Aug. 12, 1969 G. KUBERA 3,461,001

METHOD OF PRODUCING METAL BODIES WITH HEAT- AND WEAR-RESISTANT SURFACES

Filed Dec. 23, 1964 2 Sheets-Sheet 1

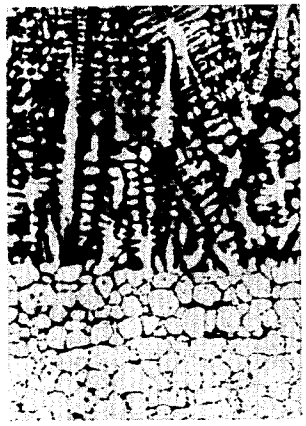


FIG. 1
100 X MAG.
CHROMIUM-NICKEL STEEL

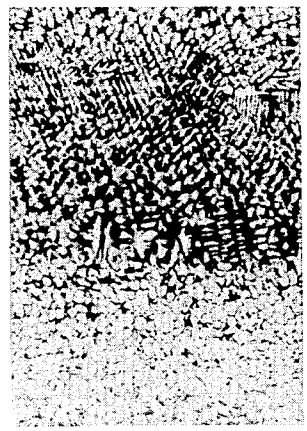


FIG. 2
100 X MAG.
CHROMIUM-MOLYBDENUM STEEL



FIG. 3
CHROMIUM-MOLYBDENUM ALLOY
100 X MAG.

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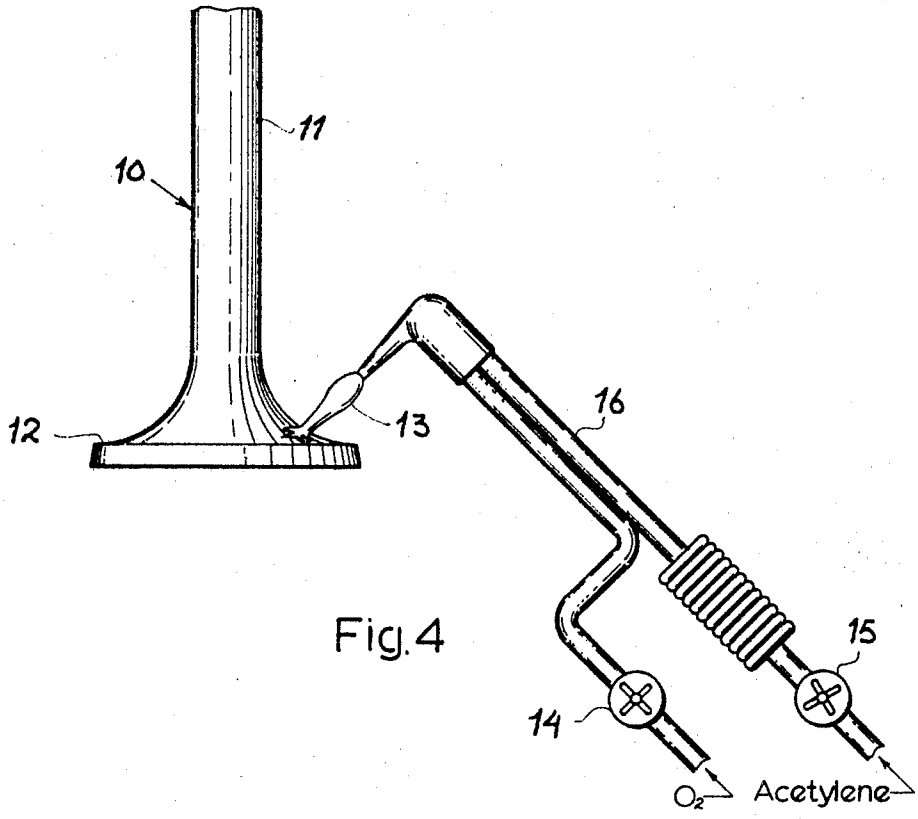


Fig. 4

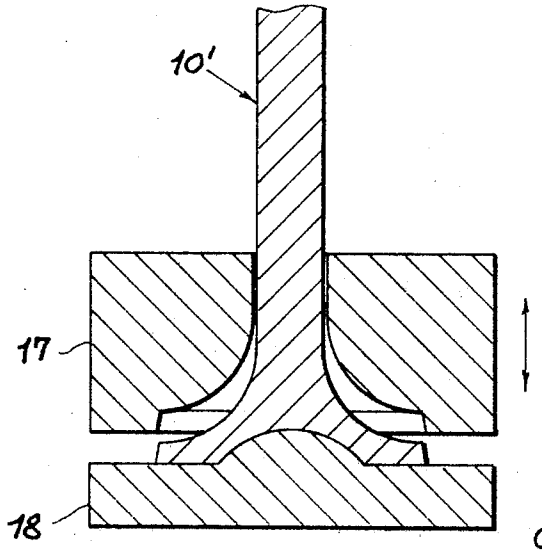


Fig. 5

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METHOD OF PRODUCING METAL BODIES WITH HEAT- AND WEAR-RESISTANT SURFACES

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Continuation-in-part of application Ser. No. 393,783, Sept. 1, 1964. This application Dec. 23, 1964, Ser. No. 423,636

Claims priority, application Germany, Sept. 1, 1963, T 24,670

Int. Cl. C21d 7/13

U.S. Cl. 148—11.5 9 Claims

ABSTRACT OF THE DISCLOSURE

A method of providing a metal body, especially a poppet valve for internal-combustion engines, with a heat-resistant surface zone, the poppet valve being composed at least in the region of this zone of an alloy from the group of austenitic, ferritic and martensitic steels and cobalt-chromium or chromium molybdenum alloys containing little iron, wherein a limited or localized portion of the poppet-valve body is heated to a temperature in its melting-point range (1300° C. to 1600° C.) with an oxy-acetylene flame supplied with 10 to 800% stoichiometric excess of acetylene to smelt (i.e. at least partially liquefy) the surface zone, and thereafter forging the smelted zone by mechanical-working techniques.

This application is a continuation-in-part of my application Ser. No. 393,783, filed Sept. 1, 1964 (now abandoned).

My present invention relates to a method of producing metallic bodies with wear- and heat-resistant surfaces and, more particularly, to a method of increasing the heat- and wear-resistance of exposed surfaces of metallic bodies of the iron group.

In my copending application Ser. No. 252,497 filed Jan. 18, 1963, Patent No. 3,358,350 I disclose a method of producing valve bodies for internal-combustion engines wherein the bodies have a high degree of resistance to the elevated temperature prevalent in the combustion and manifold chambers of an internal-combustion engine. Poppet, mushroom and tulip valves are the most general types employed in the exhaust and intake ducts of internal combustion engines and all of these valves have been heretofore produced from refractory alloys containing one or more of the metals of the iron group, i.e. ion, nickel, cobalt, chromium and molybdenum. Earlier valve bodies, however, were not entirely satisfactory because of certain physical properties of the metal from which they were composed or because of their relatively low wear resistance at elevated temperatures. In general, it may be said that refractory steels, e.g. tungsten steels having a high resistance to thermal energy, have a relatively low hardness and, when incorporated in the intake or exhaust valves of automotive vehicles, deteriorate rapidly as a consequence of mechanical erosion.

To increase the hardness of steel bodies to be used in the production of valves for internal combustion engines,

it has been proposed to form the valve body from primarily austenitic steels under conditions by which the nitrogen concentration within the steel is elevated and the steel is brought close to its hardness level at the precipitation point. By this means, austenitic steels of high thermal resistance with Rockwell hardness values of HR_c (max.)=40 can be obtained. In further efforts along these lines, the steel was alloyed with chromium and molybdenum to raise the hardness value to HR_c (max.)=56 although the heat resistance of the alloy was reduced below that of the usual austenitic steel. In yet another technique, selected surface areas of a steel body were reinforced or strengthened by a so-called "armoring" technique wherein toughening layers of heat-resistant metal are laminated onto the surface of this body. Since the valve body is subjected to a wide range of temperatures, the different coefficients of thermal expansion of the laminate layers results in stressing of the body; moreover, the armoring process itself is extemely expensive. In general, it may be said that there is no simple and relatively inexpensive method currently practiced whereby a metallic body can be locally treated to increase both its wear and heat resistance to the extent necessary for the use of the bodies as valves of internal combustion engines.

It is, therefore, the principal object of the present invention to provide a method of treating the surfaces of metallic bodies and especially bodies composed of one or more of the metals of the "iron" group (i.e. iron, nickel, chromium, cobalt, tungsten and molybdenum), whereby the heat and wear resistance of the treated surfaces can be substantially increased. Tungsten, molybdenum and chromium (group VI–B of the Periodic Chart, 41st Edition, Handbook of Chemistry and Physics) being defined as part of the iron group for the purposes of this invention.

Another object of this invention is to provide a metal body having a surface zone of relatively tough and heat resistant crystal or lattice structure essentially integral with a support structure of lesser heat esistance and toughness wherein thermal strains do not materially develop union subjection of the body to extremes of temperature.

Yet a further object of my invention is to provide a method of treating the surfaces of internal-combustion engine valve bodies to permit them to withstand the high temperatures of the combustion process and marring of the seating surfaces during prolonged use.

These objects and others which will become apparent hereinafter, are attained in accordance with the present invention by a method of producing metallic bodies (e.g. for use in internal-combustion engine valves) wherein the metallic body is composed of one or more metals of the iron group specified above and is subjected to a surface treatment resulting in a smelting transformation of a surface zone of the metal by contacting it with a reducing-gas flame at a temperature above a crystal-lattice transformation temperature and preferably at or slightly above the melting point of the alloy. Accordingly, it is an important feature of the present invention that the metallic body be subjected to an oxygen-acetylene flame containing an excess of acetylene to increase the concentration of carbon in the surface zone at which the smelting transformation takes place. While, in general, flame

temperatures between substantially 1000° and 1800° C. will suffice for the purposes of the present invention, it may be pointed out that an excess of acetylene from 10% to 800% above the molar quantity required for complete reaction with the amount of oxygen supplied, i.e. 2.5 moles oxygen/mole of acetylene, will produce both the reducing atmosphere and the necessary temperature. Excellent results are obtained when the molar quantity of acetylene is about three times the molar oxygen quantity, this proportion permitting temperatures on the order of 1300°–1600° C. to be obtained together with a reducing atmosphere. While acetylene is considered the most economical and convenient fuel for the present purposes, it may be noted that, with proper adjustment of the relative volumes of oxygen and fuel, any carbonaceous fuels having a relatively high oxygen/carbon molar combustion ratio will be suitable. The present method permits selection of the depth of the smelting transformation merely by appropriate choice of the treatment time and yields a surface structure whose lattice closely approximates the lattice formed during armoring and is distinctly different from the latter structure of the remainder of the body. The densified surface zone is found tegral with the support structure and not easily shed to be highly heat resistant and wear resistant to be inthereby even after subjection to repeated extremes of temperature.

It should be noted that it has heretofore been found to be substantially impossible by any conventional earlier methods to enrich a surface zone of a body composed of austenitic steel with carbon and that even martinsitic steels can be only limitedly enriched with carbon by local treatments if other difficulties are not to result. It can also be pointed out that this local enrichment of the steel with carbon is necessary because a general increase in the carbon concentration throughout the body prior to the formation or shaping thereof renders the steel mass so difficultly deformable and brittle that effective shaping cannot be carried out. It is, therefore, another important feature of the present invention that the metallic body be treated in the form of a valve blank which is later shaped to the desired configuration of the valve and along those surfaces which are destined to form the surfaces of the valve exposed to the high-temperature gases. A blank may, therefore, be roughly shaped to the general outline of the valve configuration and then subjected to treatment with the oxy-acetylene flame at those areas at which the wear and heat resistance is to be increased, the blank then being forged, extruded or pressed into the final configuration of the valve.

According to a further specific feature of this invention, the surface zones of the valve body which have been subjected to a mechanical working, preferably by forging, to increase the hardness of these surfaces zones to a still greater extent, e.g. by upwards of 12% for chromium-molybdenum alloy steels. A thermal hardening can be employed in addition to or in place of the mechanical working although it is desirable to use both methods of increasing the hardness of the body. Thus it is contemplated, in accordance with the instant invention, to heat the valve body to a temperature of about 1050° C. for a period of about one hour and then quench the valve in water or oil. A further increase in hardness of about 10% can be gained in this manner.

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. 1 is a photomicrograph in an enlargement of 100 times of the transition zone of a poppet valve composed of chromium-nickel alloy steel, the high-temperature and wear-resistant zone being shown as the upper part of the photomicrograph;

FIG. 2 is a photomicrograph of the transition zone of an internal-combustion-engine valve enlarged 100 times and composed of chroumium-molybednum alloy steel, the treated surface being shown above the untreated portion of the body;

FIG. 3 is a photomicrograph enlarged 100 times of the transition zone of a valve composed of a chromium-molybdenum alloy, according to the present invention, the upper zone being enriched with carbon in accordance with the present invention; and

FIG. 4 is a perspective view showing the treatment of a valve blank in accordance with the present invention.

FIG. 5 is a perspective view showing the treatment in a forging operation in accordance with the present invention.

In FIG. 4, I show a valve body **10** adapted to be further shaped for use in an internal-combustion engine and having a stem **11** and a seat-forming portion **12** extending transversely thereto. The seat-forming portion of the valve and, if desired, the end of the stem, is treated by subjecting it to local heat treatment in an oxy-acetylene flame **13** whose temperature is slightly above the melting point of the metal from which the valve body is composed. An oxygen valve **14** and an acetylene valve **15** are provided on the conventional torch **16** from which the flame **13** is emitted. It should be noted that the heat treatment can be carried out with an annular array of burner nozzles if desired. The valves maintain the preferable 3:1 molar ratio of acetylene to oxygen.

Example I

An austenitic steel consisting of 0.45 weight-percent carbon, 2.50 weight-percent silicon, 1.15 weight-percent manganese, 18.0 weight-percent chromium, 9.0 weight-percent nickel and 1.0 weight-percent tungsten, the remainder bing iron, is formed into a valve body for an internal-combustion engine of the general configuration illustrated in FIG. 4 by the combined extrusion and pressing technique disclosed in my copending application mentioned above. The setting surface of the body is found to have a hardness HR_c less than 40. When the body is subjected to treatment with an oxy-acetylene flame formed by combustion of 3 moles of acetylene per mole of oxygen, this flame being played around the setting surface for a period of about 5 minutes, the surface is formed to have a hardness of approximately HR_c 48 and to retain this hardness even after repeated heating to temperatures in excess of 800° C. The oxy-acetylene flame is found to have a temperature of about 1500° C. A photomicrograph of the transformation zone is shown in FIG. 1, from which it may be seen that the unaltered portion of the body (lower zone in FIG. 1) has a coarse-grained structure containing a minimum of lattice carbon, whereas the transformed surface zone (upper region in FIG. 1) has a fine-grained structure containing considerable lattice carbon identifiable as black regions or specks between the grains.

The body is then subjected to repeated forging operations (5-ton strokes for 3 minutes) and is found to have its treated surface zone increased in hardness to about HR_c55, as illustrated in FIG. 5. Subsequent treatment of the body or treatment thereof in the absence of the forging step by raising it to a temperature of 1050° C. and maintaining it at this temperature for one hour with subsequent quenching in oil to room temperature resulted in an increase of the hardness by 10% when measured by the Rockwell C method.

Example II

Similar results are obtained with a chromium-nickel alloy steel containing no detectiable tungsten and having the following composition: 0.25 weight-percent carbon, 1.0 weight-percent (maximum) silicon, 1.50 weight-percent (maximum) manganese, 21.0 weight-percent chromium, 12.0 weight-percent nickel and 0.2 weight-percent nitrogen, the remainder being iron. The high nitrogen content of this steel results in a hardness which is about

5% greater than that of the steel of Example I prior to forging or the subsequent heat-treating step. Again an oxyacetylene flame formed by combustion of three moles of acetylene per mole of oxygen was used.

Example III

Another austenitic steel treated in accordance with the steps of Example I and yielding similar results although containing significantly less nickel and more manganese and nitrogen was composed of 0.50 weight-percent carbon, 0.25 weight-percent (maximum) silicon, 9.0 weight-percent manganese, 21.0 weight-percent chromium, 3.9 weight-percent nickel, and 0.50 weight-percent nitrogen, the remainder being iron.

Example IV

The present method can also be effectively carried out with ferritic steels with essentially the same parameters as those given in Example I. In this case, the steel has the following composition: 0.80 weight-percent carbon, 2.35 weight-percent silicon, 0.40 weight-percent manganese, 20.0 weight-percent chromium and 1.35 weight-percent nickel, the balance being iron.

Example V

FIG. 2 illustrates a chromium-molybdenum alloy steel treated in accordance with the present invention with the parameters given in Example I whose hardness values are 5% greater through the several treatment steps. The alloy consists of 0.85 weight-percent carbon, 1.25 weight-percent manganese, 17.5 weight-percent chromium, 2.35 weight-percent molybdenum and 0.50 weight-percent vanadium, the remainder being iron. This material is treated at a temperature of 1520° C. with about 2.5 moles of acetylene per mole of oxygen constituting the reducing flame. The subsequent treatment steps are the same as those carried out in Example I.

Example VI

Like the chromium-molybdenum steel of Example V, another martensitic steel with which the parameters of Example I can be used consists of 0.45 weight-percent carbon, 3.05 weight-percent silicon, 0.45 weight-percent manganese and 8.0 weight-percent chromium, the balance being iron. In this case, however, hardness values 10% less than those of Example I are obtained.

Example VII

An alloy free from iron or containing only a minimum quantity thereof but composed of one or more metals of the iron group previously defined also can be treated in accordance with the present invention. Thus a chromium-cobalt alloy consisting of 0.2 weight-percent (maximum) carbon, 2.0 weight-percent silicon, 27.0 weight-percent chromium, 63.0 weight-percent cobalt and 4.5 weight-percent tungsten, the balance being iron, can be treated as described in Example I to yield a heat-resistant and wear-resistant surface. The treatment temperature is between 1400° and 1500° C. with about two moles of acetylene employed per mole of oxygen. Hardness values comparable to those obtained with Example III are observed.

I claim:

1. A method of making a valve for an internal-combustion engine comprising the steps of forming into said valve with a stem and a seat-forming portion surrounding said stem, a metal body composed of an alloy selected from the group which consists of austenitic, ferritic, and martensitic steels and cobalt-chromium and chromium-molybdenum alloys containing little iron, said portion having a localized heat-resistant surface zone extending over a limited part of the body; subjecting said zone to a smelting surface transformation by a reducing-gas flame resulting from the burning of a stoichiometric excess of a high-carbon-number hydrocarbon in oxygen at a temperature at least in the melting-point range of said body and ranging between substantially 1300° C. and 1600° C. while the balance of said body remains unaffected by said flame and mechanically working said surface zone of said body.

2. The method defined in claim 1 wherein said body has substantially the following composition:

	Weight-percent
Carbon	0.45
Silicon	2.50
Manganese	1.15
Chromium	18.0
Nickel	9.0
Tungsten	1.0
Iron	Balance

3. The method as defined in claim 1 wherein said body has substantially the following composition:

	Weight-percent
Carbon	0.25
Silicon (max.)	1.00
Manganese (max.)	1.50
Chromium	21.0
Nickel	12.0
Nitrogen	0.20
Iron	Balance

4. The method defined in claim 1 wherein said body has substantially the following composition:

	Weight-percent
Carbon	0.50
Silicon	0.25
Manganese	9.0
Chromium	21.0
Nickel	3.9
Nitrogen	Balance

5. The method defined in claim 1 wherein said body has substantially the following composition:

	Weight-percent
Carbon	0.80
Silicon	2.25
Manganese	0.40
Chromium	20.0
Nickel	1.35
Iron	Balance

6. The method defined in claim 1 wherein said body has substantially the following composition:

	Weight-percent
Carbon	0.85
Manganese	1.25
Chromium	17.5
Molybdenum	2.35
Vanadium	0.5
Iron	Balance

7. The method defined in claim 1 wherein said body has substantially the following composition:

	Weight-percent
Carbon	0.45
Silicon	3.5
Manganese	0.45
Chromium	8.0
Iron	Balance

8. The method defined in claim 1 wherein said body has substantially the following composition:

	Weight-percent
Carbon (max.)	0.20
Silicon	2.0
Chromium	27.0
Cobalt	63.0
Tungsten	4.5
Iron	Balance

9. A method of providing a poppet-valve body for internal-combustion engines, composed of an alloy selected from the group which consists of austenitic, ferritic, and martensitic steels and cobalt-chromium and chromium-molybdenum alloys containing little iron, with a localized heat-resistant surface zone extending over a limited portion of the body, comprising the steps of subjecting a surface of said body at said portion to a smelting transformation by a reducing gas flame resulting from the burning of a 10% to 800% stoichiometric excess of acetylene in oxygen at a temperature in the melting-point range of said body and ranging between substantially 1300° C. and 1600° C., and forging said surface zone of said body.

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U.S. Cl. X.R.

29—156; 148—12