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COMPLETE SPECIFICATION

Improvements in the Application of Sprayed Metal Coatings to Solid Objects

We, METALLIZING ENGINEERING Co. INC., a Corporation organised and existing under the laws of the State of New Jersey, United States of America, of 38—14, 30th Street, Long Island City, State of New York, United States of America, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to new and useful improvements in the application of sprayed metal coatings to solid objects.

The industrial practice of coating with metal is frequently applied to solid objects by metal spraying. For this purpose the metal to be applied is projected against the surface to be covered in the form of a spray, the particles of which are in a molten or heat plastic condition. As a rule, metal spraying is carried out with the use of flame type metal spray guns, i.e., devices in which the metal is fed to a heating zone from which zone metal particles, at least some of which are molten or in a heat plastic condition, are propelled against the surface to be sprayed. The propulsion may be effected either by centrifugal means or by means of a blast of air or other gas. One of the most widely used forms of spraying device is a metal spray gun utilizing the metal to be sprayed in the form of a rod or wire which is fed by a suitable feed mechanism into a heating zone which is produced by the combustion of a combustible and a combustion supporting gas. Such rod or wire may be a relatively solid rod or wire of such metal, or alternatively it may be composed of particles of such metal bonded together by a suitable binder such as a plastic material. In the latter case the binder is usually of the kind which will volatilize as the result of the applied heat of the spray gun.

Application of sprayed metal is carried out for a variety of purposes, as for example to protect a surface such as a shaft or sleeve surface against corrosion, to provide a coating of the desired ornamental or bearing characteristics or to build up worn sections of parts.

In making spray metal coatings, particularly in the formation or rebuilding of bearings or other working surfaces of machine parts, it is essential that the applied spray metal adheres to the surface to which it is applied with a high degree of bond, for otherwise the applied spray metal may come off. For the purpose of securing the requisite degree of bonding, the surface to which the spray metal is to be applied is as a rule suitably pre-conditioned. In the past such pre-conditioning treatment has been generally of two kinds—roughening and heating. Roughening has been carried out by mechanical roughening and also roughening by the deposition of metal by an electrical fusing procedure.

Mechanical roughening of a metal surface to adapt the same to receive and retain applied spray metal must be of a type involving the formation of a multiple number of closely spaced cavities with peened and splayed edges and interspaces forming a multitude of key ways. In the past, the most common method of procuring such type surfaces has been by sand or grit blasting. Sand or grit blasting, however, is in many cases unsatisfactory and will often not yield a surface capable of bonding applied spray metal with a satisfactory degree of bond. Spray metal has a tendency to shrink and in many cases a sand or grit blasted surface does not provide a sufficient bonding surface to prevent the separation of the applied metal

[*Price 2/8*]

coating from the base particularly under working conditions. Furthermore, many machine parts or the like, due to their configuration, or their structural relation to other parts, are unsuitable for sand or grit blasting. One of the basic disadvantages of the sand or grit blasting procedure is due to the fact that the blasting causes compressive stresses in the blasted surface which frequently results in warpage of the object blasted, particularly where such object has a relatively thin section.

An alternative form of mechanical surface roughening for spray metal bonding purposes is that of machine roughening a surface to be sprayed in a particular manner designed to procure the above mentioned surface characteristics essential for spray metal bonding. This surface roughening method, however, is such that it has the same inherent limitations and drawbacks as the ones involving sand or grit blasting. There is one basic limitation inherent in all of the methods of mechanical roughening hitherto used for rendering metal surfaces capable of satisfactorily bonding applied spray metal. This limitation resides in the fact that these methods are not adaptable to hardened metal articles or surfaces. Thus many hardened parts, for instance, cannot be properly surface-conditioned by mechanical roughening procedures, such as grit or sand blasting or rough machining. Though partly hardened mechanical parts have been prepared by grit or sand blasting, using very hard grit such as aluminum oxide abrasive, nevertheless the bond obtained is usually very unsatisfactory.

Electrical methods of fusing or welding electrode metal to a base metal to produce a roughened surface consisting of the applied electrode metal have been used as a means for pre-conditioning metal surfaces for receiving and bonding applied spray metal. Such methods, however, have had the disadvantage of requiring special expensive electrical transformer equipment and also the further additional limitation that the roughening or preparing of surfaces by these methods is slow and laborious and requires considerable skill on the part of the operator. One of the most important limitations of the electrical methods of surface preparation resides in the fact that a poor bond can be inadvertently produced by an operator because of the fact that poorly deposited electrode metal cannot be readily detected from that which is properly applied. Another limitation of the electrical methods of surface preparation lies in the fact that such methods cause localized heating of the base metal to relatively high temperatures. Such heating frequently causes localized changes in the metal structure of the base which materially reduces the fatigue strength of the base metal. Another disadvantage of the electrical method of fusing or welding electrode metal to a base metal to produce a roughened surface is due to the fact that such electrical method tends to produce tensile stress in the surface of the object treated and such stresses frequently cause warpage, particularly on an object that has a relatively thin section.

The heating method of surface conditioning a metallic base to bond thereto applied spray metal involves the heating of the surface to a relatively high temperature and thereafter spraying the hot surface with metal. This method is not widely used and requires, as a general rule, considerable skill and elaborate equipment and is relatively expensive. Furthermore, in most cases the temperature to which the surface or base must be heated is so high that it tends to warp or otherwise destroy the article to which the metal spray is to be applied. A further limitation in the method of heating to produce bonding resides in the fact that most metals oxidize to an objectionable degree when heated in air. Another limitation inherent in the heating method is the fact that it is not feasible for use on most hardened metal articles as they will soften and thus lose their hardness if they are heated to the temperatures necessary to secure the desired degree of bonding to the spray metal applied thereto.

There is the basic limitation inherent in practically all of the hitherto used conditioning methods for rendering metal surfaces capable of satisfactory bonding applied spray metal. This limitation resides in the fact that all hitherto used conditioning methods materially adversely affect the surface condition of the base to which they are applied and all such methods require a distinct and costly step of pre-conditioning the base surface before the metal spraying operation can be performed.

One object of the invention comprises, *inter alia*, a method for applying spray metal to surfaces of inorganic materials including surfaces of metal and non-metal, and of the latter preferably vitreous surfaces such as glass or ceramic, which method is substantially free from the aforementioned limitations inherent

in hitherto known practices.

Another object of this invention is to provide a method for bonding spray metal to surfaces and, particularly to surfaces of metal and non-metal vitreous surfaces such as glass and other vitreous surfaces including ceramics, which does not materially affect more than a thin skin of the surface to which the spray metal is applied.

A further object of the invention is the novel spray metal coated articles in which the spray metal adheres to the base surface in a novel manner and with a high degree of bond.

The objects of the invention will become apparent from the following description:

The invention is essentially an improvement in the method for applying spray metal to an inorganic non-sprayed surface, particularly such a surface of metal or of non-metal vitreous material, with a high degree of bond, which comprises conditioning such surface for spray metal bonding by spraying by means of a flame type spray gun of the wire-feed kind at least a flash coating of molybdenum directly thereon and thereafter spraying metal onto the thus coated surface.

British Patent Specification No. 588,202 discloses the preparation of electrical laminated contacts. The laminations are asserted to be prepared by the alternate application of an electrically high conductive metal and of a high melting or refractory metallic material. Molybdenum is mentioned among the latter. Reference is also made in this specification to depositing the alternate lamellæ upon each other by using a metal spray gun.

The invention is particularly applicable to surfaces which are usually not adapted to receive and retain applied spray metal with a desired degree of bond, such as for example relatively smooth surfaces. These surfaces need not be conditioned in any other manner, nor need heat treatment be applied.

Within the broad concept of the invention the molybdenum sprayed onto the surface, to be thereafter coated with spray metal, may be applied to any desired thickness. By way of lower limit, a flash coating of the molybdenum suffices, i.e., a relatively thin coating as may be obtained, for instance, by a relatively rapid once-or-twice over application of the molybdenum spraying gun and not necessarily presenting a continuous coating. The more continuous the coating is, however, the better will be the bonding strength with which the subsequently applied spray metal will adhere to the base surface. If only relatively low bonding requirements exist, i.e., as for example when spraying relatively thin coatings of lower melting point metals, a smaller degree of continuity of the flash coating is required than would be necessary if, for instance, a thicker coating of a higher melting point metal is to be applied. In the latter case the higher bonding requirements necessitate a greater continuity of the flash coating. For best results, however, we find it of advantage to apply a substantially continuous flash coating of molybdenum onto the base. Within the preferred embodiment of the invention at least .0005 inches and preferably .002 inches of substantially continuous molybdenum coating is recommended. The upper limit of the molybdenum coating is only dictated by practical and economical considerations. Once a coating thickness of the desired bonding characteristics is applied, any additional thickness will not further substantially improve the bonding characteristics of the molybdenum layer.

The metal spraying is carried out by use of a flame type metal spray gun which uses wire or rod as a source of metal.

The molybdenum that we may use in accordance with our invention may be pure molybdenum or a molybdenum alloy or composition. In the latter case we prefer a relatively high molybdenum content, such as an alloy or composition having 90% or more molybdenum. We may, however, use any alloy of molybdenum having 40% or greater molybdenum content and alloyed with any other metals which are known to alloy with molybdenum.

Whenever the term "molybdenum" is used herein, it is intended to designate thereby substantially pure molybdenum as well as alloys or compositions containing at least 40% molybdenum. When referring to a molybdenum composition we mean thereby a composition containing finely divided metallic molybdenum in combination with other elements or metals and not necessarily alloyed therewith.

The surface of the object to be metal sprayed may be perfectly smooth and no roughening or other conditioning treatment other than cleaning (if necessary) is required. The surface to be sprayed upon with molybdenum should, however, be a clean surface. Cleaning may be accomplished satisfactorily in numerous ways, such as by abrasion, light sand blasting or acid etching. These are

particularly to be used with metals when there is any danger of oxides being present on the surface. If the surface is relatively clean of oxides and is merely to be freed from dirt particles or greasy matter, it may suffice if the same is cleaned with a suitable solvent. Ordinarily after machining metals without the use of a lubricant or coolant, a surface emerges sufficiently clean to be immediately sprayed upon with molybdenum. In the case of glass, the degree of adhesion of the applied spray metal to the base may be further enhanced, if desired, if the glass surface is slightly abraded or frosted as by etching, light grinding. This may be particularly advantageous when spraying onto a relatively cool glass surface to counteract or ameliorate the effects of possible heat shock.

Any metal which is capable of being sprayed may then be sprayed directly onto the molybdenum sprayed surface. The final metal to be sprayed is selected according to its characteristics to meet the requirements of the particular job being done. For example, the journal of a rotating shaft may require a hard, dense metal to operate in a journal bearing. For a case of this sort, a common metal to use would be high carbon steel. The journal would first be sufficiently undercut, such as by machining or grinding, to provide space for the application of the sprayed metal, molybdenum would then be metal sprayed onto the undercut surface of the shaft by means of a flame type spray gun of the wire-feed kind to a thickness of, for instance, .001 inches to .003 inches, and thereafter the high carbon steel would be metal sprayed onto the journal section to a sufficient thickness to permit machining or grinding of the metal sprayed surface to a desired final journal size.

Sometimes it is advantageous to preheat the surface of the object to be sprayed before the spray application of the molybdenum or after such application and prior to the application of the final coating of sprayed metal. In either case, the preheating tends to reduce the stress in the final sprayed-on coating and is carried out at relatively low temperatures (as compared with temperatures required by heat bonding methods). The preheating temperatures need not exceed 300° F. In the case of glass and ceramic objects, mild preheating may sometimes be advantageous to reduce the effect of heat shock on the glass. Heat shock sometimes results, when spraying on glass, at localized points where particles of hot sprayed metal strike the cold glass and cause strains which may subsequently become the focal points of localized fractures.

It is also at times of advantage to provide grooves and ridges or other forms of an irregular contour on the surface of the base to be metal sprayed. Such grooves or other irregular contours have several advantageous functions although they are not a necessary requirement of the bonding procedure set forth in this invention. One of the advantageous functions of grooves or other irregular contours of the base, is the increase in surface area which such contours provide, which results in an increase bond to the sprayed metal due to such increased area of bonding. Another advantageous function of such contours is the beneficial effect on the structure of the sprayed metal layer. Such beneficial effect is due to the folding of the stratification layers of such sprayed metal structure. Sprayed metal structures resulting from spraying onto a surface with an irregular contour are generally stronger due to the folding of stratifications or laminations than the structures resulting from the spraying of the same metal onto a substantially even surface.

One of the primary commercial advantages of this invention resides not only in the cost saving that results from the elimination of the previously required surface preparation step but frequently also in the saving of the spraying of the additional metal necessary to fill the intricacies and other spaces provided by roughening methods of surface preparation and also the saving in the additional time and expense required in machining or grinding the final sprayed metal surface. When roughening methods are used, the rough contours of the base are partially reproduced on the final surface and must be removed by machining or otherwise if an even surface is to result. By the method in accordance with our invention it is possible to apply sprayed metal coatings to smooth surfaces, without the use of excessive heat or the use of roughening methods, and hence reduce the amount of metal spraying required and also the amount of final machining and grinding required on a typical metal sprayed machine element. Prior to this invention, in order to apply sprayed metal coatings to smooth metal surfaces, the smooth metal surfaces had to be roughened or excessive heat applied.

An outstanding advantage of the sprayed metal objects produced in accordance with this invention is the

fact that the sprayed metal coating may be made extremely thin and may be even ground clear through to the base, producing a coating with a feather edge which will still remain securely bonded to the base. With previous methods of surface preparation, particularly methods involving mechanical roughening, such thin coatings, involving feather edges, were not practical due to the failure of the bond at localized areas adjacent to the very thin sections of the sprayed coating.

In accordance with our invention it is possible, not only to select molybdenum or a molybdenum alloy or composition for the first coating applied to the surface of the object, but also to use the same or a different molybdenum or molybdenum alloy or composition for the subsequently applied spray metal coating. In this case the entire coating could be of the same molybdenum or molybdenum alloy. The use of molybdenum for the subsequently applied sprayed metal layer is particularly advantageous for thin coatings such as could be used for restoring worn pressed fit areas of a shaft which is pressed into a hub. In such cases, it is unnecessary to undercut the shaft by machining or grinding in the usual manner since no additional minimum space is required for the sprayed metal. The worn areas are sprayed with molybdenum and thereafter ground to size. This practice produces very thin coatings with feather edges as they approach the ends of the worn area. This cannot be satisfactorily done with previously known methods of spray metal bonding by surface preparation.

When applying the molybdenum by means of a flame type spray gun of the wire-feed kind, we prefer to use a rod or wire of essentially pure molybdenum produced by sintering powdered molybdenum. Such a sintered rod or wire may be sprayed directly in such a metallizing gun but we prefer to mechanically work the sintered material by swaging and/or drawing to produce the final rod or wire.

Although the application of one subsequent metal to the first coating of molybdenum alloy on the object to be metal sprayed has been previously discussed, it is obvious that any number of different metals may be subsequently applied to form as many layers of different kinds of metal as desired.

The following examples are furnished by way of illustration but not of limitation:

EXAMPLE 1.

A carbon steel shaft having a carbon content of .45% is first mounted in a lathe and the area to be built up with sprayed metal is first reduced in diameter by a cutting tool to a diameter such as to leave sufficient space for the desired thickness of the thereafter-to-be-applied sprayed metal coating. In this case the desired coating is to be approximately .030 inches thick and it is desired that the finished sprayed metal coating be flush with the original diameter of the shaft. Therefore the original diameter of the shaft is undercut to .060 inches smaller in diameter than the original throughout the area to be sprayed.

The cutting with the tool in the lathe is done dry without use of lubricant or coolants so as to avoid contamination of the metal surface.

A flash coating, in this case approximately .002 inches thick, of molybdenum is then applied by metal spraying to the undercut surface of the shaft. This coating is applied by a conventional flame type metallizing gun of the wire feed kind, utilizing .091 inches diameter sintered and drawn molybdenum wire. The gun nozzle is held at a distance of about 5 inches from the surface of the shaft. The gun is adjusted so as not to have an excessively oxidizing type flame. During the application of the molybdenum coating, the shaft is rotated in the lathe and the gun is moved so as to cause the spray to rapidly traverse the surface of the shaft in order to apply the desired thickness of molybdenum in about two passes of the spray.

After the molybdenum coating has been applied a sprayed metal coating of an 18—8 type stainless steel is applied. This coating is applied using the same metallizing gun, a $\frac{1}{8}$" diameter wire of stainless steel being utilized in the gun and employing a standard spraying procedure by moving the spraying gun back and forth over the rotating shaft sufficiently rapidly to produce layers of approximately .005 inches thick with each pass of the gun. The gun is held with its nozzle approximately 6 inches distant from the surface of the shaft. The spraying is continued until the coating has been built up to a diameter approximately .015 inches larger than the original shaft diameter.

The sprayed stainless steel coating is ground to the original shaft diameter, utilizing conventional grinding equipment for the purpose.

EXAMPLE 2.

A cold finished mild steel plate approximately 2" × 3" × $\frac{1}{8}$" thick is used. One flat surface of the plate is cleaned with fine emery paper leaving a clean,

substantially smooth surface.

A flash coating, in this case approximately .003 inches thick, of molybdenum is then applied by spraying onto the clean surface of the plate. The spraying is done by the use of a conventional flame type spray gun of the wire feed type and molybdenum wire approximately .091 inches in diameter is used. The coating is applied by moving the gun so as to cause the spray to traverse the plate at a rate to apply the molybdenum coating in about five passes, holding the gun at a distance of approximately 6 inches.

High carbon steel containing approximately .80% carbon is then sprayed onto the sprayed metal surface on the plate using the same metal spray gun and a $\frac{1}{8}$ inch steel wire. The gun is operated in a conventional manner and a coating is applied by moving the gun so as to cause the spray to traverse the work at a rate such as to deposit between about .003 inches and .005 inches steel at a pass. The spraying is continued until a thickness of approximately $\frac{1}{8}$ inch of spray metal coating is obtained on the plate.

EXAMPLE 3.

A plate similar to the one prepared in Example 2 is prepared in the same manner and sprayed with a molybdenum layer in the same manner as set forth in Example 2. After the spraying of the molybdenum layer, a coating of aluminium bronze (approximately 9% aluminium) is applied, using the same metal spray gun and applying it in the same manner as described above in Example 2 for the application of high carbon steel. The aluminium bronze is applied to the same final thickness of approximately $\frac{1}{8}$ inch.

EXAMPLE 4.

As a means of evaluating the bond strength between the applied spray metal coatings and the base, the following test is conducted.

Plates are prepared, as set forth above in Examples 2 and 3. These plates consist of mild steel plates with thin coatings of sprayed molybdenum and coatings approximately $\frac{1}{8}$ inch of high carbon steel and aluminium bronze respectively. One end of each plate is smoothed so as to expose the boundary between the sprayed metal and the base. Pieces of these coatings are removed from the steel plates by placing the sharp point of a chisel at the edge of the ground surface of the plate at the boundary between the sprayed metal coating and the base and driving the chisel. Both the removed pieces of coating and the exposed surface of the base are then examined. The pieces of sprayed high carbon steel show continuous coatings of sprayed molybdenum on the side of the piece adjacent the plate, and the plate to which they were bonded also shows a continuous coating of molybdenum. The pieces of aluminium bronze show no evidence of molybdenum on the surface adjacent the plate, and the plate from which they were removed shows a continuous coating of aluminium bronze covering the sprayed molybdenum coating.

The test shows that the strength of the molybdenum layer in a direction perpendicular to the plate is stronger than the internal strength of the sprayed aluminium bronze in the same direction but weaker than the strength of the sprayed high carbon steel in this direction.

EXAMPLE 5.

The following further shows the strength with which the applied spray metal coating adheres to the base:

A test piece of a cold finished mild steel bar about 1 inch in diameter and about 2 inches long is used. A $\frac{3}{8}$ inch hole is then coaxially drilled through the center of the rod. A cold finished mild steel rod, closely but slidably fitting the bar, is then inserted to project slightly beyond the first end and leaving a handle portion at the second end. The rod is then secured in this position in the axial bore and is ground flush with the first end to a smooth finish. Using the equipment and procedure as for instance outlined in Example 2, a .003 inch application of sprayed molybdenum is made on the ground surface covering the entire first end including the flush end of the rod. The rod is then pulled back, thereby shearing with a relatively sharply defined edge, the coating over the rod end from the coating over the first end of the bar. After removal of any surface burrs the rod is replaced to its original position with the molybdenum surfaces flush with each other. .10% carbon steel is then sprayed, in the manner set forth in Example 2, to a thickness of about $\frac{1}{8}$ inch. The thus prepared test piece is then placed in a testing device in which measurable pull is exerted on the handle portion of the rod and the amount of pull in pounds is observed which is required to break the rod from the applied spray metal. In this case the total pull required divided by the area of the sprayed end of the rod gives the tensile strength in pounds per square inch of the bond between the rod surface and applied spray metal. In this case the bond strength in tension is about 2000 pounds

per square inch. Failure takes place within the molybdenum coating.

The flame type metal spray gun of the wire feed type used in the above described examples is one having a normal capacity for spraying about 10 pounds of a $\frac{1}{8}$ inch .10% carbon steel wire per hour. Guns of different capacity may be used in which case the particular operating conditions are to be adapted to those regulating the normal spraying procedure of the particular equipment used, and if necessary with the additional provision of appropriate safeguards or adjustment to avoid excessive oxidizing conditions.

The molybdenum wire specified in the various preceding examples is a commercial sintered and drawn molybdenum wire conventionally designated as "black oxide finish — no anneal." It is a substantially pure molybdenum wire. Other wires or rods of molybdenum or molybdenum alloys or compositions may be substituted for the specific molybdenum used in the aforedescribed examples with good results. Such are, for instance, molybdenum wire or rods commercially designated as "hydrogen cleaned and annealed" and "chemical plus hydrogen cleaned and annealed" and also such molybdenum alloys or compositions at 50—50 molybdenum-tungsten, 60—40 molybdenum-tungsten, 70-molybdenum 30-iron, and similar wires containing a high percentage of molybdenum.

Particularly strong bonding characteristics are exhibited by the use of the molybdenum coating in conjunction with the alloys of steel, including stainless alloys of steel and also with the alloys of aluminium and of magnesium.

Any number of bases in combination with any number of applied spray metals may be prepared in accordance with the invention. Test pieces of various combinations which were prepared utilizing the equipment and procedures set forth in the preceding examples, showed in each case satisfactory adhesion of the applied spray metal to the base, failure usually occuring by fracture in either the molybdenum or the superimposed spray metal. By way of exemplification, suitable base metals for instance include steels and iron alloys either in the soft or hardened condition, including cast iron, nickel and the various nickel alloys such as those sold under the registered trade marks Monel and Inconel, copper and copper alloys including brass, zinc, lead, tin aluminium and aluminium alloys, magnesium and magnesium alloys, chromium-cobalt- and/or tungsten compositions or alloys. The following are examples of spray metals which may be applied to these bases: aluminium and aluminium alloys, copper and copper alloys, including bronzes and brasses, steel, steel alloys including various carbon steels and also including stainless steel alloys, iron, zinc, lead and lead alloys including babbitt — tin.

During spraying operations it is advisable, as for instance set forth in the examples, to avoid conditions of oxidation during spraying. The reason is that excessive oxidation of the subdivided molybdenum particles will impair the adhesion characteristics of the ultimately applied spray metal coating to the base. Excessive oxidation conditions may be avoided by using a relatively slow wire speed for the molybdenum as it feeds through the gun and by using oxygen as little as possible and still obtain a sufficiently high temperature in the melting zone.

Under certain circumstances, it is recommended and may be desirable to reduce oxidation conditions during the spraying process by spraying in an atmosphere of an inert gas and/or by utilizing an inert gas as the blast conveying gas for the propulsion of the spray metal.

In the application of the invention to metallic surfaces, the same has proven useful for a variety of purposes, particularly in such cases as the repair of cylinder cracks, cracks across valve seats, filling cracks, defects or blow-holes in castings, etc. In addition to the relatively high degree of adhesion between the applied spray metal and the base, the products obtained in accordance with the invention show a relatively high resistance to corrosive influence upon the surface of the base. They are further characterized by relatively high shear strength, i.e., resistance to shearing forces exerted in a direction parallel to the surface direction of the base.

In the application of the invention to non-metal vitreous surfaces and particularly to surfaces of glass and ceramics, the molybdenum is applied in the same manner as specified in the hereinabove enumerated examples, using the same spraying techniques and equipment. The ultimately applied spray metal adheres to the base with a high degree of bond and no surface preparation or pre-treatment other than cleaning is necessary.

The following examples are furnished by way of illustrating the application of the invention to these types of surfaces:

EXAMPLE 6.

The surface of a glass-lined steel tank from which a portion of the glass had been accidently chipped is desired to be

repaired. The crack should be enlarged sufficiently to permit easy application of the metal spray by means of a small portable grinder. The edges of the glass should be ground to a taper and an area surrounding the defect should be ground slightly.

A flash coating of molybdenum just thick enough to completely cover the surface of the defect is applied by metal spraying using the equipment as set forth in the preceding examples. In this case, however, the nozzles is set at a distance of approximately 12 inches away from the glass surface in order to avoid heat-shock to the glass giving rise to an impairment of its strength.

Pure tin is then sprayed onto the molybdenum-coated defective area, using conventional metal spraying equipment and technique to a sufficient thickness to permit of finishing to the original surface contour of the glass tank.

The surface of the tin is then finished by grinding with a portable grinding tool, to as nearly as possible conform to the original contour of the glass-lined tank. If desired, the tin surface may be hand polished, such as by use of a fine abrasive cloth.

EXAMPLE 7.

A glazed ceramic insulator to which it is desired to attach a metal ring may be prepared for soldering by metal spraying as follows: the glazed surface of the porcelain to which it is desired to solder is coated with a thin layer of molybdenum by metal spraying (approximately .002 inches thick) in a manner set forth in the preceding example. Prior to metal spraying the area which is not to be coated, is protected from the metal spray by masking with a suitable mask such as conventional adhesive masking tape.

Thereafter a coating of approximately .005 inches of copper is metal sprayed in the conventional manner, as for instance set forth in the preceding examples, onto the surface covered by the molybdenum. The sprayed copper coating firmly adheres to the porcelain and may then be soldered by using lead-tin solder in the conventional manner.

Magnesium or aluminium alloy can be substituted for the porcelain in the above example, thereby making available for the first time an effective method for the satisfactory soldering to these metals and their alloys.

In the application of the molybdenum spray onto non-metallic surfaces, it is of course understood that the surface to which the spray is to be applied should be one which does not tend to decomposition at the temperature to which the surface sprayed becomes heated.

In the application of the process to vitreous surfaces, adhesion of the applied spray metal to the base is of a high order, tests showing failure to occur in the vitreous material. As set forth in the example, when spraying molybdenum onto vitreous surfaces, it is desirable to spray at a somewhat greater distance from the surface to be sprayed than is normally used when spraying metallic surfaces. This is in order to avoid heat-shock. Alternatively, however, the vitreous surface may be pre-heated and in some cases it may be desirable to resort to a combination of pre-heating and spraying at a greater distance from the base. In all cases, however, the distance should not be so great that the spraying efficiency is interfered with by over-cooling of the propelled metal spray before it reaches the base surfaces to which it is applied.

Another advantageous application of the invention by way of preferred embodiment thereof is the manufacture of thin bearing shells. Thin shells of a hard metal such as steel lined with a still thinner inner coating of a bearing metal are used extensively for bearing bushings to operate with rotating journals of shafts, as in crank shafts in automobiles, air craft engines, and other internal combustion engines. In the past, it has not been practical to apply the bearing metal to such thin shells because the methods of preparation for bonding ~~spraying~~ metal have been destructive to such shells by causing severe warpage. For economically applying sprayed metal to such shells it is necessary that any method of preparation used leave a relatively smooth surface because of the very thin amount of bearing metal applied.

The following example is furnished by way of illustrating the manufacture such thin bearing shells having a sprayed bearing metal thereon.

EXAMPLE 8.

A thin bearing shell for use for the backing of a bearing metal for an air craft engine connecting rod bearing is to be surfaced with a suitable bearing metal. The shell in this case consists of a strip of steel 1" wide and $\frac{1}{16}$" thick which has been formed into the shape of a semi-circle $2\frac{1}{2}$" in diameter. The inner surface of the shell is to be coated with silver with a final thickness after finishing .005 inches.

The clean metal shell is coated with a flash coating of molybdenum by metal spraying just thick enough to completely cover the inner surface. The spraying of the molybdenum in this case is carried out the same as described in connection

with Example 1.

The molybdenum coated inner surface of the shell is then sprayed with silver using the same metal spray gun and .091 inches diameter silver wire to a thickness of .007 inches.

The shell is then machined to a smooth surface about .002 inches of silver being removed to produce the desired finish and diameter.

It is understood that any bearing metal may be applied in accordance with the invention to any relatively thin shell of a relatively hard backing metal. Within the preferred application of this embodiment of our invention the sprayed bearing metal is applied onto a molybdenum sprayed hard metal backing shell not exceeding about ¼" thickness.

It is apparent from the foregoing that the novel spray metal coated article in accordance with the invention thus comprises an article having an inorganic surface, a layer of spray metal and intermediate said inorganic surface and said layer of spray metal, in surface-to-surface bond therewith, a layer of sprayed molybdenum of at least flash coating thickness.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A method for applying spray metal to an inorganic non-sprayed surface with a high degree of bond, characterised in that the surface is conditioned for spray metal bonding by spraying by means of a flame type spray gun of the wire-feed kind at least a flash coating of molybdenum directly thereon and thereafter spraying metal on to the surface thus coated.

2. A method according to claim 1, characterised in that the molybdenum coating is sprayed onto a metal surface, for instance a steel surface or a magnesium or aluminium alloy surface.

3. A method according to claim 1, characterised in that the molybdenum coating is sprayed onto a non-metal vitreous surface for instance a glass or ceramic surface.

4. A method according to any one of claims 1 to 3 inclusive characterised in that the molybdenum is sprayed in a thickness of at least .0005 inches.

5. A method according to any one of claims 1 to 3 inclusive, characterised in that the molybdenum coating is sprayed in a thickness of at least .002 inches.

6. A method according to any of claims 1 to 5, inclusive, characterised in that the molybdenum is pure molybdenum.

7. A spray metal coated article, produced according to any one of claims 1 to 6, inclusive.

Dated the 21st day of September, 1948.

WM. BROOKES & SON,
No. 1, Quality Court, Chancery Lane,
London, W.C.2,
Chartered Patent Agents.

Reference has been directed in pursuance of Section 7, sub-section (4) of the Patents and Designs Acts, 1907 to 1946, to Specification No. 588,202.

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LONDON, W.C.2.

with Example 1.

The molybdenum coated inner surface of the shell is then sprayed with silver using the same metal spray gun and .091 inches diameter silver wire to a thickness of .007 inches.

The shell is then machined to a smooth surface about .002 inches of silver being removed to produce the desired finish and diameter.

It is understood that any bearing metal may be applied in accordance with the invention to any relatively thin shell of a relatively hard backing metal. Within the preferred application of this embodiment of our invention the sprayed bearing metal is applied onto a molybdenum sprayed hard metal backing shell not exceeding about $\frac{1}{8}$" thickness.

It is apparent from the foregoing that the novel spray metal coated article in accordance with the invention thus comprises an article having an inorganic surface, a layer of spray metal and intermediate said inorganic surface and said layer of spray metal, in surface-to-surface bond therewith, a layer of sprayed molybdenum of at least flash coating thickness.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A method for applying spray metal to an inorganic non-sprayed surface with a high degree of bond, characterised in that the surface is conditioned for spray metal bonding by spraying by means of a flame type spray gun of the wire-feed kind at least a flash coating of molybdenum directly thereon and thereafter spraying metal on to the surface thus coated.

2. A method according to claim 1, characterised in that the molybdenum coating is sprayed onto a metal surface, for instance a steel surface or a magnesium or aluminium alloy surface.

3. A method according to claim 1, characterised in that the molybdenum coating is sprayed onto a non-metal vitreous surface for instance a glass or ceramic surface.

4. A method according to any one of claims 1 to 3 inclusive characterised in that the molybdenum is sprayed in a thickness of at least .0005 inches.

5. A method according to any one of claims 1 to 3 inclusive, characterised in that the molybdenum coating is sprayed in a thickness of at least .002 inches.

6. A method according to any of claims 1 to 5, inclusive, characterised in that the molybdenum is pure molybdenum.

7. A spray metal coated article, produced according to any one of claims 1 to 6, inclusive.

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