer particles must be either stored or discarded. In recent years, increased emphasis on the surface cleanliness of steel has resulted in an increase in the use of automatic scarfing machines to scarf the steel surfaces. Because of the use of automatic scarfing machines, the volume of scarfer spittings produced in a steel plant has increased. At the present time, the scarfer spittings are a waste product for which no good use has been found.

In our copending UK Patent Application No. 21756/78 (Serial No. 1598613), there is described and claimed a size-graded abrasive steel material produced from scarfer spittings for blast cleaning metallic and non-metallic surfaces, characterized by having a hardness within the range of R_c 20 to 35, a microstructure comprised of untempered lath-like martensite substantially free from intergranular and intragranular cracking, a grain size of about 3 to 4 as determined by ASTM E11-63 "Estimating the Average Grain Size of Metals," plate 1, and having an impact toughness such that a cumulative weight percent loss of 100% occurs after not less than 2500 impacts when tested by the method described in "Metallic Shot and Grit Mechanical Testing - SAE 445A" appearing in the SAE Handbook 1976 of the Society of Automotive Engineers, dated 1976. Such size-graded abrasive steel materials are useful in machine or manual blast cleaning of metallic and nonmetallic surfaces.

According to one aspect of the present invention, there is provided a method for preparing scarfer spittings comprised of steel cores enclosed in shells of iron oxides and being within a size range of plus 50.8mm to about minus #100 sieve size for use as size-graded steel abrasives useful in blast cleaning metallic and nonmetallic surfaces, comprising:

(a) screening said scarfer spittings in a first screening step to separate large non-usable spittings from smaller spittings and to remove foreign matter,

(b) charging said smaller spittings into a grinding mill,
(c) removing said shells of iron oxides from around said cores of said smaller spittings in said mill,
(d) screening the mixture produced in step (c) in a second screening step to separate said steel cores from said iron oxide shells, and
(e) screening said steel cores in a third screening step to produce a size-graded metallic abrasive product.

According to another aspect of the present invention, there is provided a method for beneficiating a waste product comprised of particles within a size-range of plus 50.8mm and minus #100 sieve size and characterised by a dual structure of steel cores enclosed in brittle shells of iron oxides for use as size-graded abrasives suitable for blast cleaning metallic and nonmetallic surfaces, comprising:
(a) screening said waste product to make a size separation at about 6.35mm size,
(b) charging the minus 6.35mm fraction into a grinding mill,
(c) rotating said grinding mill for a time whereby said brittle shells are fractured and removed from the surfaces of said cores,
(d) discharging said fractured brittle shells and said cores from said grinding mill,
(e) screening said fractured brittle shells and said cores in a second screening step to separate said steel cores from said iron oxide, and
(f) screening said steel cores in a third screening step to produce a size-graded abrasive product.

In a specific aspect of this method, the mixture of metallic cores and the fine particles of the shells is screened to separate the cores from the fine particles of shells and to make a size separation on a #35 mesh sieve size. The plus #35 sieve size fraction, comprising metallic cores, is stored. The minus #35 sieve size fraction, comprised of metallic cores and particles of shells, is screened on a #100 sieve to separate substantially all the plus #100 sieve size cores from the minus #100 sieve size cores and particles of shells. The plus #100 sieve size cores are mixed with the plus #35 sieve size cores. The minus #100 sieve size cores and particles of shells are recycled to the steel plant. The mixture of plus #35 sieve size and plus #100 sieve size cores is dried in a rotary drier and is then screened on a series of sieves into a plurality of sizes useful as size-graded metallic abrasives.

Methods embodying the invention for producing size-graded abrasive steel materials will now be described in more detail with reference to the accompnying drawings, in which:

Figure 1 is a reproduction of a photomicrograph taken at 100 magnifications of metallic cores produced by a method embodying the invention.

Figure 2 is a reproduction of a photomicrograph taken at 100 magnifications of prior art metallic abrasives.

It has been discovered that a useful product can be obtained from scarfer spittings, which are a steel plant waste product having a wide range of sizes and comprised of a dual structure of metallic cores enclosed in shells of iron oxides, by removing the shells. The freed cores can be used as size-graded metallic abrasives to blast clean metallic and non-metallic surfaces. The metallic cores are separated into various sizes on a series of sieves to produce size-graded abrasives which meet the requirements of SAE Shot and Grit Specifications J444.

In a preferred method embodying the invention, a size-graded steel abrasive material is produced from scarfer spittings, ranging in size from plus 2 inches (50.8mm) (i.e. a size which will not pass through a 2 inch sieve) to minus #100 sieve size (i.e. a size which will pass through a #100 sieve). The scarfer spittings are screened in a first screening step to separate substantially all the plus 1/4 inch (6.35mm) spittings and all foreign matter which has been collected with the scarfer spittings, from substantially all the minus 1/4 inch (6.35mm) spittings. The plus 1/4 inch (6.35mm) fraction of spittings is then separated from the foreign matter and is recycled to the steel plant to recover the iron which they contain. The foreign matter is discarded. The minus 1/4 inch (6.35mm) fraction of spittings is charged into a rotating continuous wet grinding mill which contains grinding media, such as steel, iron or ceramic balls or pebbles ranging in size 1/4 inch (6.35mm) to 1½ inches (38.1mm) in diameter. The size and weight of the grinding media selected for use in the grinding mill is of sufficient size and weight and of a type to fracture the brittle shells of iron oxides into relatively fine particles, which break away from the metallic cores, without materially affecting the shapes or the surfaces of the cores. The minus 1/4 inch (6.35 mm) spittings and the grinding media are tumbled for a time, usually not less than about eight minutes, to cause the brittle shells of iron oxide to fracture into fine particles. About 20 weight percent of the cores freed from the shells have a generally spherical shape and a relatively smooth surface. The remainder (about 80 weight percent) of the cores have irregular non-angular surfaces. The mixture of cores and fine particles of iron oxides formed in the mill, together with a portion of grinding media which breaks down during service, is removed from the mill through a discharge screen having appropriate openings, for example a #16 sieve size. The mixture is screened in a second wet screening step to separate substantially all the plus #100 sieve size cores from the minus #100 sieve size cores and particles of shells and grinding media. For ease of operation and to prevent overloading of the screens, the mixture is preferably first screened on a #35 sieve size to separate the plus #35 sieve size cores which comprise about 40 weight percent of the feed to the mill from the minus #35 sieve size cores, particles of shells and the grinding media. An insignificant quantity of grinding media may remain in the #35 sieve size. The plus #35 sieve size fraction is stored in a storage bin or hopper. The minus #35 sieve size fraction of cores and particles of shells and any broken grinding media remaining in the fraction are then screened on a #100 sieve to make the desired separation at #100 sieve size. All the plus #100 sieve size fraction of cores which comprise about 35 weight percent of the feed to the mill are mixed with the plus #35 sieve size cores in the storage bin or hopper. The minus #100 sieve size fraction of particles of shells and cores, which comprise about 25 weight percent of the feed are recycled to the sintering plant to reclaim the iron which they contain. Prior to separating the metallic cores into various sizes of size-graded metallic abrasives, they are dried in a suitable dryer, for example a fluid bed dryer or a rotary dryer at a temperature of not less than about 300F (149C). The dried metallic cores are then separated or size graded on a series of screens into various sizes to produce size-graded metallic abrasives according to SAE Shot and Grit Specification J444. In this specification, whenever screen or sieve sizes are used such screen and sieve sizes are United States Sieve Series. In a particularly preferred method embodying the invention, a continuous mill is used to beneficiate the spittings described above, in which case the minus 1/4 inch (6.35 mm) spittings are continuously fed into the mill at a rate sufficient to obtain maximum throughput. Grinding media are added from time to time to maintain the proper ratio between the spittings and grinding media to maintain maximum efficiency of grinding and throughput.

While a method for beneficiating scarfer spittings to produce size-graded metallic abrasives in which a wet continuous grinding mill using balls of, for example, steel or ceramic material or pebbles has been described, it is possible, as an alternative, to use a batch-type grinding mill in which the grinding media may, for example, be steel or ceramic balls or pebbles or to use an autogeneous mill in which the scarfer spittings are employed as both the material to be beneficiated and the grinding media required to beneficiate the spittings. In the batch method, a quantity of a mixture containing desired amounts of spittings and grinding media are charged into the mill. The mill is operated for a period of time, not less than eight minutes. The mill is stopped and the mixture or batch in the mill is removed and processed as described above and another batch is charged into the mill.

In an autogeneous mill, the spittings fall upon each other with sufficient force to fracture the brittle shells of iron oxides. During tumbling, the spittings rub against each other and as a result some of the shells of iron oxides are removed by abrasion. The metallic cores and the particles of shells are discharged from the mill through a screen having suitable openings. The discharged material is treated in the manner described above for the operation of the continuous wet mill to separate the metallic cores from the particles of shells and to produce size-graded shot and grit abrasives.

The spittings may be beneficiated in an impact mill in which the spittings are hurled against a target with sufficient force to fracture the shells in a one-point impact. The spittings may be recycled to the mill a sufficient number of times to remove the shells or a series of mills may be used.

Any of the above mills may be used dry, however, in a dry operation, copious amounts of dust are generated. It is therefore preferred to wet grind and wet screen to prevent excessive generation of dust.

It has been found that in any of the above processes, except the impact mill but in particular when an autogeneous mill is used, small areas of iron oxides may adhere to the surfaces of the smaller sized cores, that is, cores which are sufficiently small to pass a #40 sieve size. The smaller cores are therefore preferably subjected to a final beneficiating step in which they are impacted by a one-point impact in an impact mill to remove any iron oxides which may adhere to the surfaces of the cores.

The metallic cores have substantially the same composition as the steel which has been scarfed. Such compositions can be any AISI carbon or alloy grade of steel but are generally of the low carbon grades having a typical chemical composition of 0.03 to 0.08 weight percent carbon, .10 to .30 weight percent manganese, under .02 sulfur, under .01 phosphorus, under .02 silicon and the remainder substantially iron and incidental impurities usually associated with such grades of steel. Since the particles of scarfer spittings are customarily quenched and cooled in water while they are at a relatively high temperature, the microstructures and hardness of the particles are usually that of comparable grades of water quenched steel.

Turning to the Figures 1 and 2, a typical microstructure of the metallic cores produced by a method embodying the invention is shown in Figure 1 and a typical microstructure of a commercially available steel abrasive is shown in Figure 2. The cores and abrasives have a size of - minus #20, plus #40 sieve size. The microstructures of the metallic cores shown in Figure 1 comprise lath-like untempered martensite substantially devoid of any retained austenite, devoid of any intergranular or intragranular cracking and having a grain size of between 3 and 4 as determined by the method described in ASTM E112-63 "Estimating the Average Grain Size of Metals", plate 1. The microstructures of the commercially available metallic abrasive, shown in Figure 2, comprise plate-like tempered martensite with areas of alloy segregation and carbides and intragranular microcracks extending across the plates of untempered martensite and a grain size of about 7-8.

Typical chemical compositions of the cores and commercial abrasives are shown below:

Element	Cores (Weight percent)	Abrasives
Carbon	.06	.97
Manganese	.10	.96
Phosphorus	.014	.017
Sulfur	.012	.031
Silicon	less than .01	.93
Iron	96.5	95.8

Remainder incidental impurities and oxygen.

The hardness of the metallic cores was between R_c 20 and 35 with segregate areas of about R_c 45-50 while the commercially available steel abrasive had a hardness of R_c 45 to 50. The intragranular microcracks in the commerically available steel abrasives can act as stress points causing transverse cracking across the grains of the abrasives leading to early failure of the abrasives when used in the high stress process of blast cleaning metallic and non-metallic surfaces.

The metallic cores prepared by the method embodying the invention can be used to machine or manually blast clean the surface of metallic and non-metallic material. The time required to machine blast clean the surface of a ferrous metal with the metallic cores is somewhat shorter than the time required when using conventional steel shot or grit of comparable size. The presence of both substantially smooth surfaced spherical metallic cores and irregularly shaped metallic cores results in a machine blast cleaned surface which has a surface profile intermediate between the surface profile formed by using steel shot or the surface profile formed by using steel grit.

The breakdown rate or impact resistance of the metallic cores prepared by the method herein described and a commercially available metallic abrasive grit having a R_c 45-50 were compared as described in "Metallic Shot and Grit Mechanical Testing - SAE 445A" appearing in the SAE Handbook, 1976, of the Society of Automotive Engineers, dated 1976. The test may be conducted on an Ervin Test machine as outlined and shown in Bulletin 644 of the Alloy Metal Abrasives Division of Ervin Industries, 121 S. Division Street, Ann Arbor, Michigan. In the test, a measured amount of a screened metallic abrasive of known size is prepared. One hundred grams of the abrasive is charged into the test machine. The test machine has a throwing arm which rotates at 6900 revolutions per minute, and an anvil and recirculating device which rotate around the throwing wheel on the same axis at 25 revolutions per minute. Each particle of abrasive is subjected to one impact each time the anvil and recirculating device rotate. The number of rotations are counted to show the impacts the abrasive can absorb.

The 100 grams (0.22 pounds) of abrasive are subjected to a number of impacts. The machine is stopped and the abrasive particles are removed from the machine and carefully screened to remove all the fine particles from the sample. The remaining abrasives are weighed and a sufficient amount of fresh abrasive needed to bring the sample up to 100 grams (0.22 pounds) is added. The 100 gram (0.22 pounds) sample is then subjected to another known plurality of impacts and the procedure is repeated until about 100 weight percent of the test abrasives have been replaced. The results of the comparison tests on a G-40 grit are shown below.

No. of impacts	Weight percent loss		Cumulative weight percent loss	
	Commercial	Metallic cores	Commercial	Metallic cores
250	16.8	4.6	16.8	4.6
500	10.0	6.4	26.8	11.0
750	8.7	7.5	35.5	18.5
1000	8.3	9.0	43.8	27.5
1250	8.1	10.1	51.9	37.6
1500	9.2	10.0	61.1	47.6
1750	8.8	11.2	69.9	58.8
2000	9.7	11.5	79.6	70.3
2250	9.5	11.6	89.1	81.9
2500	10.0	11.6	99.1	93.5

After 2500 impacts almost 100 weight percent of the original amount of the commercial metallic grit abrasive had been replaced whereas only 93.5 weight percent of the metallic cores had been replaced, indicating that the metallic cores herein described were more resistant to impact than the same size commercially available steel grit.

A size-graded abrasive steel material produced by a method in accordance with the invention has an impact toughness such that a cumulative weight percent loss of 100% occurs after not less than 2500 impacts when tested by the above method.

In an example of a method embodying the invention for producing a size-graded abrasive steel material 66,000 pounds (29,937.1 kilograms) of scarfer spittings were screened on a 1/4 inch (6.35mm) screen to separate plus 1/4 inch (6.35mm) spittings and foreign matter from minus 1/4 inch (6.35mm) spittings. Less than 1 weight percent of the total feed was larger than 1/4 inch (6.35mm). The remaining 65,600 pounds (29,710.3 kilograms) passed through the screen. These relatively finer particles were charged at a rate of 1500 pounds per hour (680.4 kilograms per hour) along with 40 gallons per hour (151.4 liters per hour) water into a wet mill containing 1000 pounds (453.6 kilograms) of steel balls which ranged in size from 1/4 inch (6.35 mm) to one inch (25.4 mm) in diameter. The resultant mixture of spittings and water was continuously discharged from the mill onto a #35 sieve. About 40 weight percent of the spittings feed was retained on the sieve. The remaining 60 weight percent passed through the sieve. The chemical analyses of the plus #35 sieve product are as follow:

Element	Product retained on #35 sieve weight percent	Product passing through #35 sieve weight percent
C	0.05	0.04
Mn	0.10	0.49
P	0.017	0.013
S	0.010	0.016
Si	<0.01	0.03
Fe	96.3	78.8

Remainder incidental impurities and oxygen

The metallic cores retained on the #35 sieve were dried and sized into typical SAE cast steel shot size ranges. The particles passing through the #35 sieve were further screened on a #100 sieve to remove the fine oxide shells. The product retained on the #100 sieve was dried and passed through a dry impact mill to remove additional oxides from the finer metallic cores. The product from the dry impact mill was screened on a #70 and #100 sieve.

The chemistry of the products retained on the #70 and #100 sieves is as follows:

Element	Product retained on #70 & #100 sieve weight percent	Product passing through #100 sieve weight percent
C	0.05	0.09
Mn	0.10	0.53
P	0.017	0.013
S	0.010	0.016
Si	<0.01	0.04
Fe	96.3	74.9

Remainder incidental impurities and oxygen

Microscopic examination of a representative sample of the metallic cores was made at 100 diameters. The microstructure consisted of untempered lath-like martensite. No evidence of intragranular cracks was seen. The hardness was between 28 and 32 R_c.

The metallic cores were size-graded on a series of sieves. The weight percent of the cores retained on each sieve is shown below:

Sieve #	Weight percent
6	0.9
8	1.6
12	2.1
20	9.0
40	14.7
70	8.4
100	4.1

The remaining 59.2 weight percent consisted of particles of shells

Representative samples of the metallic cores were subjected to a durability test in an Ervin breakdown test. Samples of the metallic cores were recycled between 2700 and 3000 times in the test. The results compare favorably with commercially available steel shot and grit since only the best grades of these abrasives gave similar values in the Ervin breakdown test.

The cleaning action of metallic cores produced by beneficiating scarfer spittings was compared to the cleaning action of standard SAE 280 grade steel shot. To compare the cleaning action of the abrasives, the surface of a steel plate 4 feet by 8 feet by 3/8 inch (1.22 meters by 2.44 meters by 9.5 millimeters) covered with mill scale and patches of rust was divided into two equal parts. One part was cleaned with the metallic cores of the invention and the other part was cleaned with the steel shot. The abrasives were impinged onto the surfaces to be cleaned through a hand-held compressed air nozzle having an opening of 1/4 inch (6.35 mm) at a pressure of 100 pounds per square inch (7.03 kilograms per square centimeter). The nozzle was held about 8 to 12 inches (20.32 to 30.48 centimeters) away from the surfaces of the steel plate in a position perpendicular to the surfaces. The results of the cleaning action are shown below in Table I:

TABLE I

Comparison of cleaning action of metallic cores and standard SAE 280 steel shot

	Metallic cores	SAE 280 steel shot
Quantity of abrasive used	2.9 pounds per sq.ft. (14.16 kilograms per sq.m.)	3.5 pounds per sq. ft. (17.09 kilograms per sq.m.)
Particle size of abrasive	16 by 50 sieve (U.S.S.)	16 by 40 sieve (U.S.S.)
Surface cleanliness	Near white	Near white
Cleaning rate	240 sq.ft. per hr. (22.3 sq.m./hr.)	205 sq.ft. per hr. (19.1 sq.m./hr.)
Profile of cleaned surface	2.5-3 mils (63.5-76 microns)	2-3 mils (51-76 microns)

WHAT WE CLAIM IS:-

1. A method for preparing scarfer spittings comprised of steel cores enclosed in shells of iron oxides and being within a size range of plus 50.8 mm to about minus #100 sieve size for use as size-graded steel abrasives useful in blast cleaning metallic and nonmetallic surfaces, comprising:

(a) screening said scarfer spittings in a first screening step to separate large non-usable spittings from smaller spittings and to remove foreign matter,

(b) charging said smaller spittings into a grinding mill,
(c) removing said shells of iron oxides from around said cores of said smaller spittings in said mill,
(d) screen the mixture produced in step (c) in a second screening step to separate said steel cores from said iron oxide shells, and
(e) screening said steel cores in a third screening step to produce a size-graded metallic abrasive product.

2. A method for beneficiating a waste product comprised of particles within a size range of plus 50.8 mm and minus #100 sieve size and characterized by a dual structure of steel cores enclosed in brittle shells of iron oxides for use as size-graded abrasives suitable for blast cleaning metallic and nonmetallic surfaces, comprising:
(a) screening said waste product to make a size separation at about 6.35 mm size,
(b) charging the minus 6.35 mm fraction into a grinding mill,
(c) rotating said grinding mill for a time whereby said brittle shells are fractured and removed from the surfaces of said cores,
(d) discharging said fractured brittle shells and said cores from said grinding mill,
(e) screening said fractured brittle shells and said cores in a second screening step to separate said steel cores from said iron oxide, and
(f) screening said steel cores in a third screening step to produce a size-graded abrasive product.

3. The method of either claim 1 or 2 in which the mill in step (b) is a ball mill.
4. The method of either claim 1 or 2 in which the mill in step (b) is a pebble mill.
5. The method of either claim 1 or 2 in which the mill in step (b) is an autogeneous mill.
6. The method of either claim 1 or 2 in which water is added to said mill in step (c).
7. The method of claim 3 in which the grinding media are steel balls.
8. The method of claim 3 in which the grinding media are ceramic balls.
9. The method of claim 4 in which the grinding media are steel pebbles.
10. The method of claim 4 in which the grinding media are ceramic pebbles.
11. The method of either claim 1 or 2 in which the scarfer spittings are charged into a batch mill in step (b).
12. The method of either claim 1 or 2 in which the scarfer spittings are charged into a continuous mill in step (b).
13. A method for preparing scarfer spittings according to claim 1 and substantially as hereinbefore described.

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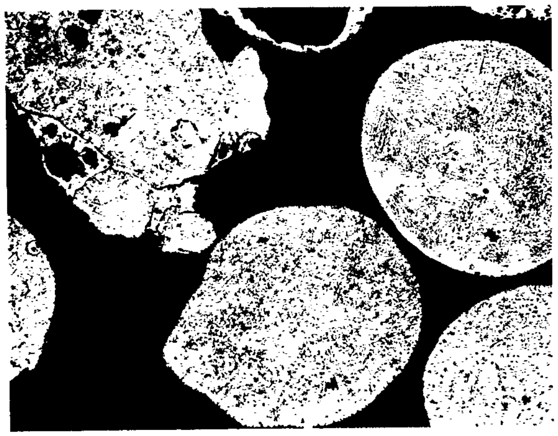

FIG. 1

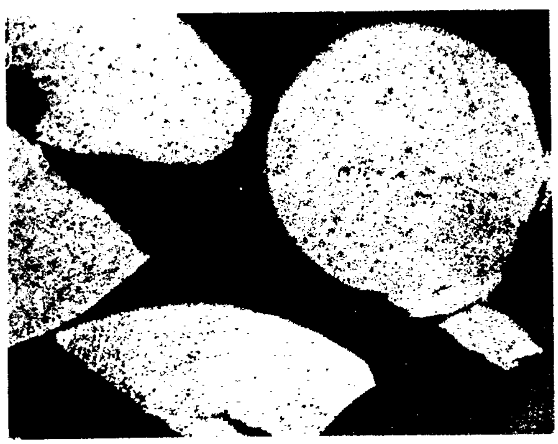

FIG. 2