

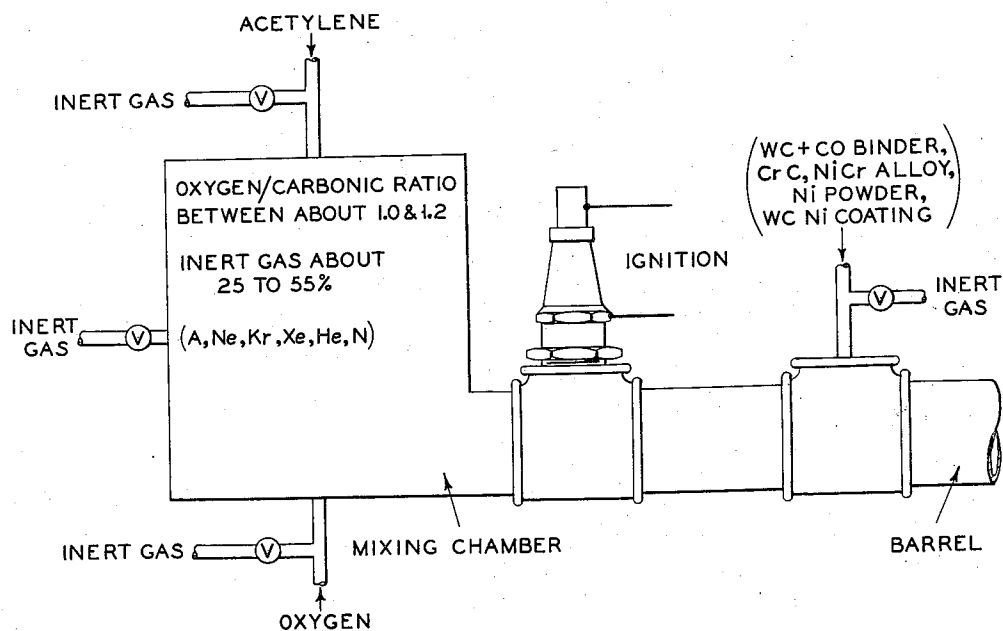
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FLAME PLATING USING DETONATION REACTANTS

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FLAME PLATING USING DETONATION REACTANTS

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This invention relates to an improved method of flame plating by means of detonations. More particularly, it relates to such a process wherein improved coatings are obtained by diluting the detonation reactants.

According to this invention there is provided an improvement over the basic detonation gun flame-plating process, which process comprises the steps of introducing desired fuel and oxidant gases into a detonation gun, introducing a comminuted coating material into the gun, and detonating the resultant charge to heat and propel the coating material out of the gun onto an article to be coated. The improvement comprises adding an inert diluting gas in an amount between about 25 and 55 percent by volume of the total gas present in the gun.

As the industrial community has progressed, an increasing demand has resulted for materials and coatings which can withstand severe conditions of erosion, high temperature, and corrosion. For the most part, the desired refractory, wear-resistant compositions could not be applied by known prior art methods.

The detonation-gun plating process covered in United States Patent No. 2,714,563 is quite useful for applying refractory coatings, such as tungsten carbide associated with or without lower melting point binder metals such as cobalt. This process comprises providing a detonable mixture of oxidant and fuel in a detonation gun having a mixing and ignition chamber and an elongated barrel, introducing a power into the barrel, igniting the detonable mixture and impinging the powder onto a workpiece to form a dense, adherent coating. This coating consists of irregularly shaped microscopic leaves or lamellules interlocking and overlapping with each other.

As disclosed in the above patent, control of the detonation coating conditions is obtained principally by varying the detonation mixture both in ratio of oxidant to fuel and in use of different combustant materials. This prior art process has shortcomings when used with particular coating mixtures and especially when impact resistant coatings are desired. For example, in protecting compressor blade wear surfaces, a coating is required which is hard enough to give resistance to wear caused by rubbing and also is resilient enough to withstand impact forces without failure. This latter characteristic is provided by measurable increased modulus of rupture of the coating. Prior detonation-applied coatings have not had sufficient impact resistance.

Some coating mixtures such as tungsten carbide-chromium carbide-nickel as disclosed in application Serial No. 738,300 of J. F. Pelton et al., filed concurrently herewith, and chromium carbide-nickel-chromium as disclosed in application Serial No. 738,299 of J. F. Pelton et al., also filed concurrently herewith, are difficult to apply as dense, adherent coatings by means of the above-disclosed detonation process. These coating mixtures are particularly useful in that they result in coatings having improved corrosion and high-temperature oxidation resistance and improved surface finish for precision surfaces, such as those found on gage blocks.

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It is a principal object of this invention to provide an improved process for the operation of a detonation gun for flame-plating whereby improved coatings may be obtained.

In the drawing the single figure is a diagram of the detonation gun having legends indicating materials used. An improved detonation-plating process has been developed which overcomes the disadvantages of the prior art. This process comprises adding between about 25 and 55 percent by volume of the total gas present in the detonation gun as an inert gaseous diluent to the detonation mixture. The term "inert" is intended to include the chemically inert gases—argon, neon, krypton, xenon, helium—and also other gases such as nitrogen which will not react with the gases forming the detonable mixture nor more than slightly with the coating material. Nitrogen is preferred as the additive since it is relatively inexpensive and is readily available. In order not to change the oxidation-reduction potential of the detonation flame, the additive is preferably chemically inert to the coating material under the coating process conditions. There may be a slight nitriding effect when nitrogen is used as the diluent, but the nitride thus formed is quite hard and has good refractory properties.

This improved process is useful in that it enables increased control to be obtained over detonation-plating conditions. The gaseous diluent reduces or tends to reduce the flame temperature since it does not participate in the detonation reaction. Major changes in plating temperatures have been obtained in prior detonation gun processes by varying the mixtures of oxidant and fuel and by using different materials for oxidant and fuel. However, this control was still insufficient to produce acceptable coatings for particular mixtures and applications. Also, whenever the oxidant/fuel ratio is changed, the detonation conditions change to often produce undesirable chemical changes in the coating. The present process adds the fine control necessary to enable the detonation-plating process to be used with an increased number of coating compositions and also for new and more widely useful applications based on these resulting coatings.

Inert carrier gas streams have previously been used with prior detonation-plating processes to introduce coating material into the barrel of a detonation gun. The volume of this inert gas in the detonation mixture is relatively small, i.e., less than about 10 volume percent.

It thus did not help materially to improve the coating results.

It has been found according to the present invention that the improved process requires at least about 25 volume percent total inert gas additive before an effective improvement results in the coatings. At above about 55 volume percent diluent it is found that the reaction temperature has been lowered to such an extent that inferior coatings can result. These diluent values include any inert gas used as a carrier for injecting coating powder into the detonation gun. Different coating compositions have different preferred process diluent amounts, but they all lie within the above limits of 25 and 55 volume percent.

The inert gas additive can be introduced to the detonation mixture in any convenient manner. It could be introduced through the fuel line, the oxidant line, or through the coating powder inlet tube. Likewise, a separate line could be used.

Tungsten carbide with cobalt binder is a widely used coating mixture applied by means of the detonation coating process. Prior results using no inert gas diluent other than the powder carrier gas resulted in samples having coating modulus of rupture values of about 67,000 p.s.i. A preferred addition of about 46 volume percent total

nitrogen results in a tungsten carbide-cobalt coating having a modulus of rupture of about 106,000 p.s.i. This coating has considerably more impact resistance than similar coatings applied by prior nondiluted detonation processes. This result is believed to be caused in part by retention of higher amounts of cobalt binder in the final coating apparently resulting from lowered flame temperature of the nitrogen-containing detonation mixture. Coating mixtures of tungsten carbide-cobalt alloy containing about 9 weight percent cobalt as applied by prior detonation processes resulted in coatings containing about 7 weight percent cobalt. Similar coatings applied by the improved detonation process employing 46 volume percent nitrogen addition contained about 15 weight percent cobalt. The cobalt content of the coatings produced by prior art methods has been limited by the raw materials available. It is impractical and almost impossible to obtain a tungsten carbide-cobalt alloy containing more than about 9 weight percent cobalt in powdered form necessary for coating. The higher cobalt content alloys are extremely difficult to pulverize. The hardness is decreased somewhat from about 1380 to about 1180 VPN, but the resulting coating is still hard enough to provide desirable wear resistance. The tungsten carbide in the form of WC retained in the coating also increased substantially upon use of nitrogen dilution. In prior tungsten carbide-cobalt coatings the final coating contained about 2-3 weight percent WC. In similar coatings obtained by the present invention, the WC content is about 30-40 weight percent. This factor, in combination with increased binder retention, helps to obtain the improved coating properties.

The following examples describe the use of this improved process for applying particular coating compositions.

EXAMPLE I

Tungsten carbide-cobalt coating

Acetylene at 1.65 c.f.m. and oxygen at 1.65 c.f.m. were introduced to a detonation gun to form a detonable mixture having an oxygen/carbon atomic ratio of 1.0. Nitrogen was introduced through the acetylene line at 2.2 c.f.m. Finely divided (less than 325 mesh) tungsten carbide-cobalt powder containing about 9 weight percent cobalt was fed into the barrel of the detonation gun by means of a 0.6 c.f.m. nitrogen stream. The detonation mixture surrounding the coating particles thus contained 46 volume percent nitrogen. The detonation mixture was ignited about four times per second and the resulting detonation and shock waves impinged the powder onto a metal workpiece to form a dense, adherent, wear-resistant coating having improved impact resistance, a modulus of rupture 106,000 p.s.i., and a hardness of 1100 VPN as measured with a 300 gram load.

EXAMPLE II

Tungsten carbide-chromium carbide-nickel coating

Acetylene at 1.55 c.f.m. and oxygen at 1.55 c.f.m. were introduced to a detonation gun to form a detonable mixture having an oxygen/carbon atomic ratio of 1.0. Nitrogen was introduced through the acetylene line at 1.67 c.f.m. Finely divided powder having a composition of about 70 weight percent tungsten carbide (WC and lower carbides)—24 weight percent chromium carbide (Cr_3C_2 and lower carbides)—6 weight percent nickel was fed into the barrel of the detonation gun by means of a 0.4 c.f.m. nitrogen stream. The detonation mixture surrounding the coating particles thus contained 40 volume percent nitrogen. The detonation mixture was ignited about four times per second and the powder was impinged onto a metal workpiece to form a dense, adherent coating having improved surface finish and corrosion-resistant properties as well as having improved oxidation resistance. It had a hardness of 110 VPN as measured with a 300 gram load. This coating could not be satisfac-

torily applied by prior detonation processes which did not use inert gas additive to detonation mixture.

EXAMPLE III

Chromium carbide-nickel-chromium coating

Acetylene at 1.50 c.f.m. and oxygen at 1.80 c.f.m. were introduced to a detonation gun to form a detonable mixture having an oxygen/carbon atomic ratio of 1.2. Nitrogen was introduced through the acetylene line at 2.2 c.f.m. Finely divided powder having a composition of about 85 weight percent chromium carbide (Cr_3C_2)—15 weight percent nickel-chromium alloy (80 percent nickel—20 percent chromium) was fed into the barrel of the detonation gun by means of a 0.6 c.f.m. nitrogen stream. The detonation mixture surrounding the coating particles thus contained 46 volume percent nitrogen. The detonation mixture was ignited about four times per second and the powder was impinged onto a metal workpiece to form a dense, adherent coating having corrosion-resistance and high-temperature oxidation resistance properties and having a hardness between 800 and 850 VPN as measured with a 300 gram load. This coating could likewise not be satisfactorily applied by prior detonation processes.

EXAMPLE IV

Nickel metal coating

Acetylene at 1.65 c.f.m. and oxygen at 1.65 c.f.m. were introduced to a detonation gun to form a detonable mixture having an oxygen/carbon atomic ratio of 1.0. Nitrogen was additionally introduced through the acetylene line at 2.2 c.f.m. Finely divided nickel metal powder was fed into the barrel of the detonation gun by means of a 0.6 c.f.m. nitrogen carrier gas stream. The detonation mixture surrounding the coating particles thus contained about 46 volume percent nitrogen. The detonation mixture was ignited about four times per second and the resulting detonation and shock waves impinged the nickel powder onto a workpiece to form a dense nickel coating having an acceptable surface finish. When nitrogen dilution is not used with this material, the resulting coating is unsatisfactory due to lumps and irregularities.

EXAMPLE V

Tungsten carbide-chromium-nickel coating

Acetylene at 1.83 c.f.m. and oxygen at 2.02 c.f.m. were introduced to a detonation gun in sufficient quantities to form a detonable mixture having an oxygen/carbon atomic ratio of 1.1. Nitrogen at 1.65 c.f.m. was introduced to this detonable mixture so as to constitute about 35 percent by volume. Finely divided tungsten carbide powder containing 20 weight percent metal alloy binder (80 percent chromium—20 percent nickel) was fed into the barrel of the detonation gun. The detonation mixture was ignited about four times per second and the powder was impinged onto a metal workpiece to form a dense adherent coating having a hardness of 1089 VPN.

It may be seen from the above examples that the use of the instant process greatly improved previously attained coatings and made possible other coatings that were unsatisfactory when performed by known processes. It will be noticed from Examples I, III, and IV that a nitrogen concentration in the total gas of about 46 volume percent appears to be within an optimum level for a number of different coatings. However, as is evident from Examples II and V, the exact dilution for best results should be adjusted according to the compositions employed and the coating properties desired. As stated above, however, this dilution will always be between about 25 and 55 volume percent. The specific examples of coatings applied by the improved process are only illustrative of inherent advantages residing therein and are not intended to be construed as limiting in any manner.

What is claimed is:

1. In the process of flame plating with a detonation gun which comprises the steps of introducing desired fuel and oxidant gases into the gun to form a detonatable mixture, introducing a powdered coating material into said detonatable mixture within the gun, and detonating the fuel-oxidant mixture to impinge the coating material onto an article to be coated, the improvement which comprises using a detonatable fuel-oxidant mixture having an oxygen/carbon atomic ratio between about 1.0 and 1.2 and containing inert diluting gas in an amount between about 25 and 55 percent by volume of the total gas present.

2. In the process of flame plating with a detonation gun which comprises the steps of introducing desired fuel and oxidant gases into the gun to form a detonatable mixture, introducing a powdered coating material into said detonatable mixture within the gun, and detonating the fuel-oxidant mixture to impinge the coating material onto the article to be coated, the improvement which comprises using a detonatable fuel-oxidant mixture having an oxygen/carbon atomic ratio between about 1.0 and 1.2 and containing between about 25 and 55 percent by volume of the total gas present of a diluting gas composed of one or more of the group consisting of argon, neon, krypton, xenon, helium, and nitrogen.

3. The improved process set forth in claim 1 wherein the inert diluting gas is nitrogen.

4. The improved process set forth in claim 1 wherein the inert diluting gas is argon.

5. In the process for operating a detonation gun having a mixing and ignition chamber and a barrel portion which comprises introducing desired fuel and oxidant gases into said gun through said mixing and ignition chamber, introducing a comminuted coating material into said barrel portion, and detonating the mixture within said gun to impinge the coating material onto an article to be coated, the improvement which comprises using a detonatable fuel-oxidant mixture having an oxygen/carbon ratio between about 1.0 and 1.2 and containing between about 25 and 55 percent by volume of the total gas present of an inert diluting gas.

6. The improved process set forth in claim 5 above in which at least part of the inert diluting gas is introduced into the gun as an entraining medium for the comminuted coating material.

7. The improved process set forth in claim 5 above in which at least part of said inert diluting gas is introduced through the mixing and ignition chamber with the fuel and oxidant gases.

8. In the process for operating a detonation gun having a mixing and ignition chamber and a barrel portion which comprises the steps of introducing desired fuel and oxidant gas through said ignition and mixing chamber, introducing a comminuted coating composition comprising about 91 weight percent of tungsten carbide and 9 weight percent of cobalt into the barrel portion of the gun and detonating the mixture to propel the coating composition out of the front end of the gun onto an article to be coated, the improvement which comprises using a detonatable fuel-oxidant mixture having an oxygen/carbon ratio between about 1.0 and 1.2 and containing nitrogen at a concentration of about 46 percent of the total gas volume to act as a diluent in the detonable mixture.

9. In a process for operating a detonation gun having

a mixing and ignition chamber and a barrel portion which comprises the steps of introducing desired fuel and oxidant gas through said ignition and mixing chamber, introducing a comminuted coating composition comprising about 70 weight percent tungsten carbide, 24 weight percent chromium carbide, and 6 weight percent nickel into the barrel portion of the gun and detonating the mixture to propel the coating composition out of the front end of the gun onto an article to be coated, the improvement which comprises using a detonatable fuel-oxidant mixture having an oxygen/carbon ratio between about 1.0 and 1.2 and containing nitrogen at a concentration of about 40 percent of the total gas volume to act as a diluent in the detonable mixture.

10. In the process for operating a detonation gun having a mixing and ignition chamber and a barrel portion which comprises the steps of introducing desired fuel and oxidant gas through said ignition and mixing chamber, introducing a comminuted coating composition comprising about 85 weight percent of chromium carbide and 15 weight percent of a nickel-chromium alloy (80 percent nickel-20 percent chromium) into the barrel portion of the gun and detonating the mixture to propel the coating composition out of the front end of the gun onto an article to be coated, the improvement which comprises using a detonatable fuel-oxidant mixture having an oxygen/carbon ratio between about 1.0 and 1.2 and containing nitrogen at a concentration of about 46 percent of the total gas volume to act as a diluent in the detonable mixture.

11. In the process for operating a detonation gun having a mixing and ignition chamber and a barrel portion which comprises the steps of introducing desired fuel and oxidant gas through said ignition and mixing chamber, introducing a comminuted coating composition comprising finely divided nickel powder into the barrel portion of the gun and detonating the mixture to propel the coating composition out of the front end of the gun onto an article to be coated, the improvement which comprises using a detonatable fuel-oxidant mixture having an oxygen/carbon ratio between about 1.0 and 1.2 and containing nitrogen at a concentration of about 46 percent of the total gas volume to act as a diluent in the detonable mixture.

12. In the process for operating a detonation gun having a mixing and ignition chamber and a barrel portion which comprises the steps of introducing desired fuel and oxidant gas through said ignition and mixing chamber, introducing a comminuted coating composition comprising about 80 weight percent tungsten carbide and 20 weight percent of chromium-nickel alloy (80 percent chromium-20 percent nickel) into the barrel portion of the gun and detonating the mixture to propel the coating composition out of the front end of the gun onto an article to be coated, the improvement which comprises using a detonatable fuel-oxidant mixture having an oxygen/carbon ratio between about 1.0 and 1.2 and containing nitrogen at a concentration of about 35 percent of the total gas volume to act as a diluent in the detonable mixture.

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