Disclosed is a process and apparatus for preparing a substrate having a high coefficient of friction on a surface, and the high friction substrate. A pre-process of sanding can be used, followed by thermal wire coating of the sanded surface. The surface can have a static and dynamic coefficient of friction greater than or equal to 0.85.
1102: Provide substrate having a surface

1104: Sand surface of a substrate

1106: Coat the sanded surface using a thermal wire coating
30 Degree minimum Angularity of machined cut

.003 Minimum Machined Grooved Depth

Substrate any thickness

Figure 21D
Prior Art
PROCESS AND DEVICE FOR SUBSTRATE WITH INCREASED SLIP RESISTANCE

INTEGRATION BY REFERENCE TO ANY PRIORITY APPLICATIONS

[0001] Any and all applications for which a foreign or domestic priority claim is identified in the Application Data Sheet as filed with the present application are hereby incorporated by reference under 37 CFR 1.57.

BACKGROUND

[0002] The present disclosure is generally related to a process increasing slip resistance on a substrate.

SUMMARY

[0003] Embodiments of a spray device are disclosed for increasing the coefficient of friction of a substrate can comprise at least one pair of spray tips configured to melt a metallic material, at least one sander configured to irregularly sand a surface of a substrate, and a spray gun configured to spray the metallic material onto a sanded surface of the substrate, wherein the spray device is configured to deposit the metallic material onto the surface of the substrate so that the surface has a static coefficient of friction greater than or equal to about 0.85.

[0004] In some embodiments, the sander can be configured to move in the X-Y-Z axes. In some embodiments, the substrate surface can have a static coefficient of friction greater than or equal to about 0.90, 0.95, or 1.0.

[0005] Embodiments of a method of treating a surface for increasing friction are disclosed and can comprise providing a substrate with a sanded surface, sanding the surface of the substrate, and depositing a material on the surface of the substrate through electronic arc spraying, wherein the surface of the substrate has a static coefficient of friction after depositing the material of greater than or equal to about 0.85, 0.90, 0.95, or 1.0.

[0006] In some embodiments, the surface of the substrate can have a dynamic coefficient of friction after depositing the metallic material of greater than or equal to about 1.0. In some embodiments, the method can be further comprise depositing an additional layer on top of the material. In some embodiments, the additional layer can comprise zinc. In some embodiments, the additional layer can comprise zinc from a galvanization process.

[0007] Embodiments of a product having slip-resistant coating are disclosed and can comprise a substrate having at least one surface, wherein the surfave is sanded and configured to promote adhesion to a metallic spray, and a coating of metallic spray deposited directly onto the sanded surface, wherein the coating is configured to adhere to the sanded surface of the substrate, wherein the surface and coating combination has a static coefficient of friction greater than or equal to about 0.85.

[0008] In some embodiments, the surface and coating combination can have a static coefficient of friction greater than or equal to about 0.90. In some embodiments, the surface and coating combination can have a static coefficient of friction greater than or equal to about 0.95. In some embodiments, the surface and coating combination can have a static coefficient of friction greater than or equal to about 1.0. In some embodiments, the surface and coating combination can have a static coefficient of friction greater than or equal to about 1.04.

[0009] In some embodiments, the product can comprise an additional layer on top of the coating. In some embodiments, the additional layer can comprise paint. In some embodiments, the additional layer can comprise paint. In some embodiments, the additional layer can comprise zinc from a galvanization process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 illustrates an embodiment of a vault manufactured through embodiments of the described process.

[0011] FIG. 2 illustrates example layouts for use in embodiments of the described process.

[0012] FIG. 3A-F illustrate embodiments of a sanding machine used in embodiments of the disclosed process.

[0013] FIG. 4 illustrates a component of an embodiment of a metallic spray process.

[0014] FIG. 5 illustrates an embodiment of an electric arc spray system.

[0015] FIG. 6 illustrates an embodiment of a spray gun.

[0016] FIG. 7 illustrates an example of an unguarded embodiment of a spray gun.

[0017] FIG. 8 illustrates different embodiments of an air cap.


[0019] FIGS. 10A-B illustrate embodiments of a thermal spraying machine.

[0020] FIG. 11 illustrates an embodiment of the disclosed process.

[0021] FIG. 12A-F illustrate steel being put through embodiments of the disclosed process.

[0022] FIGS. 13A-C illustrate aluminum being put through embodiments of the disclosed process.

[0023] FIGS. 14A-D illustrate a substrate after embodiments of the disclosed sanding pre-process.

[0024] FIGS. 15A-B illustrate a steel sample before being put through embodiments of the disclosed process at different magnifications.

[0025] FIG. 16 illustrates a steel sample after a sanding treatment according to an embodiment of the disclosed process at 100x magnification.

[0026] FIGS. 17A-C illustrate a steel sample after thermal spray coating according to embodiments of the disclosed process.

[0027] FIGS. 18A-B illustrate an aluminum sample before being put through embodiments of the disclosed process at different magnifications.

[0028] FIGS. 19A-B illustrates an aluminum sample after a sanding treatment according to embodiments of the disclosed process at 100x magnification.

[0029] FIGS. 20A-C illustrate an aluminum sample after thermal spray coating according to embodiments of the disclosed process.


DETAILED DESCRIPTION

[0031] Surfaces can be manufactured with an increased coefficient of friction, which can allow them to be used as a surface in which people or vehicles can travel over. One
process for increasing surface friction coefficient can be through the use of thermal wire coating by an electric arc spray device. However, the pre-treatment of the surface can have a significant impact on the adhesion of the thermal wire coating, and thus on the surface friction coefficient. For example, the adhesion between the base metal and the deposited metallic spray as a result of thermal wire coating is sometimes less than satisfactory, resulting in a lower static coefficient of friction and, in some cases, delamination. This can lead to reduced slip-resistant, and thus injury or property damage.

[0032] One previous method for surface preparation involves blasting the surface with an abrasive media (such as garnet) to roughen the surface. The problem with this method is that it is can result in fairly rounded impressions in the material (on a microscopic level) that do not allow the coating to interlock to the surface. Consequently, the bonding is weak between the surface material and the thermal spray, and the finished material is prone to delaminating of the coating. This method also induces stresses into a single (upper) surface, resulting in excessive bowing and flatness problems. Grit blasting also tends to leave behind a fine dust that needs to be cleaned (removed) to allow proper adhesion of the spray coating, which increases the time needed to produce the coated surface.

[0033] Another method involves machining with a milling machine or router, such as described in U.S. Pat. App. Pub. 2009/0197045, hereby incorporated by reference in its entirety. However, this method can cause rapid failure of the cutting tools without the use of coolants, or additional cleaning if coolants are used. Further, the machining process has limited tolerance for plate irregularities and flatness issues, and the cutting tools often break when crossing cutouts or openings in the plate. Machining is also limited to flat parts. Further, the use of a milling machine or a router produces predictable consistent set patterns of grooves, in generally circular patterns. FIGS. 21A-E illustrate the set groove patterns that are created by U.S. Pat. App. Pub. 2009/0197045. These predictable consistent set patterns lead to less adhesion of thermal spray than the below described embodiments of the method achieve. In addition, this method is a milling process done with a cutting fluid. The cutting fluid forms a film barrier on the surface of a substrate, which can cause adhesion issues depending on the amount of fluid. Thermal metal spray does not adequately adhere to this type of surface, plus it creates herring bone patterns, which are not aesthetically pleasing.

[0034] Accordingly, described herein is a process using a pre-processing technique for a surface followed by the application of thermally sprayed wire coatings to add slip-resistant characteristics to various fabricated products, such as fabricated metal products. Further, embodiments of the described process can provide a highly wear-resistant surface. In some embodiments, the substrate can be pre-processed before thermal spraying by first sanding the substrate to promote adhesion of the thermal spray to the substrate, thus eliminating the adhesion issues that are common in the prior art.

[0035] After the sanding pre-process, the substrate can be sprayed with a thermal wire coating so that the thermal wire coating adheres to the substrate. The spraying can strongly adhere to the sanded substrate in order to achieve a high coefficient of friction on the surface. The disclosed sanding pre-processing can provide superior coating adhesion as compared to other preparation methods, and can therefore produce a final product with a high coefficient of friction. Further, in some embodiments of the disclosed process, coating adhesion can be greatly improved, and thus scrap rates can be lowered.

[0036] Embodiments of the disclosed process can be used to reduce slipping hazards on, for example, flooring, latches, vaults, ladders, stairways, utility covers, catwalks, and other products/substrates exposed to pedestrian or vehicular traffic. Embodiments of the disclosed process can also be used on walls, ceilings, or other places, and the location does not limit the disclosure. In some embodiments, thermal spraying, such as wire arc spraying, can be used to produce a slip resistant surface. Wire arc spray is a form of thermal spraying where two consumable metal wires (e.g., feedstock) are fed independently into a spray gun. In some embodiments, non-metal wires can be used. These wires can then be charged, and an arc and/or plasma can be generated between them. The arc and/or plasma can be created through electrical or chemical means, and the creation method does not limit the disclosure. The heat from this arc can melt the incoming wire, which can then be entrained in an air jet from the spray gun. This entrained molten metal can then be deposited in a substrate, such as by spraying, where the molten metal can solidify and be mechanically bound to the substrate. The resulting surface of the substrate that is receiving the deposited metallic spray has very high co-efficient of friction values. Depending on the surface of the substrate, the thermal spraying may adhere to the substrate in a better or worse fashion. Further, depending on the surface of the substrate, the adhesion of the metal spray to the substrate can be inconsistent.

[0037] In some embodiments, the surface of the substrate can be galvanized after thermal spraying, which can allow for greater adhesion of the thermal spray coating. During the galvanization process, a protective layer, typically zinc, is coated on a substrate material. Often, the substrate material is steel or iron. The galvanization process can be used to prevent rusting. There are numerous methods for galvanizing a material, such as electrochemical and electrodeposition, as well as hot-dip galvanization, and the method of galvanization does not limit the disclosure. In some embodiments, the galvanization process may increase adhesion of the thermal spray coating due to the heat generated in the galvanizing process.

[0039] FIG. 1 illustrates an embodiment of a typical installation of a vault which can be used with embodiments of the disclosed process, although other products can be used as well. In some embodiments, a vault 100 can be located below the ground, and a top surface 102 can be exposed above the ground, as shown in FIG. 1. In some embodiments, the top surface 102 can be flush with the rest of the ground 104 surrounding the vault 100. In some embodiments, the top surface 102 can be raised or lowered from the ground 104. People, animals, and vehicles, for example, can come into contact with the top surface 102 of the vault 100 by walking or driving across the top surface 102.

[0040] In some embodiments, the vaults can be manufactured from aluminum, though other types of metals, such as, for example, steel, can be used and the type of metal does not limit the disclosure. If an untreated metal vault top surface 102 was used, people, animals, or vehicles could slip when they come in contact with the top surface 102 of the vault 100, which can lead to injury or property damage. Therefore, it can be advantageous to have a top surface 102 that has a higher coefficient of friction, which can prevent slippage. Using
embodiments of the disclosed process, the surface 102 can have a coefficient of friction of about 0.85, 0.90, 0.95, or 1.0, or greater than about 0.85, 0.90, 0.95, or 1.0, both for static and dynamic friction.

[0041] While above is disclosed a vault that uses an embodiment of the disclosed process to increase slip resistance, the disclosure is not so limited and embodiments of the disclosed process can be used for treating any number of surfaces.

Slip Resistant Processing

[0042] Sanding Pre-Process

[0043] FIG. 11 illustrates an embodiment of the disclosed process. First, a substrate having a surface can be provided 1102. Where the coefficient of friction of the surface is increased. The surface of the substrate can be sanded 1104, as described below, to promote and increase adhesion of a thermal wire coating to the surface of the substrate. The sanded surface can then be coated using a thermal wire coating 1106, or other coating method, where the coating can adhere strongly to the surface of the substrate via the sanding, allowing for a higher coefficient of friction such as, for example, static and dynamic coefficients of friction of greater than about 0.85, 0.90, 0.95, or 1.0.

[0044] In some embodiments, a substrate can undergo different processing techniques to improve the friction coefficient, and thus the slip resistance, of the substrate. For example, the substrate can be sanded prior to thermal spray, which can provide for enhanced adhesion of the spray to the substrate. Disclosed below are embodiments of a sanding pre-process.

[0045] FIG. 2 illustrates embodiments of a sanding machine that can be used in the disclosed process. These sanding machines can be, for example, grinders 202, which are large industrial sanding machines as shown in FIG. 2, although other types of sanders can be used and the type of sander does not limit the disclosure. For example, in some embodiments a wide belt sanding machine, or other sanding implement such as, for example, a smaller handheld belt and rotating sander can be used. Further, the sanding machines can have a coarse grit, such as 24 or 36 grit, though the grit size is not limiting.

[0046] The finished surface using embodiments of the disclosed process can have different surface roughness. For example, the surface can have a fine texture that approximates 80 to 100 grit sandpaper, with an average particle size of about 0.010" to about 0.015". The fine texture can be used where falling on the rougher surface could likely lead to injury. The finished surface could also have a medium roughness, which can approximate a 36 grit sandpaper, with an average particle size of about 0.020" to about 0.030". The finished surface could also have a coarse roughness with an average particle size from about 0.030" to about 0.040". However, other finishes and textures can be used, and are not limiting.

[0047] FIGS. 3A-F illustrate further examples of an embodiment of a sanding machine that can be used in embodiments of the described process. FIG. 3A shows an outer view of an embodiment of a sanding machine 300. FIG. 3B illustrates the internal sanding mechanisms of embodiments of a sanding machine 300. As further shown in FIG. 3C in some embodiments the sanding machine 300 can include a plurality of sanding heads 302. For example, the sanding machine 300 can have 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 sanding heads, and the number of heads is not limiting. Further, the sanding machine 300 can have the heads 302 be height adjustable, which can allow for control in the Z direction. Therefore, the sanding machine 300 can be used to sand substrates that vary in thickness across the substrate, unlike, for example, a mill or router, thus providing advantageous over the methods used in the prior art. FIG. 3D illustrates embodiments in which the heads 302 can also track in the Y direction, shown by the arrows. This allows for the sanding heads 302 to have further defined direction control. In some embodiments, the sanding machine 300 can have a sanding table 304 to place a piece that will be sanded by the heads 302. FIG. 3E illustrates embodiments of the sanding machine 300 where the sanding table 304 can be located on a truck. This track allows the table 304 to be moved in the X direction.

[0048] Accordingly, the sanding machine 300 can move a piece to be sanding in all three dimensions to allow for optimized sanding prior to thermal spraying. Further, the three dimensional motion allows for sanding of irregularly shaped, or non-flat, parts. In some embodiments, the sanding machine 300 can use a rubber contact roller to press the belt against the substrate/part, ensuring some compliance with any surface irregularities or minor flatness issues, which is a problem with machining type surface preparation such as on a milling machine or router.

[0049] FIG. 3F illustrates an embodiment of the sanding machine 300 having further components. For example, the sanding machine 300 can have a load table 306 located proximate to the sanding table 304. By having the dual tables 304/306, allows for improved ease of sanding multiple pieces.

[0050] In some embodiments, the sanding pre-process step can be used to roughen the base substrate. This roughened surface can provide for a greater surface area for the adhesion of the thermal spray coating. In some embodiments, the disclosed sanding process can produce a linear “grained” finish on the substrate. In some embodiments, the sanding pre-process can be used to produce relatively non-consistent, or non-repeating, or non-ordered, or non-periodic, or non-regular, or irregular, or random, or unsystematic, or indiscriminate patterns on the surface of the substrate. Therefore, no specific pattern may emerge on the surface of the substrate. In some embodiments, no repeating pattern may be seen in any 10 mm×10 mm area, or any 100 mm×100 mm area, or any 1 mm by 1 mm area, or any 10 mm×10 mm area, or any 100 mm×100 mm area of the substrate. This is a significant, and advantageous, difference as compared to the prior art process, which produce patterns as shown in FIG. 21A-C. As the spray of the thermal metal tends to be relatively random as well, the sprayed material can more easily attach to the surface of the substrate that also has a generally random sanded pattern. Therefore, the sanding pre-process could increase the overall adhesion as compared to, for example, pre-processing that produces a set or repeating pattern such as those in 2009/0197045, thereby improving the coefficient of friction and slip resistance. Further, the sanding process can produce a generally non-rounded pattern on the substrate, which can improve adhesion with the thermal wire coating. In addition, the disclosed sanding process can also remove any mill scale or other contaminants that would interfere with the bond of the thermal wire coating. In some embodiments, the entire surface of the substrate is sanded, while in other embodiments only parts of the substrate are sanded.
[0051] Thermal Spray Process

[0052] After the sanding pre-process, the sanded substrate can then be thermal sprayed. The thermal spray can adhere to the sanded substrate, thus providing for increased slip resistance on the substrate.

[0053] FIG. 4 illustrates an embodiment of components for a metallic arc spray machine 400 for producing a thermal wire coating. In some embodiments, the arc spray machine can have a power source 402, a wire feeder 404, and a spray gun 406. In some embodiments, the power source 402 can convert input power, and can output DC power. The power source 402 can be used at 27.5 V and 220 A; however other parameters can be used, and the parameters do not limit the disclosure. For example, 12, 15, 20, 25, 30, 35, 40, 45, or 50 volts and 100, 150, 200, 250, 300, 350 or 400 amps can be used. The power source 402 can have an output that varies due to input variation from an agency. In some embodiments, the voltage can be adjusted during peak demand cycles. The wire feeder 404 can have a wire straighter in some embodiments, and can have an adjustable power feed. In some embodiments, the feed rate of the wire into the wire feeder 404 can be about 50 ft./min. However, this rate is not limiting and other rates such as, for example, 10, 20, 30, 40, 60, 70, 80, 90, or 100 ft./min. could be used. The feed rate can vary based on the settings of the power source 402 and the distance from the spray gun 406 to the material to be sprayed. Further, in some embodiments the wire feeder 404 can have air pressure adjustment which can vary based on spray gun 406 distance and type of wire.

The spray gun 406 can guide the wire from the wire feeder 404, and in some embodiments can have an adjustable spray. The spray pattern of the spray gun 406 can be adjustable through, for example, an air cap on the spray gun 406. The spray gun 406 can experience significant operator interaction for cleaning and wire breaking. FIG. 5 illustrates an embodiment of an electric arc spray system.

[0054] FIG. 6 illustrates an embodiment of a spray gun for spraying molten wires onto a substrate, or a thermal wire coating. Spray gun 600 can be made from numerous different pieces, none of which are limited to this disclosure. In some embodiments, the gun 600 can have a center base gunhead 602. An air connector 604 supported by shielded air connector tugging 612 can send pressurized air into the gunhead 602. At the other end of the gunhead 602, there can be a wire guides 606 and a wire guide retainer 608. Further, located at the far end past the wire guide retainer 608 can be an air cap 610, which can control spray patterns. In some embodiments, a guard can be used for a spray gun 600, and in some embodiments a guard may not be used. An example of an unguarded spray gun is shown in FIG. 7.

[0055] FIG. 8 illustrates different embodiments of an air cap 610. The air cap 610 may have shields, or may not have shields. Further, the air cap 610 may be configured for high velocity, with or without a shield. In some embodiment, the air cap 610 may have a spray lock for controlling spray of material.

[0056] FIGS. 9A-C illustrate embodiments of operation control variables for thermal spraying of a substrate, or other variables can be used as well. FIG. 9A illustrates embodiments of spray width “A” and spray travel “B” of a spray gun. The spray width can be adjustable and can increase or decrease in size. In some embodiments, the air cap or the air pressure can control the spray width. Further, the spray travel speed can be adjustable. This can be caused by the distance the spray gun is from a part, the deposit transfer efficiency, or the head travel speed. FIG. 9B illustrates an offset control “C” that can be used in some embodiments. In some embodiments, the material deposit can be crowned. In some embodiments, the offset width can be a function of spray width, travel speed, air pressure, air cap, wire type, voltage, amperage, and wire feed rate. FIG. 9C illustrates an example of a resultant deposition in embodiments of spraying. The travel pattern ends up in a relatively S shape, with some overlap based on path. However, other travel patterns can be used and the travel pattern is not limiting. Further, the deposition can have a rate of approximately 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 min./sq. ft., although this rate is not limiting. In some embodiments, the deposition rate is about 7.27 min./sq. ft. While the travel pattern itself may be generally precise, due to the nature of the thermal spray apparatus, a relatively random spray may likely still occur. Accordingly, the randomized sanding process disclosed above can be advantageous in increasing the adhesion between the spray and a substrate.

[0057] FIGS. 10A-B illustrate embodiments of a thermal spraying machine 1000, though other types of thermal spraying machines can be used as well, and the type does not limit the disclosure. The machine can have X axis and Y axis travel controls 1002, and the machine 1000 can move a substrate in the Y axis with table controls 1004, so all three dimensions can be used. In some embodiments, only two dimensions can be used. In some embodiments, only one dimension can be used. Further, the machine 1000 can have a wire storage and changing platform 1006, and an air collection system 1008. An air collection system can be in front of a spray head, in rear of a spray head, or both. FIG. 10B illustrates another view of an embodiment of a thermal spraying machine 1000. As shown, the machine can use a wire feed 1010 which passes the wires into a spray gun 1012 for thermal spraying. The machine 1000 can also have a twin table 1014 for moving any substrate pieces, and a power source 1016.

[0058] For embodiments of the disclosed process, different thermal spray materials can be used. For example, these sprays can be iron, nickel, copper, or aluminum based. However, the type of spray is not limiting.

Materials

[0059] As described above, different materials can be used in the disclosed process. For example, steel pieces may be put through embodiments of the disclosed process. FIGS. 12A-F illustrates steel before and after certain embodiments of processes described above. FIG. 12A shows a steel plate prior to any sanding procedure. FIG. 12B shows a steel plate after sanding, but prior to any spray processing. FIGS. 12C-F show the steel after spray processing, including for galvanized and painted steel. FIGS. 12C-D show bare steel after the spray processing. FIG. 12E shows painted steel after the spray processing. FIG. 12F shows galvanized steel after the spray processing.

[0060] Steels that can be used in the above described process include ASTM A36 carbon steel plates, bars, structural shapes, and threaded rods, ASTM A500 Grade B carbon steel HSS rectangles and rounds, ASTM A529 carbon steel plates, bars, and structural shapes, ASTM A572 high strength low alloy steel plates, bars, and structural shapes, ASTM A618 high strength low alloy steel HSS rectangles and rounds, ASTM A656 high strength low alloy steel plates, ASTM A913 high strength low alloy steel structural shapes, ASTM A982 high strength low alloy steel structural shapes, ASTM A514 quenched and tempered alloy steel plates, ASTM A852
quenched and tempered low alloy steel plates, or ASTM A786 steel floor plate meeting the strength requirements of ASTM A36, ASTM A572, and ASTM A588. However, the type of steel does not limit the disclosure and other coatings could be used. All of the above ASTM standards are hereby incorporated by reference in their entirety.

[0061] FIGS. 13A-C illustrate the above described process using aluminum. FIG. 13A illustrates the aluminum prior to any sanding, FIG. 13B illustrates the aluminum after sanding, and FIG. 13C illustrates the aluminum after spray processing.

[0062] Aluminum that can be used in the above described process include ASTM B208 aluminum and aluminum alloy sheet and plate, ANSI 6061 aluminum and aluminum alloy extrusions, ASTM B211 aluminum and aluminum alloy extruded bar, rod, and wire, ASTM B221 aluminum and aluminum alloy extruded bars, rods, wire, profiles, and tubes, ASTM B429 aluminum and aluminum alloy extruded tube, and ASTM B928 high magnesium aluminum alloy sheet and plate. However, the type of aluminum does not limit the disclosure and other aluminum could be used. All of the above ANSI and ASTM standards are hereby incorporated by reference in their entirety.

[0063] For both steel and aluminum, as well as other substrates, the above process can be applied to finished products or raw products that are further processed, such as welding, shearing, or forming. In some embodiments, the finished product can have a hot-dip galvanized finish per ASTM A123, hereby incorporated by reference in its entirety. In some embodiments, the final products can be left raw. In some embodiments, the products can be painted with, for example, water or oil based paints or epoxies.

[0064] FIGS. 14A-D illustrate a substrate after embodiments of the disclosed sanding pre-process. FIGS. 14A-B illustrate an embodiment of a surface finish after using embodiments of the described sanding pre-process using 80 grit sand paper in a grainer. FIG. 14C illustrates an embodiment of a surface finish after using embodiments of the described sanding pre-process using a hand sander with 80 grit sand paper. FIG. 14D illustrates an embodiment of a surface finish after using embodiments of the described sanding pre-process using a circular sander with 80 grit sand paper. Other types of sanders can be used as well, and this list is not limiting.

[0065] As shown, different types of patterns can be formed through the use of different types of sanders, which may help increase adherence of the wire coating. For example, the grainer can create relatively linear roughness lines, as shown in FIGS. 14A-B. These roughness lines can be relatively straight, or can have some curves. In some embodiments, relatively random roughness can be created through the use of a hand sander, as shown in FIG. 14C. The application of the sander can vary under a user’s control. Further, generally rounded roughness lines can be created on a substrate using a circular sander, as shown in FIG. 14D. One or more of the above described sanding processes can be used in embodiments of the disclosed process. In addition, a substrate can be sanded multiple times to create different roughness lines. Further, as shown in FIGS. 14A-D, after sanding, mill scale deposits can also be removed, along with any forming oils or other coating substances. By having a finished dry surface with the respective roughness lines, adhesion between the surface and a wire coating can be improved.

Testing

[0066] The definition of static coefficient of friction (SCOF) is well defined in many physics texts as a ratio of the horizontal force required to start a fixed mass moving divided by the mass of the object. This method of testing a surface has been used for years prior to more advanced developments in test methods.

[0067] General performance requirements for vaults are a flat surface static coefficient friction of 0.60 and an incline surface static coefficient of friction of 0.80 according to ASTM C-1028, hereby incorporated by reference in its entirety. Additionally, a vault should have a dynamic coefficient of friction of 0.35 under California Test Method 342, hereby incorporated by reference in its entirety. Further, using an initial abrasion test using ASTM C-418 or ASTM D-2486, the entirety of both which are incorporated by reference in their entirety, the vault should meet the test using a 3.2 lb block, a 10 inch travel, for 1,000 cycles, where the mass reduction is no greater than 0.03%.

[0068] Further, long term abrasion resistance testing could be done under ASTM C-418 or ASTM D-2486, the entirety of which are incorporated by reference in their entirety. The same sample as used in the initial resistance test can be used, but the long term testing has 3,500 cycles. Following, long term slip resistance testing can be performed under ASTM C-1028 for the static coefficient of friction. The same sample as used in the long term abrasion resistance test can be used, and to pass the results should be not less than 90% of the initial slip resistance test.

[0069] Two methods of testing were used in this product review. The American Society of Testing and Materials (ASTM) F-1679 method uses a variable angle tribometer which applies horizontal and vertical forces to the surface at the same time in much the same way an individual walks. This standard was developed and came out of the walkway surfaces group of ASTM. This method is preferred by many who are involved in hazard controls, including HSCSL, as the best method by which to assess the level of hazard presented by any particular surface.

[0070] The ASTM C-1028 method comes out of the ceramics group of ASTM and can under-estimate the hazard presented by a surface particularly in wet testing.

[0071] While both of these methods can provide valid data for slip resistance on dry floor surfaces, drag sled devices are subject to sticktion when testing wet. Since nearly every surface is “slip-resistant” in a dry state, the concern in measurement of slip-resistance is on a wetted surface. Sticktion, which can result in artificially high readings, is the bond that is established between the surfaces and the liquid interface. This force was measured by the drag-sled as it initiates its movement.


[0073] The test instrument for these tests was a variable incidence tribometer (VIT) which was calibrated by the manufacturer on August, 2010 which is valid until August, 2011.

[0074] A calibration tile was used to assure proper response of the VIT. The test tile provided readings that were in-line with prior readings. The test foot material for this test was a Neolite® test foot. Neolite® is specified by most slip-testing standards and offers a standard test material that is homogenous, consistent in its performance over time, and produced to a defined standard.
Prior to each measurement the VIT was inspected and the test foot was checked for freedom of movement. The VIT was then charged. The operating pressure was set to 25 psi.

When conducting testing on a dry surface, the test foot needs to be sanded periodically to prevent polishing of the test foot, which can result in lower readings. Under wet testing the foot does not need to be re-sanded as polishing is not typically observed. The actuation button was depressed for ½ a second while the mast was lowered by ¼ turn each stroke until a slip-event occurred. The measurement was taken at this point.

In 2006, the ASTM withdrew this standard from the books for two reasons. 1) The instrument (English XL) is proprietary and the ASTM has a rule against specifying proprietary instruments in its testing standards. 2) The instrument does not currently have a precision and bias statement in the format required by ASTM. At the same time as ASTM F-1679 being dropped, the F-1677 was also dropped for the same reasons. The fact that these standards were sidled by ASTM policies has no bearing on their merit as testing methods. Both methods are used and favored by individuals in the field of tribometry. These methods are still used to define hazard levels in legal proceedings and by numerous manufacturers to assess their product’s performance. They are also specified by name in the National Fire Protection Association standard on fire apparatus performance criteria.

The ASTM F-13 committee continues to actively work on a generic ASTM standard which would cover all tribometers which are able to effectively rank surfaces from least to most slippery. This standard has been voted in several forms, but has not yet been passed as a final standard, but good progress has been made. A recent vote in early 2011 continues to move closer to a final standard.

ASTM C-1028: Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method

The test foot material for this test was also a NeoLite® test foot. NeoLite® is specified by most ASTM slip-testing standards and offers a standard test material that is homogeneous, consistent in its performance over time, and produced to a defined standard.

A specified calibration tile was cleaned with Hilliard’s Remover on-site and left to air dry. A metal testing sled mounted with a 2" square piece of NeoLite® was sanded several times in each cardinal direction using 400 grit silicon carbide paper with a block backing. Sanding was done in a separate location of the room to avoid dust contamination. The NeoLite® test foot was brushed clean with a brush prior to bringing the test sled into the sample test area.

The test sled was placed on the reference tile and a NIST-traceable 50 lbs. weight was placed on the sled. A Chatillon LB’ peak force gauge (SN 08881) was used to obtain eight readings, two in each cardinal direction. The meter was last calibrated on Mar. 2, 2011 and due for recalibration on Mar. 2, 2012. A correction/calibration factor was determined:

\[ X_d = 0.86 \times \left( \frac{Y}{50 + X} \right) \]

Where \( r \) is each reading, \( s \) is the sled weight and \( n \) is the number of readings.

A second metal test foot was prepared by soaking the foot in distilled water for 5 minutes. This foot was applied to the standard tile and the 50 lbs. weight was placed on the tile. Distilled water was applied to the surface to be tested. Again eight reference readings were taken, two in each cardinal direction. A wet correction/calibration factor was determined:

\[ X_w = 0.51 \times \left( \frac{Y}{50 + X} \right) \]

Where \( r \) is each reading, \( s \) is the sled weight and \( n \) is the number of readings.

The dry test foot was re-sanded and placed on the floor with the weight applied. The peak force gauge was used to take twelve separate readings, four in each cardinal direction.

The wet test was performed in the same way using the test sled which had soaked in distilled water. Results were recorded and results were determined by:

\[ C_OF = \frac{\sum X_{d\\,\times\\,50\\,+\\,X}}{\sum X_{w\\,\times\\,50\\,+\\,X}} \]

Where:

\[ R = \text{the results of the peak forces for the condition measured} \]

\[ N = \text{number of tests} \]

\[ X = \text{correction factors (Xd or Xw)} \]

\[ S = \text{Weight of the Sled} \]

As a test method to assess slip-resistance from a hazard perspective it has severe limitations. Unfortunately, this method often finds its way into specifications and local regulations, because it is a method often cited by manufacturers and producers of materials. This method favors a statement of safety by over-stating the wet slip-resistance. This means that some materials which would not be deemed “safe” by other test methods will be classified as acceptable under C-1028.

The method works rather well of dry surfaces and provides a result which is reasonably accurate when compared to other methods. Any delay between the instant of surface contact and the application of the horizontal force sticktion will occur. This will overstate the result.

In wet testing, the water surface film is squeezed out of the interface between the test foot bottom and the walking surface so that the tendency to slip is greatly reduced.

Results:

Embodiments of substrates formed from the above described process were tested under ASTM F-1679 and ASTM C-1028, hereby incorporated by reference in their entirety and described above, on both steel and aluminum. The threshold of safety is a value of 0.50, and any product exceeding this level is generally considered to be safe.

The results of testing under ASTM F-1679 are shown in Table 1.

<table>
<thead>
<tr>
<th>Material Identification (ASTM F-1679)</th>
<th>Dry</th>
<th>Wet</th>
</tr>
</thead>
<tbody>
<tr>
<td>A36 Steel with Polymet PMET 50</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
</tr>
<tr>
<td>6061 Aluminum with TAFA 01T</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
</tr>
</tbody>
</table>

As shown in the above table, the testing results show that the slip-resistance was off scale for both wet and dry conditions.
surfaces, and over double what is considered safe, illustrating the enhanced slip-resistance properties of the above described process.

The above described process were tested on both steel and aluminum, and the results are shown in Table 2.

### TABLE 2

<table>
<thead>
<tr>
<th>Material Identification (ASTM C-1028)</th>
<th>Dry</th>
<th>Wet</th>
</tr>
</thead>
<tbody>
<tr>
<td>A36 Steel with PMET 50</td>
<td>1.04</td>
<td>1.14</td>
</tr>
<tr>
<td>6061 Aluminum with O1T</td>
<td>1.04</td>
<td>1.06</td>
</tr>
</tbody>
</table>

Table 2 again shows the enhanced slip-resistance of the above described process. Therefore, surfaces formed from embodiments of the above described process provide equally good traction in both wet and dry conditions. Further, the above described process could produce a surface that exceeds all established slip-resistance standards including, but not limited to, ADA, OSHA, and NFPA. The full testing data set is shown in the below tables 3 and 4.

### TABLE 3

<table>
<thead>
<tr>
<th>Steel Treated Slip-Resistant</th>
<th>N</th>
<th>S</th>
<th>E</th>
<th>W</th>
<th>ASTM-1679 Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
</tr>
<tr>
<td>2</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
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<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
</tr>
<tr>
<td>Average</td>
<td>&gt;1.00</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aluminum Treated Slip-Resistant</th>
<th>N</th>
<th>S</th>
<th>E</th>
<th>W</th>
<th>ASTM-1679 Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
</tr>
<tr>
<td>2</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
</tr>
<tr>
<td>3</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
</tr>
<tr>
<td>4</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
<td>&gt;1.00</td>
</tr>
<tr>
<td>Average</td>
<td>&gt;1.00</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 4

<table>
<thead>
<tr>
<th>C-1028 Slip-Testing Jensen Precast Product</th>
<th>Product ID: Steel Treated Slip-Resistant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>N</td>
</tr>
<tr>
<td>Dry</td>
<td>1</td>
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<td>2</td>
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<tr>
<td>Calibration</td>
<td>N</td>
</tr>
<tr>
<td>WET</td>
<td>30.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C-1028 Slip-Testing Jensen Precast Product</th>
<th>Product ID: Aluminum Treated Slip-Resistant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>N</td>
</tr>
<tr>
<td>DRY</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>66.00</td>
</tr>
<tr>
<td>3</td>
<td>65.20</td>
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<tr>
<td>Calibration</td>
<td>N</td>
</tr>
<tr>
<td>WET</td>
<td>26.4</td>
</tr>
</tbody>
</table>

Table 5 shows a comparison of embodiments of the recited process, illustrated as Trax Plate™, as to other processes.
described coating process can operate in the X-Y-Z axis, allowing for the use of the process on non-flat parts.

SEM Analysis

[0100] Embodiments of the above-disclosed method were performed on steel and aluminum samples. These samples were then reviewed and analyzed using a scanning electron microscope (SEM). The SEM was carried out on a Quanta 200i 3D dual beam SEM/FIB system. The samples were first sputter coated with 10 nm of Pd to improve the image resolution by decreasing surface charging of the samples. The beam was accelerated by a 10 kV field with a total beam current of 1.2 nA.

[0101] FIGS. 15A-B illustrate a steel sample before any treatment was done at 100x and 500x magnification. As shown, the surface of the steel sample is generally rough, and has no major identifying characteristics. FIG. 16 illustrates the steel sample after an embodiment of a sanding treatment as disclosed above at 100x magnification. As shown, grit scratch marks can be seen on the surface of the steel. Further, the marks are not evenly spaced, or necessarily parallel, thus the marks are essentially random. Additionally, no residue (be it grit or lubricant) is left on the surface of the steel.

[0102] FIGS. 17A-C illustrate the steel sample after a thermal spray coating at 35x and 100x magnification. The coated surface shown in FIG. 17A is fairly uniform over the entire sample size. There are some distinct topographical features locally. The coating seems to fully cover the surface of the sample.

[0103] FIGS. 18A-B illustrate an aluminum sample before any treatment was done at 35 and 100 magnification. As shown, the sample has some divots, markings, and other dislocations. FIGS. 19A-B illustrate the aluminum sample after an embodiment of a sanding treatment as disclosed above at 100x and 500x magnification. As shown, many of the divots have been removed from the sample. Further, no residue (be it grit or lubricant) is left on the surface of the aluminum.

[0104] FIGS. 20A-C illustrate the aluminum sample after a thermal spray coating at 35x, 100x, and 500x magnification. The coated surface shown in FIG. 20A is fairly uniform over the entire sample size. There are some distinct topographical features locally. The coating seems to fully cover the surface of the sample.

[0105] The method described above provides for a different surface, and thus advantageous coating characteristics, over methods of the prior art. For example, FIGS. 21A-E illustrates a milling method for treating the surface of a substrate of the prior art. As shown, the milling creates repeated circular patterns over the surface of a substrate, which is different than the above disclosed process. Moreover, the milling method requires the use of a lubricant, which can leave a residue on the surface of the substrate. Because there is residue left of the surface of the substrate, a coating, such as from a thermal spray, may not properly adhere.

[0106] From the foregoing description, it will be appreciated that an inventive product and approaches for substrates with increased slip resistance are disclosed. While several components, techniques and aspects have been described with a certain degree of particularity, it is manifest that many changes can be made in the specific designs, constructions and method of operation herein described without departing from the spirit and scope of this disclosure.

[0107] Certain features that are described in this disclosure in the context of separate implementations can also be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation can also be implemented in multiple implementations separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations, one or more features from a claimed combination can, in some cases, be excised from the combination, and the combination may be claimed as any subcombination or variation of any subcombination.

[0108] Moreover, while methods may be depicted in the drawings or described in the specification in a particular order, such methods need not be performed in the particular order shown or in sequential order, and that all methods need not be performed, to achieve desirable results. Other methods that are not depicted or described can be incorporated in the example methods and processes. For example, one or more additional methods can be performed before, after, simultaneously, or between any of the described methods. Further, the methods may be rearranged or reordered in other implementations. Also, the separation of various system components in the implementations described above should not be understood as requiring such separation in all implementations, and it should be understood that the described components and systems can generally be integrated together in a single product or packaged into multiple products. Additionally, other implementations are within the scope of this disclosure.

[0109] Conditional language, such as “can,” “could,” “might,” or “may,” unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include or do not include, certain features, elements, and/or steps. Thus, such conditional language is not generally intended to imply that features, elements, and/or steps are in any way required for one or more embodiments.

[0110] Conjunctive language such as the phrase “at least one of X, Y, and Z,” unless specifically stated otherwise, is otherwise understood with the context as used in general to convey that an item, item, etc., may be either X, Y, or Z. Thus, such conjunctive language is not generally intended to imply that certain embodiments require the presence of at least one of X, at least one of Y, and at least one of Z.

[0111] Language of degree used herein, such as the terms “approximately,” “about,” “generally,” and “substantially” as used herein represent a value, amount, or characteristic close to the stated value, amount, or characteristic that still performs a desired function or achieves a desired result. For example, the terms “approximately,” “about,” “generally,” and “substantially” may refer to an amount that is within less than or equal to 10% of, within less than or equal to 5% of, within less than or equal to 1% of, within less than or equal to 0.1% of, and within less than or equal to 0.01% of the stated amount.

[0112] Some embodiments have been described in connection with the accompanying drawings. The figures are drawn to scale, but such scale should not be limiting, since dimensions and proportions other than what are shown are contemplated and are within the scope of the disclosed inventions. Distances, angles, etc. are merely illustrative and do not necessarily bear an exact relationship to actual dimensions and layout of the devices illustrated. Components can be added, removed, and/or rearranged. Further, the disclosure herein of
any particular feature, aspect, method, property, characteristic, quality, attribute, element, or the like in connection with various embodiments can be used in all other embodiments set forth herein. Additionally, it will be recognized that any methods described herein may be practiced using any device suitable for performing the recited steps.

While a number of embodiments and variations thereof have been described in detail, other modifications and methods of using the same will be apparent to those of skill in the art. Accordingly, it should be understood that various applications, modifications, materials, and substitutions can be made of equivalents without departing from the unique and inventive disclosure herein or the scope of the claims.

What is claimed is:

1. A system for increasing the coefficient of friction of a substrate comprising:
   at least one pair of spray tips configured to melt a metallic material;
   at least one sander configured to generally irregularly sand a surface of a substrate; and
   a spray gun configured to spray the metallic material onto a sanded surface of the substrate;
   wherein the spray device is configured to deposit the metallic material onto the surface of the substrate so that the surface has a static coefficient of friction of greater than or equal to about 0.85;

2. The system of claim 1, wherein the sander and spray gun are configured to move in the X-Y-Z axes.

3. The device of claim 2, wherein the substrate can be non-flat.

4. The system of claim 1, wherein the surface has a static coefficient of friction of greater than or equal to about 0.90.

5. The system of claim 1, wherein the surface has a static coefficient of friction of greater than or equal to about 0.95.

6. The system of claim 1, wherein the surface has a static coefficient of friction of greater than or equal to about 1.0.

7. A method of treating a surface for increasing friction comprising:
   providing a substrate with at least one surface;
   generally irregularly sanding the at least one surface of the substrate; and
   depositing a material on the surface of the substrate through spray coating;
   wherein the surface of the substrate has a coefficient of friction after depositing the material of greater than or equal to about 0.85.

8. The method of claim 7, wherein the surface of the substrate has a static coefficient of friction of greater than or equal to about 0.90.

9. The method of claim 7, wherein the surface of the substrate has a static coefficient of friction of greater than or equal to about 0.95.

10. The method of claim 7, wherein the surface has a static coefficient of friction of greater than or equal to about 1.0.

11. The method of claim 7, wherein the surface of the substrate has a dynamic coefficient of friction after depositing the metallic material of greater than or equal to about 1.0.

12. The method of claim 7, further comprising depositing an additional layer on top of the material.

13. The method of claim 12, wherein the additional layer comprises paint.

14. The method of claim 12, wherein the additional layer comprises zinc from a galvanization process.

15. A product having a slip-resistant coating comprising:
   a substrate having at least one surface, wherein the surface is sanded and configured to promote adhesion to a metallic spray; and
   a coating of metallic spray deposited directly onto the sanded surface, wherein the coating is configured to adhere to the sanded surface of the substrate;
   wherein the surface and coating combination has a static coefficient of friction of greater than or equal to about 0.85.

16. The product of claim 15, wherein the surface and coating combination has a static coefficient of friction of greater than or equal to about 0.90.

17. The product of claim 15, wherein the surface and coating combination has a static coefficient of friction of greater than or equal to about 0.95.

18. The product of claim 15, wherein the surface and coating combination has a static coefficient of friction of greater than or equal to about 1.0.

19. The product of claim 15, wherein the surface and coating combination has a static coefficient of friction of greater than or equal to about 1.04.

20. The product of claim 15, wherein the product comprises an additional layer on top of the coating.

21. The product of claim 20, wherein the additional layer comprises paint.

22. The product of claim 20, wherein the additional layer comprises zinc from a galvanization process.

* * * * *