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SPRAY-COATING PROCESS

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The present invention relates generally to a process of coating a metal surface with a protective metal, and more particularly to an improved process for continuously spray-coating a ferrous metal base with a thin, firmly adherent film of a protective metal, such as aluminum, copper, tin, zinc, or a protective alloy coating.

In a conventional metal spraying process in which globules of molten metal are projected onto a relatively cold base metal surface by a carrier gas, the metal globules solidify on striking the relatively cold surface of the base metal and are only mechanically bonded to the base metal surface. It is, therefore, generally recognized that some means of heating either or both the coating and the base metal must be employed in order to form a fusion bond between the coating and the base metal. In some instances, it has been proposed to heat the base to an elevated temperature prior to, or simultaneously with, a coating operation, and in other instances the coating is heated after being deposited in the desired thickness on the base metal. When, however, the base metal is heated to an elevated temperature, it has been observed that an excessive amount of an intermetallic compound is frequently formed, such as an aluminum-iron compound, tin-iron compound, or a zinc-iron compound, which results in a brittle and otherwise poorly adherent coating. When the surface coating metal is maintained at a relatively low temperature during the coating operation to avoid formation of intermetallic compounds, there is often insufficient bonding between the coating and the base. There has thus been no completely satisfactory process devised for spray-coating a ferrous metal base with a relatively thin, firmly adherent film of a protective metal of the foregoing class.

Accordingly, it is an object of the present invention to provide an improved metal spray-coating process which produces continuously, a thin, strongly adherent spray metal coating on a ferrous base.

It is a further object of the present invention to provide an improved metal spray coating which forms a secure fusion bond with a ferrous metal base, while avoiding the formation of substantial amounts of intermetallic compound between the coating metal and the base metal.

It is a still further object of the present invention to produce an improved process for continuously providing a thin, protective film of aluminum which is firmly adherent to a ferrous metal base.

Other objects of the present invention will be apparent from the detailed description and claims to follow.

According to the present invention, one of the commonly employed protective metals, such as Al, Cu, Sn, Zn, or an alloy consisting of a combination of two or more of any of the said protective metals, is applied to the surface of a ferrous metal base in a non-oxidizing atmosphere, and preferably in a neutral or a reducing atmosphere, by spraying dispersed droplets of the protective metal so that substantially a single layer of droplets is sprayed and solidifies on the ferrous metal base surface with each of the droplets being spaced from the next adjacent droplets so that a substantial portion of the surface of the metal base may be exposed and not completely covered. Thereafter, and while still in a neutral or reducing atmosphere, the spray-coated surface

is exposed rapidly and for a brief time, to a temperature above the melting point of the protective coating metal. The droplets are thus rapidly melted and a lateral flow of molten metal occurs onto the exposed uncoated surface of the base metal which has also been heated rapidly and briefly as the droplets are melted, thereby rapidly forming a continuous, thin film over the entire surface of the base metal. During the brief heating, there is a fusion of the coating metal which forms on the supporting strip a smooth, even surface substantially non-porous and free of the usual surface defects which are frequently encountered in metal coatings applied by spraying. The atmosphere of the fusion chamber can be neutral or reducing to avoid surface oxidation, and specific compounds may be added to the atmosphere or can be deposited on the sprayed surface to promote formation of a uniform, clean film of fused metal such as one of the various fluxing agents in common use.

As soon as the protective metal has formed a smooth, even film or coating on the base metal surface, as above described, and within a matter of a few seconds after exposure to the radiant heat, the metal strip and coating are immediately and rapidly quenched to lower the temperature of the base metal and protective coating, minimize the formation of the aluminum-iron and the like intermetallic compound, and to prevent the formation of objectionable amounts of the intermetallic compound such as an aluminum-iron compound, which is brittle and frequently results in poor adherence of the aluminum coatings. It is preferred to use a liquid bath for rapidly quenching the base metal and coating, such as water.

It is believed that the instant process provides an improved spray coating because the discrete droplets of coating metal fuse more rapidly on reheating than do a multiplicity of overlapping droplets which completely cover the surface of the base metal, and because the metal base is heated rapidly and does not remain at the elevated temperature for a prolonged period, since it is rapidly quenched immediately after the droplets flow onto the metal base. The instant process, however, is in no way to be limited by the foregoing postulated theory of operation.

In the application of the present invention to produce an aluminum-coated strip, a continuously moving strip of steel (less than 0.1 inch thick) is, after thoroughly cleaning to remove soil from the surface thereof, continuously passed into a chamber containing a non-oxidizing atmosphere and beneath aluminum metal spray outlets having the spray outlets and the rate of travel of the strip so adjusted that discrete droplets of aluminum are deposited on the steel strip with a substantial portion of the steel strip between the droplets remaining uncoated. It will be apparent that only in a continuous process of the foregoing type is it possible to get uniformly discrete droplets on the base metal surface. The strip having the solidified spaced droplets of aluminum thereon is then rapidly and briefly heated in a non-oxidizing atmosphere to a temperature of about 1200–1400° F. for a period of about 2–10 seconds, by high density heat, such as produced by electric heating elements or as produced in a luminous wall furnace wherein the gas passes through the brick wall of the furnace and burns at the wall surface, or by other radiant heat source. The aluminum droplets are rapidly fused by direct heat from the furnace wall and also by convection heat from the metal strip which is also heated by direct exposure to the heat, without heating the base metal completely, however, as in the hot dip aluminum process. The fused aluminum droplets flow onto the heated metal surface between the droplet centers and form a smooth, continu-

ous coating of aluminum having a thickness of about less than .0005–.001 inch. Just as soon as the continuous coating has been formed on the base metal strip, the strip is withdrawn from the furnace and immediately and continuously quenched by immersion in a liquid quenching bath, such as water, to rapidly cool the steel strip and the coating, thereby reducing to a minimum the formation of intermetallic compounds normally resulting from the reaction between the aluminum and the iron of the base strip.

The same procedure is applicable for depositing a coating of other protective coating metals, such as copper, zinc, and the like, by making suitable adjustment in the furnace temperature depending on the melting point of the protective coating metal employed. If desired, the steel strip can also be pretreated with specific agents or compounds which are known to inhibit formation of intermetallic compounds between the iron in the base strip and the protective coating layer, such as molybdenum, but such pretreatment is not required as in the hot-dip aluminum coating process.

It will be evident to one skilled in the art, that each of the steps in the instant process is designed to avoid maintaining the ferrous base metal and the protective metal coating while in contact therewith at an elevated temperature for any substantial or prolonged length of time in order to minimize the heating of the base and the coating, and thereby reduce to an absolute minimum the formation of intermetallic compounds at the interface between the base metal and the coating and preventing alloying to penetrate deeply into the surface of the base metal. This is of particular importance in the production of thin, protective coatings where a substantial proportion of the coating metal might be in the form of an undesirable intermetallic compound, such as the brittle aluminum-iron alloy compound, if positive steps were not taken to reduce the formation of an intermetallic compound. Thus, by spraying the coating metal onto the base surface instead of dipping the base metal strip into a molten bath of the coating metal, the entire base metal strip is not heated to the temperature of the molten metal. Also, by subjecting only the surface area of the spaced droplets of coating metal and the base metal to radiant heat, the droplets of coating metal are very rapidly heated to the fusion temperature to form a continuous coating before the base metal is heated to an elevated temperature. And, by immediately and rapidly quenching the base metal and the surface coating metal as soon as a uniform coating is formed, a minimum of intermetallic compound is formed. It will also be apparent that the instant process in one preferred form is particularly suitable for applying a thin, protective metal coating to a thin strip or sheet of a ferrous metal, since a thin sheet can be more rapidly cooled in the final quenching step.

Others may practice the invention in any of the numerous ways which are suggested to one skilled in the art, by this disclosure, and all such practice of invention are considered to be a part hereof which fall within the scope of the appended claims.

I claim:

1. A continuous process of spray-coating a ferrous metal base with a thin protective metal which comprises: continuously spraying a molten protective metal on a ferrous metal base surface with the protective metal forming discrete spaced droplets on the surface of said metal base and leaving exposed a portion of the said metal surface between the droplets, said spraying operation being carried out in a non-oxidizing atmosphere; exposing said spray-coated metal surface while in a non-oxidizing atmosphere to a source of heat sufficient to rapidly melt said spaced droplets and heat the exposed metal surface, thereby permitting said droplets to flow together and forming a protective coating over said metal base; and rapidly quenching said heated metal base and protective metal coating to prevent formation of objectionable amounts of intermetallic compound therebetween.

2. A process as in claim 1, wherein the protective metal is selected from the group of metals consisting of aluminum, copper, tin, zinc, and an alloy combination of the foregoing metals.

3. A continuous process of spray-coating a ferrous metal base with a thin protective metal which comprises: continuously spraying molten aluminum on a ferrous metal base surface, said aluminum being sprayed on the base surface as discrete spaced droplets while leaving a portion of said metal surface exposed between the spaced droplets of aluminum, said spraying operation being carried out in a non-oxidizing atmosphere; exposing briefly said aluminum spray-coated metal surface while in a non-oxidizing atmosphere to a source of radiant heat to rapidly melt the aluminum droplets which have solidified on the base surface and permit said droplets to flow together forming an uninterrupted aluminum coating on the base surface; and rapidly quenching said heated metal base and aluminum coating to reduce formation of an intermetallic aluminum-iron compound therebetween.

4. A continuous process of spray-coating a ferrous metal base strip with a thin protective coating of aluminum which comprises: continuously spraying molten aluminum on a continuously moving strip of a ferrous metal, said aluminum being deposited on said strip in discrete spaced droplets with the surface of said strip between the spaced droplets being uncoated with aluminum and exposed to the surrounding atmosphere, said spraying being carried out in a non-oxidizing atmosphere; continuously exposing said aluminum spray-coating and said metal strip briefly to a source of radiant heat to rapidly melt the aluminum and heat said strip, whereby the droplets flow together forming an uninterrupted aluminum coating on said strip; and thereafter immediately and rapidly quenching said strip and aluminum coating in a liquid bath to prevent formation of objectionable amounts of an intermetallic aluminum-iron compound therebetween.

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