

1

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BARREL FINISHING

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This invention relates to the art of tumbling. It relates more particularly to the process known in the metal fabrication arts as barrel finishing or barrel honing. It relates to a new and novel method of barrel finishing and to novel compositions for use in barrel finishing. It relates further to novel addition agents which are adapted to improve the efficiency and economy of barrel finishing.

The fabrication of metal parts, particularly smaller metal parts, of the size that are usually handled in groups in many operations, rather than individually, by machining, stamping, forging, casting, and the like, normally results in products which require further processing before they may be regarded as finished and ready for further use. The fabrication processes leave rough surfaces, scratches, tool marks, burrs, flashes, and other irregularities which must be removed or smoothed. The finishing processes are conventionally accomplished, at least in part, by placing the metal piece parts in a container, usually polygonal in cross section, adapted to rotate, usually upon a horizontal axis. The container is then rotated at a relatively slow speed, and finishing is accomplished by the tumbling action induced thereby.

Conventionally, abrasive material such as ground quartz, Carborundum, and the like, with or without chemical agents, and together with coarse stone material, referred to in the art as "hone material," are charged with the metal piece parts, or "work," and their effect is to accelerate the finishing operation, as is well known.

This invention is based upon the discovery that barrel finishing may be vastly improved by use of certain agents in the charge which enhance the rate of metal removal in a selective manner and consonantly produce finished work possessing improved surface properties. These agents, which will be described in detail in the following specification, will be referred to as "surface conversion agents" or "conversion agents" for the sake of brevity. Use of the agents in accordance with the invention may take a variety of aspects, i.e. in the manner of addition, sequence of addition, use of assistants, and the like, all of which are to be regarded as features of the invention, and which will be described in detail hereinafter.

According to the invention, ferrous or non-ferrous metal articles are barrel finished in accordance with the processes which will be hereinafter described. Soft ferrous metal parts such as stampings, machined or unmachined malleable castings, machined or unmachined gray iron castings, ferritic stainless articles, austenitic stainless articles, case carburized articles, nitrided articles, carbo-nitrided articles, heat treated carbon and constructional alloy steel articles are included. Also included, especially in conjunction with the salt forms of the novel surface conversion agents, are non-ferrous metal articles such as white metal castings, stampings, machined parts; or such parts made of aluminum, aluminum alloys, and the like. The articles may be partially or completely fabricated and include bearings, bushings, pins, chain links, chain side bars, and other chain parts, electric control piece parts, gears, sprockets, lock parts, washing machine parts, lawn mower parts, outboard motor parts, farm machinery parts, and the like.

The prior use of abrasive material in barrel finishing processes, with or without other agents such as surface active agents, acids, or the like, while accelerating or otherwise modifying the process, is attended by various disadvantages which detract from the quality of finished

2

material, cause increased costs, and the like. For example, certain oxide hone material such as Alundum chips cut and abrade very rapidly, thus decreasing the tumbling time. Yet these materials are worn away by their own abrasive action to such an extent that their use is costly and their action very difficult to control. Moreover, variations in hardness of work render control difficult under any circumstances familiar to the prior art, and it is usual for some work to be decidedly underfinished, while others are overfinished. Acids tend to etch pits and scratches deeper while giving corners radii that are overlong.

In accordance with the invention, finishing or honing of metal pieces is carried out in a zone of agitation, such as a tumbling barrel, in the presence of an abradant material and an agent capable of converting the surface portion of the pieces to an insoluble friable skin of microscopic thickness. Agitation of the pieces in the zone results in selective removal of this layer quickly and easily by mechanical contact. As the layer is removed in such areas of contact, a new friable layer is immediately formed by the conversion agent, and the cycle is repeated. Thus a continuous process occurs of layer formation followed by removal of the layer by mechanical action, followed again by layer formation, and so on.

Removal of the converted layer is assisted by the abradant material. In areas of the pieces where the abradant does not have active forceful contact, or where the occasions of such contact are less frequent, i.e. flat surfaces and surfaces of even contour, layer removal and reformation is accordingly lessened. Portions of the surface that are not exposed to abrading contact are converted once, but no further conversion occurs. In contrast to the action of acids, the surface conversion agents remove selectively those portions of the pieces in an exposed position, i.e. the burrs, scratch edges, tool marks, sharp corners, and the like.

Suitable conversion agents are metaphosphoric acid, orthophosphoric acid, amine phosphates and other water-soluble phosphate salts such as ammonium, sodium potassium, lithium, magnesium, calcium, barium, strontium, zinc, cadmium, or chromium. Of the above, in addition to metaphosphoric acid and orthophosphoric acid, I prefer the dihydrogen phosphates of ammonium, the alkali metals, the alkaline earth metals, and organic amines.

Other conversion agents which are suitable are nitro compounds of the general formula $R-O-NO$ where R is a metal such as sodium, potassium, calcium, and the like, or an organic radical such as omega-tolyl ($C_6H_5CH_2-$); aromatic carboxylic acids such as benzoic acid or toluic acid; aromatic hydroxy carboxylic acids such as gallic acid; aliphatic acids such as acetic acid and its homologues, citric acid and its homologues, and oxalic acid and its homologues; and substituted aromatic hydroxy compounds such as trinitrophenol, dinitrophenol, and the like. These conversion agents may be used singly or in combination with each other or with the phosphate salts mentioned above.

The use of surface conversion agents in agitation finishing of metal pieces, e.g. barrel finishing, is attended by numerous advantages. The agent is consumed with the greatest possible efficiency, since it is required only to replenish the layer that is removed. Hardness and composition of metal parts do not greatly influence the process, since the friability of the converted layer is practically independent of the hardness of the parts.

The results of using my surface conversion agents are remarkable in the quality of finished piece, rate of metal removal, and continuance of effect throughout extended periods of agitation. For example, in the typical case of metaphosphoric acid as conversion agent, metal removal rates are increased ten-fold whereas the

3

surface finish is a bright silvery matte, all irregularities are removed, and sharp corners are given the desired fillet. Moreover, at the end of a twelve-hour hone or finishing cycle, metal removal rates are seventy to eighty percent of the original rate in the case of metaphosphoric acid, whereas the metal removal rate is only about forty percent of the original rate at the end of twelve hours in a control test where an alkaline detergent (sodium metasilicate) was used.

In conventional acid systems, the action of the acid is strongest during the first portion of the finishing cycle, etching all areas of the work pieces essentially at the same rate. Though the rate of metal removal is rapid, pits and scratches are deepened at substantially the same rate, or faster. The phenomenon of deepening of pits and scratches in an acid etching environment is well known in the art, and where they are V-shaped in cross section actually deepen at a greater rate than that occurring at other portions of the piece (owing to lateral removal of metal from the sloping sides of the V).

Best results with an acid system involve use of such quantities of acid that the etching action is slowed during the intermediate and final portions of the finishing cycle so as to prevent, among other things, too long fillet radii on corners of the work pieces. In order to realize advantage from the action of the acid, conditions are adjusted so that the etching effect of the first portion of the cycle is not normally overcome by mechanical abrasion during the later portion of the cycle. This leaves residual etched pits and scratches, often together with overlong fillet radii on the corners of the finished pieces.

In the novel surface conversion systems of the present invention, the metal removal is not only accelerated, but is selective. Continuous contours, i.e. the flat surfaces and surfaces of even contour are protected against further chemical action by the thin layer formed by the agent. Sharp contours are also coated, but the coating layer is broken and removed by forceful abrading contact as soon as it is formed. The metal removal rate is thus differential and selective; the most rapid at corners, scratches, burrs, and the like; less rapid at the smooth portions of the work. Furthermore, pits and scratches are not made deeper.

Other materials can be used in my novel finishing systems in addition to the conversion agents. Additional material of principal importance is an abradant, usually very finely divided, of the order of 150 to 300 mesh. It can be a mineral abrasive such as Carborundum, quartz, emery, aluminum oxide, ground stone, and the like. It can be used as a single substance, or can be used in admixture with other abrasive material.

Other assistants which can be used are coarse hone material, organic or mineral absorbents, wetting agents, oxidation inhibitors, and the like. The coarse hone material is mineral in character, and is preferably used in the form of lumps or chips of the order of three-eighths inch to two and one half inches major dimension. It can be Alundum chips, granite chips, limestone chips, quartzite chips, flint chips, coarse crushed river stone, bonded abrasive grains, and the like. Its action is to supplement the action of the finer abrasive, to distribute the abrasive slurry and to hone the work pieces with the film of abrasive slurry, to decrease the overall density of the process load, to keep the work pieces from nicking and denting each other, and to provide considerable abrasive action itself. The coarse material is conveniently referred to as hone material because of its special action on the work pieces, whereas the finer material is referred to as the abrasive.

One aspect of the use of hone material, i.e. a novel blend thereof, is an important feature of this invention and will be described in detail in the ensuing description. The use of absorbent materials is likewise

4

an important feature of this invention and will be described below.

The following examples are illustrative of the invention. They are not to be construed as limiting. In all barrel finishing experiments, the barrel is charged, first with the hone material, then with the work pieces, and then with the remaining ingredients. The amount of water may vary to give a thin or thick slurry, but in all cases herein, the amount was five gallons.

Example 1

A test run was made in a 32-inch octagon tumbling barrel set to operate at 25 revolutions per minute. The work charged was 1000 pounds of steel pins of 60 Rockwell (C). Four cubic feet, about 400 pounds, of two-inch Montello granite chips was used as hone material. Two ounces of a petroleum sulfonate wetting agent was used, and seven pounds of 280-mesh aluminum oxide was used as abrasive. Sufficient metaphosphoric acid was added to provide 12.0 pounds of H_3PO_4 per 1000 square feet of surface of the pins. Sufficient water was added to make a slurry, and the barrel was rotated for a period of six hours. At the end of the period, the pins were discharged and examined. They possessed a fine finish, with all rough elements removed, and showed no residual pits or scratches. Weighing of marked test specimens showed the rate of metal removal to be 9.5 milligrams per square inch per hour per pound of load, average for the run.

Example 2

Substituting four pounds of quartz flour (280 mesh) for the aluminum oxide abrasive gave similar results, the average metal removal rate being 9.0 milligrams per square inch per hour per pound of load (m.s.h.p.), and the finish was equally good.

Example 3

Example 1 was repeated except that the abrasive used was a mixture of five pounds of the aluminum oxide flour and two pounds of the quartz flour. The rate of metal removal was 7.5 m.s.h.p., and the surface was similar.

Example 4

Example 3 was repeated except that the test material was 1000 pounds of steel pins of 187 Brinell hardness number. The rate of metal removal was 12.0 m.s.h.p., and the surface was excellent.

Example 5

Example 1 was repeated except that the abrasive used was a mixture of two pounds of the aluminum oxide flour and two pounds of the quartz flour. The rate of metal removal was 5.5 m.s.h.p., and the surface was excellent. When the quantity of metaphosphoric acid used in the foregoing cycle was reduced to 4.0 pounds of H_3PO_4 per 1000 square feet of work surface, the metal removal rate was found to be the same, i.e. 5.5 m.s.h.p. However, when the metaphosphoric acid was increased to 20.0 pounds of H_3PO_4 per 1000 square feet of work surface, the metal removal rate rose to 8.0 m.s.h.p., average, and the rate further increased to 15.0 m.s.h.p. when one pound of ground corncobs and more metaphosphoric acid was added to the charge, the total H_3PO_4 in the last cycle being 36.0 pounds per 1000 square feet of work surface.

Substituting softer work in each of the cycles of Example 5 gave results which were essentially the same, except that the metal removal rates were uniformly higher, being increased by approximately 5 m.s.h.p.

Example 6

This example includes two comparison test runs illustrating the striking effect of my novel conversion agents as accelerants in metal removal; and it shows the surprisingly high metal removal rates which can be obtained with them, even when used alone, i.e. without abrasives.

A tumbling barrel the same as the one used in Examples

5

1 through 5 was charged with 1000 pounds of hard steel pins, 60 Rockwell (C) hardness, and the hone material was 200 pounds each of granite and aluminum oxide chips. As in the previous examples, two ounces of petroleum sulphonate was added as wetting agent. Also, a six-hour test period was used. In one run, two pounds of 280-mesh aluminum oxide was used as abrasive. In the other, no abrasive was added. In each run, metaphosphoric acid was used sufficient to provide 12.0 pounds of H_3PO_4 per 1000 square feet of work surface. The rate of metal removal in the test run without abrasive was 15.0 m.s.h.p., while it was 13.0 m.s.h.p. in the test run with abrasive, the rates being the average over each total six-hour test period. The effect is even more striking where a mixture of one pound each of aluminum oxide flour and quartz was used. The removal rate in this latter case was 12.0 m.s.h.p. in a test run where all other conditions were the same. A comparison run without abrasive gave an average metal removal rate of 15.0 m.s.h.p.

Example 7

The unique effect of my conversion agents is also evident in the case of softer material such as 187 Brinell steel pins. In a pair of comparison test runs, the conditions of Example 6 were duplicated except that the work material was such softer pins. The run wherein abrasive was used gave an average metal removal rate of 18.0 m.s.h.p., for the six-hour period, whereas that in which no abrasive was used gave an average rate of 21.0 m.s.h.p.

Example 8

This example shows that the use of abrasives is frequently of substantial advantage in my barrel finishing systems containing conversion agents, even though excellent metal removal rates can be achieved without abrasives in the case of certain relatively dense materials as shown in Examples 6 and 7, above. The conditions of Example 6 were duplicated, using a typical soft, relatively bulky test load of steel bushings of 187 Brinell hardness. With a mixture of two pounds of silicon carbide, one pound of aluminum oxide, and one pound of quartz flour, all of 280 mesh, the average metal removal rate was 14.2 m.s.h.p., and using a mixture of one pound of silicon carbide, two pounds of aluminum oxide, and two pounds of quartz flour, all of 280 mesh, the rate was slightly lower, i.e. an average of 12.5 m.s.h.p. However, when this same test was run without using any abrasive, the rate averaged 10.5 m.s.h.p.

Example 9

Example 8 was repeated, using instead, hardened steel bushings. With a mixture of one pound of 280-mesh silicon carbide, two pounds of 280-mesh quartz flour, and two pounds of 280-mesh aluminum oxide flour, the average metal removal rate was 6.0 m.s.h.p. Repeating the test run with no abrasive gave an average metal removal rate of 5.0 m.s.h.p.

COMPARATIVE EFFECT OF SURFACE CONVERSION AGENTS

Example 10

In an experiment (run A) illustrating the accelerated metal removal rate that is realized by using the novel surface conversion agents of this invention, a 32-inch octagon tumbling barrel was charged with 1000 pounds of test slugs 0.440 inch in diameter and 2.000 inches long, of 52 Rockwell (C) hardness. The charge was typical of hard dense work material such as steel pins, forged and hardened roller bearings, ball bearings, steel pins, forged and hardened pushrod cams, and the like. Two hundred pounds each of two-inch aluminum oxide chips and two-inch granite chips were added as hone material. Two pounds each of 280-mesh aluminum oxide and 280-mesh silica flour were added as abrasive. Sufficient metaphosphoric acid was added to provide 10 pounds of H_3PO_4

6

per 1000 square feet of work surface area. Two ounces of petroleum sulphonate and five gallons of water were added, and the barrel rotated at 25 revolutions per minute. The condition of the charge was examined at intervals during a test period of 20 hours. The results are given below.

Example 11

For comparison with Example 10, another run was made in exactly the same way (run B), except that the metaphosphoric acid was replaced by sufficient disodium silicate to provide twelve pounds per 1000 square feet of work surface area.

The results of the two runs (run A and run B) as reflected by the rate of metal removal are tabulated below.

TABLE I.—RATE OF METAL REMOVAL

[Milligrams per sq. in. per hour per lb. of load (average)]

Elapsed time (hours)	Run A	Run B
1	22.0	2.5
2	19.0	2.3
3	18.0	2.0
4	19.0	1.8
6	17.0	1.1
12	17.0	1.0

Example 12

For further comparison, run A, above, was duplicated, except that 15 pounds of H_2SO_3 , as sodium acid sulphite was used in place of the metaphosphoric acid (run C). This run was terminated at the end of six hours, at which time the pieces were smooth. Burrs and sharp edges had been removed, though the appearance of the surface was dull and inferior owing to incompletely removed pits and scratches. Radii of corners of the test slugs were found to be 0.020 inch or longer. Rate of metal removal averaged 11.0 m.s.h.p.

In the foregoing comparative runs of Examples 10 to 12, inclusive, examination of the test slugs from each run revealed the following.

The original slugs contained surface pits of about 0.0002 inch depth, surface scratches of the same depth with edges of about half that height above the surface of the slug, spaced 0.0002 inch apart, and contained sharp corners and burrs.

Test slugs from run A, after the first 2.5 hours of treatment showed a honed surface; pits remained approximately the original depth, but the edges of scratches had disappeared; burrs had been removed, and sharp corners were rounded to about 0.020 radii. The system had changed to alkaline, and the effect of the conversion agent as manifested by friable film formation, had considerably lessened compared with the effect at the start of the run. At the end of six hours, the pits, tool marks and scratches had disappeared, and a fine honed surface finish had been developed on the pieces.

Work pieces from run B, during the first period of treatment contained pits and scratches of approximately the original depth. In addition, the scratch edges had not been removed, nor were the corners smoothed appreciably. At the end of six hours, pits still remained (0.0001 inch deep), scratches remained (0.0001 inch deep), and scratch edges remained with almost the original height above the surface of the test pieces. Burrs were not completely removed, and corners had radii of 0.006 inch. The pieces had a dull appearance owing to the incompletely removed surface irregularities.

Work pieces from run C evidenced fairly rapid metal removal during the first two hours of treatment. Pits and scratches, however, had become appreciably deeper (0.0003 inch), though scratch edges still remained visible. Burrs had been removed, and the corners had been rounded to radii of 0.010 inch. After approximately two hours more of treatment the acid became exhausted as evidenced by the rise of pH to approximately 7.0, and

the depth of the pits and scratches had not become deeper. At the end of six hours a fine honed surface finish had been developed on the pieces, but pits and scratches still remained, having an average depth of 0.0001 inch, imparting to the work an unsatisfactory dull appearance.

In the foregoing experiment, results similar to those of run A are achieved by substituting for the metaphosphoric acid, sufficient orthophosphoric acid or water-soluble phosphates such as ammonium dihydrogen phosphate, sodium dihydrogen phosphate, or methylamine phosphate to provide four to twenty pounds or more per 1000 square feet of work surface area.

BLEND OF HONE MATERIALS

In one aspect of my invention, the hone material, which may be used with or without surface conversion agents, comprises a novel blend or mixture of two distinct types of hone material. I have discovered that when these two types are used together, their action is to supplement each other in a remarkable and unpredictable fashion. These novel blends are especially suitable for use with my surface conversion agents.

Many high-efficiency hone materials are known. Examples are fused aluminum oxide, silicon carbide, or other synthetic or natural grains in fused or bonded form as well as chips or lumps of minerals such as quartzite. They are considerably more costly than materials such as granite, flint, flint stones, basalt, and the like which are often used as hone material although low in honing efficiency, because of their great toughness and excellent durability. In addition to their cost limitation, the high-efficiency hone materials break down so rapidly that under normal operating conditions the loss per cycle is frequently as high as ten percent of the charged hone material.

I have discovered that by blending high-efficiency hone materials with one half to two parts by weight of a tough low-efficiency hone material, a highly efficient honing action is achieved without the attendant high breakdown. Typically, the honing action and rate of metal removal is essentially equal to that of the high-efficiency material used alone, whereas the breakdown of this expensive ingredient in the blend is diminished to such an extent that the ratio of the two ingredients remains constant throughout many cycles.

The high-efficiency component of my novel blend of hone materials can be characterized as an oxide, carbide, or carbonate mineral, either natural or synthetic, having a hardness greater than 4.5 on the standard mineralogical scale. The tough mineral component can be characterized as comprising a salt of an amphoteric mineral acid, the component also having a hardness greater than 4.5 on the same hardness scale.

Economically, the most important of the high-efficiency hone materials are the carbides, the carbonates, and the simple oxides of such metals as aluminum, calcium, and silicon. Examples are quartzite, emery, fused aluminum oxide, silicon carbide, corundum, and hard limestone. Examples of the tough mineral component are natural rock such as granite, basalt, syenite, diorite, gabbro, and gneiss, or minerals such as flint, feldspar, beryl, apatite, hornblende, or the like.

The following experiments illustrate the effect of the novel blends used with my novel surface conversion systems. It is to be understood, however, that the advantages of enhanced honing action and minimized breakdown can be realized in systems which do not contain surface conversion agents, as for example, those barrel finishing systems that have been previously employed in the prior art.

Example 13

A load of 1000 pounds of hard steel pins (60 Rockwell C) was charged into a 32-inch octagon tumbling barrel. There was added 200 pounds of two-inch alu-

minum oxide chips and 200 pounds of two-inch Montello granite chips as hone material. To the charge was added one pound of 280-mesh aluminum oxide and one pound of 280-mesh quartz flour. Metaphosphoric acid was added in an amount sufficient to provide twelve pounds of H_3PO_4 per 1000 square feet of pin surface. Two ounces of a petroleum sulfonate wetting agent was added and about five gallons of water. The charge was agitated by rotation of the barrel at 25 revolutions per minute. At the end of a six-hour finishing cycle, the metal removal rate was 12.0 m.s.h.p., average for the cycle.

Example 14

In a parallel comparison run, the same kind of work material was charged with 400 pounds of Montello granite instead of the blend or mixture of hone materials used in Example 13. In the comparison run, all conditions were the same, except that the amounts of abrasive constituents were doubled. The rate of metal removal at the end of a six-hour finishing cycle was 7.0 m.s.h.p., average for the cycle.

In another pair of comparison runs, the foregoing was repeated using softer and more bulky work material, i.e. steel bushings of 187 Brinell hardness number. Operating conditions were the same, except that a mixture of two pounds of 280-mesh aluminum oxide, two pounds of 280-mesh quartz flour, and one pound of 280-mesh silicon carbide was used as abrasive in each of the two runs. The aluminum oxide-granite mixture gave an average metal removal rate of 12.5 m.s.h.p., whereas the Montello granite comparison run gave 10.0 m.s.h.p., average for the run.

In runs paralleling each of the foregoing sets of comparison runs, wherein aluminum oxide chips alone are used as the hone material, the metal removal rate is approximately equal to that obtained using the oxide-granite mixture. However, the chips at the end of the run are seriously rounded and dulled, and the metal removal rate is beginning to fall rapidly.

EFFECT ON SURFACE HARDNESS, TOUGHNESS, AND FATIGUE RESISTANCE

The novel barrel finishing processes of this invention employing surface conversion agents has a variety of surprising beneficial effects on the finished work. These effects are mainly owing to the following factors which are inherent in the use of surface conversion agents.

(1) Almost perfectly homogeneous abrasive action which obviates all directional grooves and stresses.

(2) Chemical effect of the surface conversion agents upon the surface of the work in the successive removal of submicroscopic layers of metal.

(3) Uniformity of finish afforded by short honing cycles owing to the coaction between the surface conversion agents and the hone material.

(4) Selective action of the novel finishing process in removing corners, edges, tool marks, and other surface irregularities.

(5) Tumbling action inherent in the process, resulting in gentle cold working of the metal surface and in the generation of residual compressive stresses in the finished pieces; so that they are in a condition of internal stress similar to that found in shot peened work, but possess a fine smooth finish rather than the roughened surface that is characteristic of shot peened work.

Example 15

This example illustrates the effect of my process on surface hardness and metal toughness. Tests were conducted on 0.625 diameter solid steel cylinders 4.000 inches long. The material was A.I.S.I. 4142 steel, oil quenched and tempered at 600 degrees Fahrenheit. All pieces were from the same heat and received identical treatment throughout, except in the barrel finishing steps.

After quenching and tempering, the pieces were sepa-

9

rated into two lots. The first, lot A, was carefully finish ground in accordance with conventional shop practice. The other lot, lot B, was barrel finished in accordance with this invention, following substantially the procedure of Example 1, above. The work pieces from both lots were then bend tested by the free bend test, all tests being conducted at 70-75 degrees Fahrenheit. The results are tabulated below.

TABLE II.—FREE BEND TEST

Specimen No.	Lot A		Lot B	
	Hardness (Rockwell C)	Bend, degrees	Hardness (Rockwell C)	Bend, degrees
1	46	1 10	49	2 45
2	47	2 20	50	2 45
3	48	2 25	49	2 45
4	46	2 20	51	2 45
5	47	2 25	50	2 45
6	46	1 10	51	2 45
7	46	2 15	51	2 45
8	47	2 20	50	2 45
9	48	1 5	52	2 45
10	46	2 20	51	2 45

¹ Break.² No break.

The gain in toughness and surface hardness illustrated in Table II, above, is of tremendous economic importance, for it affords the use of inexpensive alloys such as A.I.S.I. 4140 and 4142 in the many uses demanding 50 Rockwell (C) hardness, whereas, heretofore it has been necessary to use expensive alloys such as A.I.S.I. 4340. Moreover, the products finished in accordance with this example possess toughness properties even superior to those of more expensive alloys such as A.I.S.I. 4340.

In addition to enhanced surface hardness and toughness, my novel barrel finishing processes also lend to the finished articles increased fatigue resistance owing to the residual stressed condition of the finished surfaces. This is evidenced by increasing fatigue resistances of specimens up to 25% and more through finishing as in the above example. The specimens of lot A averaged 25% greater in fatigue resistance than those of lot B.

USE OF ABSORBENT

As previously stated, an important aspect of the invention comprises the use of an absorbent material in my novel barrel finishing systems. Through some of the advantages surrounding the use of absorbents relate specifically to my novel packaged compositions which will be described in detail below, the use of absorbents imparts many advantages in the finishing operation itself.

One important function of the absorbent is to act as a carrier and distributor of the abrasive. Another is to serve as a reservoir for the conversion agent, releasing increments of fresh agent as the charge is agitated during the finishing cycle, thus greatly increasing the quantity of conversion agent that can be added initially and still be utilized with maximum efficiency with a consequent vast increase in average metal removal rate, as has been illustrated in Example 5. A third important function is to provide a means of adjusting, i.e. increasing the viscosity of the slurry-like charge so that a marked improvement in surface finish is attainable without sacrificing metal removal rate. The function of viscosity control is particularly important in barrel finishing soft work. Increased viscosity of the slurry minimizes the tendency of soft work to be damaged by peening, bending and nicking.

Suitable absorbent materials are ground corncobs, ground peanut hulls, bagasse pith, sawdust, ground leather scrap, ground feathers, ground soybean screenings, ground cottonseed hulls, whole or ground rice hulls, dried and ground citrus peel, ground and defatted oilseed meal residue, and the like. In addition to the foregoing organic absorbents, inorganic absorbents such as clays, i.e. bentonite clay; or the absorbent earths such as fuller's earth

10

or diatomaceous earth can be used. The fineness of the absorbent material can vary from 15 mesh to 120 mesh, or finer. The following examples are further illustrative of the advantages attending their use in my process.

Example 16

The tumbling apparatus used in the previous examples was charged with 600 pounds of hard steel bushings of 60 Rockwell (C) hardness, together with four cubic feet of Montello granite two-inch chips. Metaphosphoric acid was added in an amount sufficient to provide eight pounds of H_3PO_4 per 1000 square feet of work surface. As abrasive, a mixture of two pounds of aluminum oxide flour and two pounds of quartz flour was added, and two ounces of petroleum sulfonate was used as wetting agent. In a six hour test period, the average metal removal rate was 3.5 m.s.h.p. For comparison, the run was duplicated in every respect, except that 1 pound of ground corncobs (80 mesh) was added. The average removal rate of metal was 4.3 m.s.h.p., and the honed bushings possessed a brighter finish with excellent R.M.S. (root mean square, micro-inches hill to valley).

Example 17

Example 16 was repeated, using instead, 1000 pounds of steel bushings of 187 Brinell hardness number. The charge containing corncob meal had an average metal removal rate of 7.5 m.s.h.p., whereas that without corncob meal had a rate of metal removal of less than 6.5.

Example 18

This example illustrates the property of the absorbent to act as a reservoir for the surface conversion agent, thus enhancing its activity because fresh increments are continually fed into the system as the particles of absorbent become crushed. The conditions of Examples 16 and 17 were repeated, using one pound of ground corncobs as absorbent. The quantity of H_3PO_4 was increased to 36 pounds per 1000 square feet of work surface. At the end of a six hour test period, the average metal removal rates were 19.5 m.s.h.p. and 15.0 m.s.h.p. for the soft and hard bushings respectively.

Example 19

The procedure of Example 16 was repeated, using bushings of 60 Rockwell (C) hardness, one pound each of aluminum oxide flour, quartz flour, and corncob meal; and four pounds of H_3PO_4 per 1000 square feet of surface of the bushings, and a mixture of 200 pounds each of aluminum oxide and granite chips as hone material. The average rate of metal removal was 6.0 m.s.h.p. When the corn cob meal was omitted, three times as much H_3PO_4 was required to give the same rate of metal removal in a system otherwise identical.

Results substantially identical with the above are obtained when ground cottonseed hulls or bentonite clay is substituted for the ground corncobs of Examples 16 through 19. In the case of absorbent clays or earths, it is preferred to use about 1.5 times as much as in the case of the organic absorbents.

Example 20

Example 16 was repeated, except that the eight pounds of H_3PO_4 was added as sodium dihydrogen phosphate. In the comparison run containing corncobs, the rate of metal removal was increased in the same proportion, and the surface was brighter and better in R.M.S.

PACKAGED COMPOSITION

In one important aspect of my invention, a composition is provided, containing the ingredients necessary for a unit charge of finishing material in the proper proportions so that the composition can be added in a predetermined quantity as a bulk or packaged composition. This is rendered practical particularly by the unique property of the compositions to be substantially equally effective

tive regardless of the hardness characteristics of the work to be finished. Hence, a given charge, characterized preferably by the surface area involved, requires a quantity of my composition that is determinable without regard to the hardness of the work pieces, or for that matter, regardless of the other physical surface characteristics of the work, such as toughness, resistance to abrasion, and the like.

The most convenient form of my composition is in a package suitable for a unit barrel charge. It may be used conveniently in smaller units such as one pound or one half pound packages, and as such is suitable for adding easily varied amounts to the unit barrel charge. Moreover, it offers a great measure of convenience when in bulk form, i.e. in large bags or drums from which it can be added in easily measured quantities, by volume or weight, to the finishing barrels.

In these compositions the conversion agent, abrasive material, other materials as desired, are proportioned in such a fashion that they are always added in the proper amounts to achieve the advantages of my novel finishing process without laborious weighing and measuring of the individual constituents. In these compositions it is advantageous to include the absorbent material as an ingredient where it possesses further practical advantages in addition to those mentioned heretofore. For example, a convenient packaged composition of absorbent and conversion agent can be prepared, with or without abrasive material, antioxidant, wetting agent, or other desired ingredient for use in charging unit loads.

A typical composition is as follows:

One part by weight of concentrated solution of metaphosphoric acid, calculated as H_3PO_4 .

Three parts by weight of ground corncobs, 80 mesh.

One part by weight of silicon carbide, 280 mesh.

The metaphosphoric acid is preferably first mixed with the corncobs and the silicon carbide then added. The mixture is then thoroughly mixed to achieve a homogeneous composition. The product may then be packaged in six-pound packages, as bags or cartons, and used for a normal tumbling load; for example a 900 to 1000 pound load of steel pins or bushings.

Another suitable composition is as follows:

One part by weight of orthophosphoric acid, calculated as H_3PO_4 .

Three parts by weight of ground peanut hulls, 80 mesh.

Two parts by weight of quartz flour, 280 mesh.

The phosphoric acid is mixed with the corncobs or the peanut hulls until a homogeneous free-flowing mixture is obtained. Then the quartz flour or silicon carbide is added, and the entire mixture is mixed vigorously, with sufficient working to embed the abrasive in the particles of absorbent. This method of mixing produces a composition especially advantageous, because the abrasive is fed into the system as the particles of absorbent are mashed or crushed by the tumbling action.

Example 21

A six- or eight-pound package of either of the above two compositions is suitable for barrel finishing a 900 to 1200 pound load of steel pins. With the composition can be charged 400 pounds of a mixture of equal parts by weight of two-inch Montello granite chips and two-inch aluminum oxide chips. The above compositions of conversion agent, absorbent, and abrasive is suitable for rapid finishing to give a product of excellent quality in a finishing period of six hours or less. The surface finish is excellent in R.M.S., and is silvery matte in appearance. Removal of burrs, rounding of edges to desired radii, and removal of scale and soil is rapid and complete.

Example 22

One pound of ammonium dihydrogen phosphate powder, calculated as H_3PO_4 , and three pounds of 80-mesh ground corncobs are mixed carefully to produce a homoge-

neous dry mixture. Two ounces of petroleum sulphonate and one pound of 280-mesh silicon carbide are then added, and the whole further mixed vigorously in a small pug mill until microscopic examination shows that the silicon carbide is largely embedded in the corncob particles. The mixture is then packaged in a suitable package, such as a kraft paper bag, and the bag sealed. The package can be charged to a 32-inch octagon tumbling barrel loaded with 600 pounds of white metal castings, stampings or machined parts. It can also be used with aluminum or aluminum alloy work.

Sodium or calcium dihydrogen phosphate, calculated on the same basis, can be substituted for the ammonium dihydrogen phosphate in the foregoing composition of this example, and the packaged composition used for the same purpose.

In the foregoing novel barrel finishing compositions, the free phosphoric acids have been described in connection with ferrous metals, whereas the water-soluble phosphate salts have been described in connection with non-ferrous metals. It is to be understood that they may also be used vice versa.

The abrasive component of the compositions may be of one particular kind, as illustrated, or it may be a mixture of two or more kinds. The abrasive can be in the range of 100 to 300 mesh or finer. The particular abrasive material and fineness depends somewhat upon the particular finishing problem involved, as is well known in the art. It will depend, for example, upon the rate of metal removal desired and upon the fineness of the final surface finish desired.

Any of the absorbents described in the previous section can be used in the novel compositions. The organic absorbents are preferred, however, in compositions comprising expensive abrasives such as silicon carbide, because of their unique property of efficiently distributing the abrasive.

The proportions of ingredients in the compositions can vary over a considerable range. The conversion agent can vary from two to forty or more pounds per 1000 square feet of work surface. This means approximately 0.3 pound to 6.0 pounds per normal load of 600 to 1000 pounds of work. Higher proportions of conversion agent within this range will afford extremely high rates of metal removal, as previously illustrated in Examples 5 and 18. In the compositions, the proportion of conversion agent, calculated as H_3PO_4 , can vary from 0.1 to 10 parts by weight, the absorbent can vary from 1 to 10 parts by weight, and the abrasive can vary from 1 to 10 parts by weight.

Example 23

One-eighth part by weight of metaphosphoric acid in concentrated solution and calculated on the basis of H_3PO_4 is mixed with one part by weight of corncobs ground to pass through an 80-mesh screen. The two ingredients are thoroughly mixed until a homogeneous free-flowing meal-like product is obtained. To this is added two parts by weight of aluminum oxide (280 mesh) and one part by weight of silicon carbide (280 mesh), and the whole agitated in a beater mixer for a period of about one-half hour, until the grains of abrasive have become embedded into the particles of ground corncobs.

After thorough mixing, the product is a dry appearing meal which is free-flowing and easily poured from the beater. It is bagged in multiwalled paper bags, each bag containing five pounds of product. Each package is suitable for use with a normal tumbling load of 600 to 1000 pounds of steel bushings or pins. In use, a 32-inch octagon tumbling barrel is charged with about 400 pounds of Montello granite in the form of two-inch chips, or other suitable hone material, and the work to be finished. One package of the foregoing composition is then added to the charge, without opening if preferred. Thereupon, sufficient water is added to provide a light slurry in the

barrel, and the barrel is rotated at 25 revolutions per minute.

In a tumbling period of about six hours, using steel pins, the above composition, used as described above, with Montello granite chips as hone material, gave a metal removal rate that averaged 7.5 m.s.h.p. The appearance of the finished pins was excellent, the surface was a silver matte, the R.M.S. was excellent, and all surface imperfections were removed.

I claim:

1. A method of treating metal articles containing surface irregularities comprising removing said irregularities by tumbling said articles in a liquid aqueous medium containing at least four pounds of a phosphoric acid compound selected from the group consisting of a phosphoric acid and a water-soluble acid phosphate per 1000 square feet of surface area of said articles whereby a thin adherent surface film of a friable compound of a metal constituent of said article is formed thereon and is subsequently broken away at points of forceful tumbling contact.

2. The method of claim 1 wherein the metal articles treated are composed of iron as a principal constituent.

3. A method according to claim 1 in which the surface conversion agent is metaphosphoric acid.

4. A method according to claim 1 in which the surface conversion agent is orthophosphoric acid.

5. A method according to claim 1 in which the surface conversion agent is ammonium dihydrogen phosphate.

6. A method according to claim 1 in which the surface conversion agent is sodium dihydrogen phosphate.

7. A method according to claim 1 in which the surface conversion agent is an alkali metal dihydrogen phosphate.

8. A method according to claim 1 in which the surface conversion agent is metaphosphoric acid, and the zone of tumbling agitation contains coarse hone material and finely divided abrasive material.

9. A method according to claim 1 wherein an organic absorbent material is present in the zone of tumbling agitation.

10. A method of treating articles of ferrous metal having surface irregularities comprising tumbling said articles in the presence of a finely divided abrasive material and a coarse hone material, said hone material comprising a mixture of (1) a member selected from the group consisting of a carbide, carbonate and oxide of a metal selected from the group consisting of aluminum, calcium and silicon, said member having a hardness greater than 4.5 on the standard mineralogical scale and (2) a mineral salt of an amphoteric mineral acid having a hardness greater than 4.5 on the standard mineralogical scale.

11. A method according to claim 10 in which the zone of tumbling agitation contains a surface conversion agent selected from the group consisting of a phosphoric acid and a water-soluble phosphate.

12. A method of treating articles of ferrous metal having surface irregularities comprising tumbling said articles in the presence of a finely divided abrasive material and a coarse hone material, said hone material comprising a mixture of granite and aluminum oxide.

13. A method of treating articles of ferrous metal having surface irregularities comprising tumbling said articles in the presence of a finely divided abrasive material and a coarse hone material, said hone material comprising a mixture of granite and quartzite.

14. A method of treating articles of ferrous metal having surface irregularities comprising tumbling said articles in the presence of a finely divided abrasive material and a coarse hone material, said hone material comprising a mixture of granite and silicon carbide.

15. A composition of matter suitable for adding to barrel finishing systems comprising an absorbent material in particle form and a member of the group consisting of a phosphoric acid and a water-soluble phosphate, said absorbent material containing embedded therein a finely divided abrasive material.

16. The method of preparing a composition suitable for use in barrel finishing systems comprising mixing a member of the group consisting of a phosphoric acid and a water-soluble phosphate, particles of an absorbent material, and a finely divided abrasive material, said mixing comprising sufficient mechanical working to embed a substantial proportion of said abrasive into the bodies of said absorbent material.

17. A method of preparing a composition suitable for use in barrel finishing systems comprising absorbing an aqueous solution of a phosphoric acid with particles of ground corn cob material and mixing said absorbed particles with finely divided abrasive material, said mixing comprising sufficient mechanical working to embed a substantial proportion of said abrasive in said absorbent.

18. A composition of matter suitable for adding to barrel finishing systems comprising ground corn cob material and a phosphoric acid, said ground corn cob material containing embedded therein a finely divided abrasive material.

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