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POWDER METAL ALLOY COMPOSITION AND METHOD FOR FORMING WEAR RESISTANT COATINGS THEREWITH

Edward P. Rowady, Battle Creek, Mich., assignor to Eaton Manufacturing Company, Cleveland, Ohio, a corporation of Ohio

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This invention relates to an improved iron base alloy composition, a method for forming wear and corrosion resistant coatings therewith and the articles formed thereby. More particularly this invention concerns an improved powder metal alloy composition having improved characteristics which make it especially suitable for use as a wear resistant coating on the tip of valves for internal combustion engines.

The conditions under which valves function in internal combustion engines, particularly exhaust valves, are such as to require that the material employed in the valve have high strength at elevated temperature, creep resistance, fatigue resistance, wear resistance and resistance to corrosion from the gaseous combustion products. No single material is known which possesses all of these characteristics to the necessary or desired degree. The most widely used material in internal combustion engine exhaust valves is a ferrous base alloy containing chromium and nickel in sufficient quantities to confer the necessary resistance to corrosion and other alloying ingredients to confer the needed high temperature strength, creep and wear resistance. Since the primary wear occurs on the stem and tip portions of the valve, and the primary corrosive atmosphere is adjacent to the head portion, exhaust valves have been fabricated of a stainless steel head portion and a less expensive wear resistant steel stem portion by welding the two portions together. These composite valves thought by some to be susceptible to weld failures have not been completely accepted. When, however, the entire valve is fabricated from a chromium-nickel-iron alloy, the overall cost is increased and the wear resistance characteristics of the stem, and particularly the tip portions are unsatisfactory.

It is therefore the primary object of this invention to provide an alloy composition which can be easily and inexpensively applied to the tip portion of a valve in a continuous producton line operation.

A further object of this invention is to provide a method for applying the improved wear resistant powder metal alloy composition of this invention to the tip portion of internal engine valves, which application method simultaneously heat treats the applied coating alloy to give the desired hardness and eliminates the necessity for a separate heat treatment step which has been conventionally employed heretofore.

Another object of this invention is to provide an improved valve for use in internal combustion engines.

In accordance with this invention it has now been found that the above and related objects may be achieved by the use of an alloy having the following composition, in percent, by weight:

	Useful Range	Preferred Range
Carbon	0.5%-0.7%	0.5%-0.6%.
Manganese	0.2%-0.6%	0.2%-0.6%.
Chromium	7%-10%	7%-9%.
Silicon	2.7%-3.5%	3%-3.5%.
Boron	1%-4%	2.5%-3.5%.
Nickel	0.4% maximum	0.4% maximum.
Phosphorous	0.03% maximum	0.03% maximum.
Sulfur	0.03% maximum	0.03% maximum.
Aluminum	0.15% maximum	0.1% maximum.

The alloy for application by the preferred molten spray process of this invention should be in the form of powder, the particles thereof being smaller than about 100 Tyler screen mesh. While extremely fine particles may be employed, it is preferred that the particles have sizes in the range of about 100 to about 325 Tyler screen mesh. It is to be understood that the alloy composition may be used for purposes other than valve tip surfacing and may take the form of rods, bars or the like, and in the improved article of this invention is in the form of an integral coating on the tip of the valve, the coating having a thickness of about 0.001 inch to about 0.060 inch, and preferably about 0.015" to about 0.055" thick.

One of the important considerations which is involved in providing an acceptable valve tip wear resistant coating is that the material must be capable of application by an inexpensive procedure. It was found that powder metal alloys could be applied to the tips of valves by using plasmaweld surfacing equipment of conventional type which is commercially available, but known powder alloys were unsatisfactory because of porosity, poor bond, undesirable softness or poor wear characteristics. It was discovered that the bond to the base metal of the valve and the soundness or freedom from porosity of the coating could be improved by insuring a boron content in the wear resistant coating of at least about 1.0% by weight, and preferably about 2.5% to about 3.5%. When the alloy coating is produced by the use of plasmaweld equipment it was found that a portion of the boron content of the powder metal alloy is lost during application, and in order to insure the desired boron content in the surface coating it is necessary to employ a powder metal alloy containing from about 0.1% to about 1% more boron than is desired in the final coating, the loss being approximately proportional to the boron content. Additionally it was determined that in order for the resultant coating to have sufficient hardness to assure the desired wear resistance and ability to harden on the metal substrate at ambient temperature after plasmaweld application, that the carbon content of the alloy, wihin the above given range, was criical to success. When the carbon content is below about 0.5% or above about 0.7% by weight, the desired hardness and wear resistance is not obtained. It was also found that there is a small loss of carbon during plasmaweld application and it is recommended that the powder alloy material contain about 0.005% to .05% more carbon than is desired in the final coating.

The plasmaweld process provides an inexpensive and advantageous means for forming the coating of this invention on a metal surface. In this application procedure, no preliminary preparation of the metal to be coated is necessary except that conventional cleaning procedures should be utilized if the metal is soiled by grease, oil, or the like. Using a conventional plasmaweld surfacing machine under operating conditions of sufficient applied power to continuously melt, or vaporize, the powder metal alloy fed to its nozzle, the spray from the nozzle is directed at the surface to be coated. The inert gas, usually argon, which emanates from the nozzle together with the molten alloy vapor assures freedom from oxidizing conditions at the point of application. The heat of the applied spray is such as to raise the temperature of an extremely thin upper surface layer of the metal being coated to cause that layer to melt, weld or alloy with the vaporized alloy material impinging and depositing thereon. Thus, the applied coating becomes alloyed with and an integral part of the substrate metal. The method of this invention is applicable for use with any and all substrate metals which are capable of alloying and bonding with the above defined improved alloy composition. In its preferred form of providing a coating on the tips of inter-

nal combustion valves, the substrate metal may be any of the conventional ferrous or nickel base alloys which cannot be hardened to a hardness higher than Rockwell 50 C scale such as the stainless steels, austenitic steels, age hardenable steels, etc. In order to form a sound non-porous coating, the nozzle of the plasmaweld gun should be moved across the surface being coated in a uniform manner, or the work being coated may be moved relative to a stationary nozzle. In the coating of valve tips, it was found to be desirable to fixedly mount the nozzle for controlled oscillation and to rotate the valve under the nozzle during coating between 500 and 1200 revolutions per minute depending upon the size of valve, the speed being increased as the diameter of the valve increases. Using the above generally described conditions, it was found that the preferred coating thickness of 0.025 to 0.045 could be obtained in about 1 to 1.5 seconds' time.

It is unnecessary to supply any supplemental heat to the substrate metal either before or during plasmaweld application of the alloy composition of this invention. Subsequent of the deposition of the integral alloy coating on the surface, the part being coated is removed and cooled in air at ambient temperature. Although forced air cooling or other quenching procedures do not appear to destroy the desired characteristics of the coating, such procedures have not been found to be necessary and the rapidity of application and the lack of subsequent heat treatment procedures constitute important commercial advantages of the process of this invention.

In the case of valves coated with the cooled coating of this invention, the improved valve article is completed by grinding, buffing, machining or otherwise smoothing the coating to the desired thickness, preferably about 0.020" thickness for exhaust valve tips. While the improved article of this invention is a valve having an integral alloy coating, which covers the tip portion of the composition above set forth, the best known embodiment is the following:

A valve body fabricated from an alloy containing in percent by weight, 0.47%–0.57% carbon, 8%–10% manganese, 0.030% maximum phosphorous, 0.040%–0.090% sulfur, 20%–22% chromium, 3.25%–4.5% nickel, 0.38%–0.50% nitrogen, balance iron.

An integral alloy coating, covering the tip portion, only, having a thickness of 0.015"–0.025" and a composition, in percent by weight, of 0.5%–0.7% carbon, 2%–3.5% boron, 7%–8.5% chromium, 2.7%–3.5% silicon, 0.40% maximum nickel, 0.2%–0.6% manganese, 0.15% maximum aluminum, 0.03% maximum phosphorous, and 0.03% maximum sulfur.

The following example will illustrate the utility of a specific alloy composition of this invention, typical conditions employed in the method and a preferred form of the improved article of this invention, but it is to be understood that it is presented for illustrative purposes only and does not define the scope or limits of this invention which have been set forth hereinabove. Two sets of 40 automobile exhaust valves, approximately 1¼" diameter were coated on the tip portion only by plasmaweld application with a 0.035" coating while rotating at 500–700 revolutions per minute in 1.3 seconds. The valves were permitted to cool in air at room temperature and the coating on the tip of each was then machined to a flat surface leaving a uniform 0.020" thick coating. Inspection of the coatings by microscope showed that they were integral with the valve tip and substantially free of pores or other imperfections. The composition of the powder metal alloy fed to the Plasmarc surfacing machine, the composition of the coating on the valve tip and the valve composition per se are shown in Table I in percent by weight. These coated valves were evaluated in 1964 Cadillac engines in a standard 50 hour endurance test at 4250 revolutions per minute at wide open throttle, using Havoline #20 weight oil, in comparison with valves having the same composition as that set forth in Table I but without a surface coating on the tip portion. In the test there were no failures in either batch of the coated valves and no failures in the control batch of non-coated valves, but the average wear of the tip of the coated valves was 0.0003" while the average wear of the control valves was 0.005".

Table I

	Batch #1		Batch #2		Valve
	Powder Alloy	Alloy Coating	Powder Alloy	Alloy Coating	
Carbon	0.53	0.52	0.54	0.52	0.47–0.57.
Manganese	0.2–0.6	0.2–0.6	0.2–0.6	0.2–0.6	8–10.
Boron	2.49	2.24	3.36	2.84	Nil.
Silicon	2.9	2.9	2.9	2.9	Nil.
Chromium	7.3–7.4	7.3–7.4	7.25–7.35	7.25–7.35	20–22.
Nickel	0.40 max.	0.40 max.	0.40 max.	0.40 max.	3.25–4.5.
Phosphorous	0.03 max.	0.03 max.	0.03 max.	0.03 max.	0.03 max.
Sulfur	0.03 max.	0.03 max.	0.03 max.	0.03 max.	0.04–0.09.
Nitrogen					0.38–0.5.
Iron	Balance	Balance	Balance	Balance	Balance.

What is claimed is:

1. A composition comprising, in weight percent, 0.5–0.7 carbon, 0.2–0.6 manganese, 7–10 chromium, 2.7–3.5 silicon, 1–4 boron, 0.4 maximum nickel, 0.15 maximum aluminum, 0.03 maximum phosphorous and 0.03 maximum sulfur, balance substantially iron.

2. A composition comprising, in weight percent, 0.5–0.6 carbon, 0.2–0.5 manganese, 7–9 chromium, 3–3.5 silicon, 2.5–3.5 boron, 0.15 maximum aluminum, 0.4 maximum nickel, 0.03 maximum phosphorous, and 0.03 maximum sulfur, balance substantially iron.

3. An alloy in accordance with claim 1 wherein said alloy is in powder form.

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HYLAND BIZOT, *Primary Examiner.*

DAVID L. RECK, *Examiner.*