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METALLIZING WIRE

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8 Claims. (Cl. 29—196.3)

This invention relates to an improved metallizing rod or wire, which will be generically referred to herein and in the claims as a wire of the type used in the metal spraying art for producing sprayed metal coatings on solid objects. This application is a continuation of my co-pending application, Serial No. 609,354, filed September 12, 1956.

In carrying out the process of metal spraying, using a metallizing wire (i.e. a rod or wire), the wire is fed through a metal spray gun. Such guns are well known in the art and comprise a feeding mechanism which feeds the wire into a heating zone, in which it is melted and atomized and from which the atomized metal particles are projected in molten, or at least heat-softened condition, onto the base surface to be coated. Such metal spray guns have a source of heat for the heating zone which is frequently a flame of a combustible and combustion supporting gas mixture, such as a mixture of acetylene and oxygen. Such guns are usually provided with a source of blast gas, such as air, which is fed around the heating flame to aid in the atomization and propulsion of the metal particles. The metallizing wires must have a specific structure and are generally specifically produced for metallizing. In addition to being produced in fixed sizes to fit the available metal spray guns the wires must be specifically uniform in their outer diameter, with only small variations being permissible. Thus the wires should not be over-size by more than two-thousandths of an inch, preferably by more than one-thousandth of an inch at any portion, and should not be under-size by more than four-thousandths of an inch, and preferably by more than three-thousandths of an inch at any portion. If the wires are not produced within these tolerances, the same may not be used satisfactorily for metallizing. Thus, wires which have portions which are over-size beyond the above set forth limits, will jam in the metallizing gun, and wires which are under-size beyond the above set forth limits, will not be sprayed satisfactorily. Additionally, wires should be provided with a lubricant coating, such as a soap-type lubricant.

The requirements of a steel alloy composition of the wire used in a metal spray gun include the following:

(1) The metal must be capable of being economically produced in wire form, i.e., it must be capable of being hot-worked and cold-drawn;

(2) The wire so produced must be efficiently sprayable, i.e., it must not sputter when sprayed and must work uniformly. This last requirement appears to be related to atomization at the tip of the wire;

(3) The spray so produced must consist of uniform fine particles;

(4) The deposit efficiency must be high, i.e., a large percentage of the metal sprayed must be transferred into the deposit which is formed on the base;

(5) The metal deposited must combine low shrinkage with high internal strength and ductility;

(6) It should be possible to modify the metal to controllably produce deposits which have softness for machineability or hardness for wear.

The first requirement above listed is inherent in any alloy steel to be produced in wire form, but the remain-

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ing requirements are peculiar to the metallizing process as distinct from any other use for a specific alloy.

With respect to items 2, 3 and 4 above listed, the sprayability of metal used in a wire spray gun is affected by many factors not well understood. Efficient sprayability includes uniformity of melting of the tip, fineness of metal particles created in the atomization of the molten tip, low oxidation in transit from the melting zone to the surface upon which the deposit is being created, and the ability of each metal particle to adhere at the point where it strikes. This last is apparently the factor which controls the deposit efficiency.

The metallurgical structure of metal sprayed coatings differs considerably from the metallurgical structure of the wire used to produce them. The structure of metal sprayed coatings is not well understood. Such coatings may be likened to sintered coatings to some extent, but metal sprayed coatings, unlike sintered coatings, are not homogeneous in all directions. On the contrary, they have different physical properties when measured parallel to the coated surface and when measured perpendicular to this surface. Metallographic examination of sprayed coatings shows they are made of flattened metal particles which, although irregular, are generally flattened in a direction parallel to the coated surface.

With respect to item 5, above listed, which is related to the adhesion created between the metal sprayed deposit and the base, the factors which govern this adhesion are not well understood. Sprayed metal coatings possess internal stresses which result from the method of production. The metal shrinks upon cooling as it is applied, and builds up shrinkage stresses in the coatings. Each thin layer of particles is applied to a relatively rigid base, consisting either of the original base or the original base and the previously formed coating. For this reason no single thin layer shrinks a measurable amount. The effect of such shrinking is accumulative and as thicker coatings are built up, large stresses develop within the coating as a result of such shrinkage. These stresses are to an extent at least offset by the internal strength of the sprayed deposit. If coatings are built up on a cylindrical surface, such as a shaft, when the stresses exceed the tensile strength of the coating they may cause cracking. Such cracks on a cylindrical surface will be parallel to the axis of the cylinder. On a flat surface these stresses may cause warpage of the sprayed coating in a direction such that the edges tend to lift above the center and away from the base. When spraying metals with high shrinkage, these stresses may cause failure of the bond between the coating and the base, with the result of lifting and separation of the coating at the edges. If the base is not sufficiently rigid to withstand the shrinkage stresses, these stresses may actually cause warpage of the base itself.

The effect of these shrinkage stresses is also offset to an extent at least by the ductility of the metal deposited. In general, sprayed metal coatings are extremely brittle and have small ductility as compared with the original metal in wire form. The difference between the ductility of different sprayed coatings is, however, important. Although the ductility is relatively small, one coating with twice the ductility of another may completely avoid cracking, whereas the other will not.

It is not known what metallurgical properties determine the ductility of sprayed coatings and, in general, such ductility cannot be predicted from the known properties of the metal in wire form from which such coatings are made. In wire form high-carbon steels, particularly when hardened, have less ductility than low-carbon steels. With sprayed metal coatings, however, coatings of high-carbon steel have more ductility, less brittleness and less shrink than low-carbon steels.

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In coatings produced by spraying low-carbon steels, the shrinkage stresses are so great that the coatings may warp and crack. It has, therefore, been the practice wherever possible to use high-carbon steels or steels containing at least 12 to 14% of chromium, even though the coatings produced are so hard as to entail an excessive cost for finishing. Even so doing, however, there is a definite limit to the thickness of the deposit that can be applied by spraying without peeling or cracking due to shrinkage stresses. Particularly on flat surfaces, shrinkage effects may occur when the deposit attains a thickness of $\frac{1}{16}$ of an inch, lifting may occur when the deposit attains a thickness of $\frac{3}{32}$ of an inch, and shrinkage effects are always serious when the deposit attains a thickness of about $\frac{1}{8}$ of an inch. Some high alloy steels, such as the high-chrome stainless steels, are known which have better shrink and ductility characteristics than the high-carbon steels and some of which produce sprayed metal deposits which can be machined with difficulty. Even these, however, do not have as good characteristics as steels which can be made in accordance with this invention.

It is therefore an object of this invention to produce a metallizing wire which can be sprayed in thicker deposits than heretofore possible, while combining all other desirable properties of the spray metal deposit.

It is a further object of this invention to produce a metallizing wire which, when sprayed, will produce a coating which is soft enough to be machineable.

The wire, in accordance with the invention which achieves the above-mentioned objects, has an extremely low carbon content which does not exceed 0.06% maximum; a combined nickel, manganese, chromium and molybdenum content of not less than 8%, with the amount of nickel being at least twice the amount of chromium; and the amount of nickel plus manganese being not less than 4.0%. The amount of manganese should be more than 2.0% up to 2.6%, and the amount of chromium between 1.25 and 1.75%, the amount of nickel between 4.0 and 4.6%, and the amount of molybdenum between 1.20 and 1.60%. The wire alloy may additionally contain sulphur in the amount up to 0.035% and phosphorus in the amount of up to 0.035%. Preferably, however, the sulphur and phosphorus content should not exceed about 0.025%. Silicon is an impurity which should be avoided, but amounts of silicon up to 0.15% are permissible. It is most preferable, however, if the silicon content be kept below 0.1%. The balance of the alloy is iron which may contain such impurities and tramp elements as are sometimes found in alloy steels in the amounts so found.

The alloy metal of which the wire is formed is preferably one which has been de-oxidized with aluminum, i.e., is an aluminum de-oxidized alloy. A residue of the aluminum used as the de-oxidation agent is not required in the alloy but a residue of up to about 1% in the finished alloy may improve its sprayability and as far as is known, amounts up to 3% of residual aluminum have no harmful effect.

The preferred alloy composition of the wire in accordance with the invention has about 0.04% carbon, 0.07% silicon, 2.37% manganese, 0.010% sulphur, 0.013% phosphorus, 1.5% chromium, 4.40% nickel, 1.40% molybdenum, and the balance iron.

As a still further embodiment of this invention, I prefer to apply to the outside of the wire produced in accordance with this invention, a thin copper coating. Such a copper coating may easily be produced by any conventional plating method, such as dipping the wire after cleaning in an aqueous solution containing copper sulphate in accordance with methods well known in the art. When such wire is being finished by the cold drawing process, it is preferable to apply such a coating before the last drawing operation. This copper coating improves the spraying performance when the metallizing wire is sprayed.

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An alloy steel wire in accordance with this invention when sprayed by the ordinary metal spraying process with a metal spray gun produces metal coatings with shrinkage characteristics, brittleness characteristics and ductility characteristics which are superior to those exhibited by metal sprayed coatings produced from high-carbon steel wire, such as 0.80% carbon steel wire. The low shrinkage, low brittleness and high ductility of sprayed metal coatings produced from wire in accordance with this invention are substantially superior to those of normally machineable sprayed metal coatings produced from carbon steel wire, such as the 0.25 carbon steel wire. Sprayed metal coatings produced from wire in accordance with this invention, are readily machineable and have machineability characteristics substantially superior to those coatings produced from the 0.25% carbon steel wire.

Example 1

The wire is sprayed by feeding it through a conventional metal spray gun of the wire feed type, using acetylene and oxygen as its source of heat and air as a blast gas.

The shaft to be sprayed is first roughened on the surface to be coated by grit-blasting, using a conventional grit-blasting machine with an air pressure of approximately 90 lbs. per sq. inch gauge, and angular crushed steel grit of a size of approximately SAE No. G-16 for a sufficient time to thoroughly roughen the surface.

The shaft is then set in a lathe spindle for convenience in rotating it, the metal spray gun lighted, and the coating applied. In this case the metallizing gun is provided with 28 cu. ft. per hr. of acetylene at a pressure of 15 lbs. per sq. inch gauge, 73 cu. ft. per hr. of oxygen at 40 lbs. per sq. inch gauge, and approximately 25 cu. ft. per minute of air at 55 lbs. per sq. inch gauge. The metal wire is fed at a rate of 12 lbs. per hour. The gun is directed at the shaft and its nozzle held at a distance of approximately 7" from the shaft. The shaft is rotated at approximately 75 r.p.m. and the gun fed longitudinally of the shaft at approximately 0.030" per revolution of the shaft. The gun is moved back and forth to direct the spray over the surface to be covered until a coating thickness somewhat in excess of $\frac{1}{2}$ " on a side has been built up.

No auxiliary cooling of the shaft is provided.

With the shaft still mounted in the lathe it is machined in the normal fashion, using a tungsten steel tool bit in the lathe tool holder at a feed of approximately 0.010" per revolution.

The machining is readily accomplished and the machined surface is smooth and has an excellent appearance. The coating does not crack.

A shaft prepared and sprayed in accordance with the above example with 0.25% carbon steel wire would be more difficult to machine causing more tool wear, would not have as smooth a surface, and the machined surface would be darker. Such a coating would probably crack longitudinally of the shaft unless considerable caution were taken by providing auxiliary cooling means, and even if such cooling means were provided, the risk of cracking would still be considerable.

Example 2

A wire in accordance with this invention is provided, the same as in Example 1, and sprayed with the same gun in the same manner, except that in this case it is desired to apply a coating $\frac{1}{4}$ " thick on a surface of a 6" x 6" x $\frac{1}{2}$ " steel plate.

In this case the steel plate is blasted in the same manner with the same steel grit as was the shaft in Example 1.

In this case the gun is held by the operator by hand and moved back and forth until the desired thickness is built up.

After the spraying operation is completed no measur-

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able warpage of the coating or plate exists and the coating is firmly adherent to the plate.

If the coating were sprayed, using a low-carbon steel wire in the same manner as described in Example 2, the coating would probably warp and lift at the edges severing the bond between the sprayed coating and the blasted plate. If the coating did not actually lift at the edges, it would nevertheless pull loose if a load were applied since in the case of the coating produced by carbon steel wire the bond is potentially weakened by the shrink stresses, even in those cases where actual severance of the bond does not occur spontaneously.

The foregoing specific description is for the purpose of illustration and not of limitation and it is therefore my intention that the invention be limited only by the appended claims or their equivalents wherein I have endeavored to claim broadly all inherent novelty.

I claim:

1. A metallizing wire of the following composition:

	Percent
Carbon.....	0.06 maximum.
Silicon.....	0.15 maximum.
Manganese.....	2.0-2.60.
Sulphur.....	0.035 maximum.
Phosphorus.....	0.035 maximum.
Chromium.....	1.25-1.75.
Nickel.....	4.0-4.60.
Molybdenum.....	1.20-1.60.
Aluminum.....	3.0 maximum.
Iron.....	Balance.

2. A wire according to claim 1 carrying a thin coating of copper.

3. A wire according to claim 1 having a total content

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of nickel, manganese, chromium and molybdenum of at least 8%, a total nickel and manganese content of at least 4%, and a nickel content at least twice that of the chromium content.

4. A wire according to claim 1 in which the alloy is an aluminum de-oxidized alloy.

5. A wire according to claim 1 in which the content of silicon and aluminum are each less than 1%.

6. A metallizing wire of the following composition:

	Percent
Carbon.....	0.04
Silicon.....	0.07
Manganese.....	2.37
Sulphur.....	0.010
Phosphorus.....	0.013
Chromium.....	1.50
Nickel.....	4.40
Molybdenum.....	1.40
Iron.....	Balance

7. A wire according to claim 6 carrying a thin coating of copper.

8. A wire according to claim 6 in which the alloy is an aluminum de-oxidized alloy.

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