Feb. 7, 1967 S. W. McGEE 3,303,066

POWDER METALLURGY AGE HARDENABLE ALLOYS

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Fig. 1.

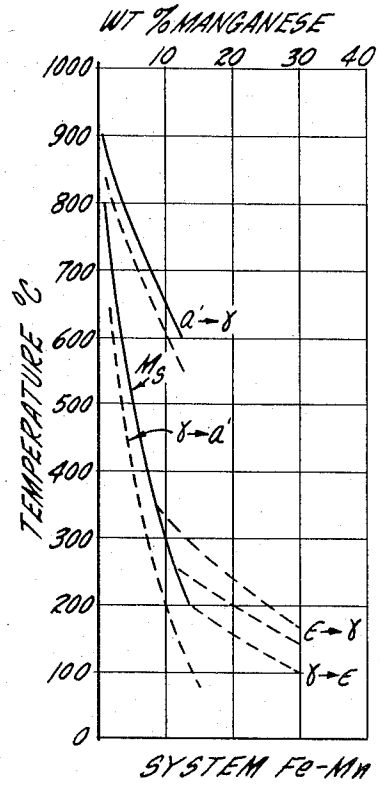
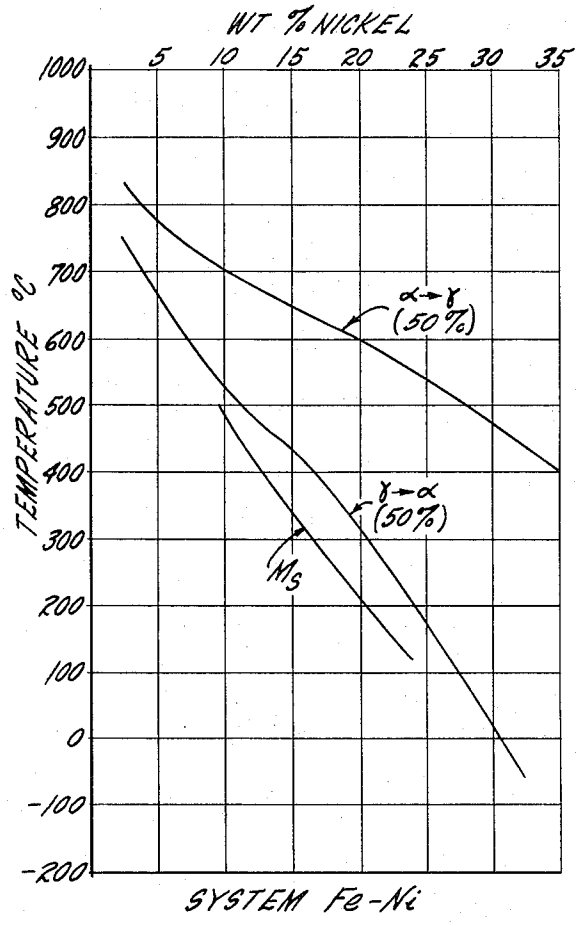


Fig. 2.



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POWDER METALLURGY AGE HARDENABLE ALLOYS

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Continuation of application Ser. No. 338,785, Jan. 20, 1964. This application Apr. 22, 1966, Ser. No. 554,612

13 Claims. (Cl. 148—126)

This invention relates to a sintered metal article and to the method of producing it and is a continuation of my co-pending application Serial No. 338,785, filed January 20, 1964, now abandoned.

It has for one object to provide ferrous metallic articles prepared from metal powders by sintering and age hardening.

It has for another object to form ferrous metallic alloyed articles by sintering, said sintered ferrous articles being of a metastable transitional crystallographic structure intermediate the austenitic face centered cubic and the ferrite body centered cubic allotropic forms of iron.

Another object relates to the method of producing and age hardening articles of the type indicated.

Other objects will appear in the ensuing specification, drawings and claims.

In a general way it may be said that the ferrous alloy sintered metal products produced by the methods disclosed and having the characteristics and properties disclosed embody age hardening which takes place with a resultant increase in the internal cohesiveness of the sintered alloy. Evidence of this is shown by increased hardness and increased tensile strength which is one of the objects of this invention to produce.

A further characteristic of the alloy articles disclosed herein is the martensitic transforming characteristic of the austenite formed at temperatures of 1300° F. or higher. This martensitic transforming characteristic results in essentially complete suppression of ferrite in the parent austenite matrix. This is illustrated in the accompanying drawings wherein:

FIGURE 1 is a diagram showing the martensitic transformation temperature ranges for the simple base system iron-manganese, and

FIGURE 2 is a diagram illustrating the same transformation for the system iron-nickel.

The crystallographic structure of the ferrous alloy articles of this invention, as produced by the method disclosed, is of the class recognized as martensitic in nature but differs from the commonly known type of martensite since, as disclosed in the present invention, the martensite is formed upon slow cooling of the sintered powder metallurgy alloys from temperatures exceeding 1300° F.

Heretofore it has been assumed that the commonly known martensite could only be formed by quenching or otherwise rapidly cooling those alloys in which it is desired to produce this crystallographic modification. A further difference between the martensite produced in the powder metallurgy alloys disclosed in the present invention from martensite as commonly known is that the alloys of the present invention are age hardenable. An important advantage of the present invention which flows from this fact is that the age hardening capability of the alloys of this invention permits greatly enhanced strength and hardness characteristics to be obtained in the alloys disclosed below.

In the past, it has been well known to produce powder metallurgy alloys capable of undergoing transformation to obtain martensitic crystallographic structures of the commonly known quenched and non-age hardenable type. The alloys of the present invention formed and proportioned of the metallic elements disclosed herein produce

for the first time, when treated according to the methods disclosed, sintered age hardenable martensitic structures of the non-quenched type.

Experience and research have shown that although it is well known to produce ferrous martensitic alloys of either quenched or non-quenched varieties by conventional melting, casting and heat treatment practices, it will be apparent that the powder metallurgy age hardenable alloys described herein and produced by the method disclosed differ intrinsically from any previously known cast and wrought products even though such previously known products are of martensitic crystal structure.

Basic differences between the products of this invention and known products of martensitic crystal structure become apparent not only in the mechanical and physical properties exhibited by the powder metallurgy sintered alloys of this invention but also by reason of microstructural nature of the alloys of this invention. To one suitably trained in metallurgy, the powder metallurgy age hardenable alloys of this invention may be readily distinguished from any cast or wrought ferrous product which may also be of martensitic crystal structure. These differences are readily evident upon the application of suitable physical tests and suitable microscopic examination.

The powder metallurgy age hardening alloys disclosed below appear as a result of investigation in practice and in technical literature to be new for the purposes indicated. In the alloys disclosed below, iron is the principal or base alloy element and it is initially present in powdered form. In may include a trace of carbon of the order of from .005% to 0.2%. One or more elements from the group including manganese, nickel, molybdenum, cobalt, vanadium, niobium, tungsten, zirconium, hafnium and titanium in proportions specified below are added to the iron base prior to or during sintering and form solid solutions with the iron base alloy. Experience has shown that upon proper age hardening treatment following sintering as disclosed below, the powder metallurgy age hardening alloys exhibit a combination of deep hardening and strength never heretofore obtained in powder metallurgy as a result of presently known methods or treatments.

The superior properties obtained in powder metallurgy age hardenable alloys disclosed are due primarily to the following intrinsic properties.

A. The martensite formed in the subject alloys is essentially free from internal stresses which when present would cause weakening of the material. The stress free condition obtained is the result of the quenchless mode of martensite formation in the subject alloys.

B. The martensite formed by this invention without quenching with these alloys responds to the age hardening treatment disclosed, which treatment greatly enhances strength and hardness. Upon the basis of physical metallurgy principles as generally recognized today, it is useful to cite the following crystallographic processes which are assumed to contribute to the age hardening reaction:

(a) Formation of intermetallic compound precipitates of the types Fe_3W_2, Fe_3Mo_2, Nb_3Fe_5, Nb_2Fe_2, VNi_3, VNi_2 and $CoNi_3$, as well as $TiMn_2$, $ZrMn_2$ and $TiNi_3$ within the martensitic matrix when subjected to age hardening may occur. The particular precipitates tending to form are regulated through choice of the alloy composition from among those disclosed herein.

(b) The short range ordering of the substitutional alloying elements such as Co, Ni, V, Mo and others, tending to occur within the martensitic matrix, is another mechanism contributing to enhanced strength and hardness through age hardening.

(c) Additionally, the development of orientation boundaries within the parent martensitic matrix utilizing

activation energy provided by the age hardening heat treatment may further enhance strength and hardness.

It has been stated that the powder metallurgy age hardening alloys herein disclosed differ essentially from other martensitic materials and as evidence of this fact it is pointed out that the alloys herein disclosed have elements added to them to fulfill specific purposes.

(1) An iron base is utilized and comprises a proportion of between 88%–61% of the total alloy. The iron base has the function and purpose of dissolving and being modified by further alloying elements. Carbon may be present, as a trace or contaminant, of the order of from .005% to 0.2%.

(2) Other elements are added as austenite stabilizing elements. These elements are chosen from the group comprising manganese and nickel. Either may be used singly or in combination. The nickel when used alone will normally be present in the proportion of from 9%–18% and the manganese when used will be present in the proportion of from 9%–12% of the total alloy content. When nickel and manganese are both present, they will be present in the proportion of from 9%–20% of the alloy content.

(3) Additional elements may be added as martensite strengthening elements and they are taken from the group comprising vanadium, cobalt, niobium, molybdenum and tungsten, either singly or in combination. The total single or combined amount of elements from this group comprises preferably from 2%–8% of the total alloy content.

(4) Metals may be added, as carbon, nitrogen and oxygen scavenging elements. These are chosen from the group zirconium, hafnium and titanium, either singly or in combination and the total of the single or combined amounts of elements just mentioned will be in the proportion of from ½%–2½%.

(5) Copper may be present in the proportion of not more than 5% of the total alloy content. The copper, when present, serves the purpose of promoting sinterability.

It has been stated that the powder metallurgy age hardening alloys herein disclosed differ, among other respects, from the commonly known alloys in which martensite is capable of formation only upon quenching or otherwise rapid cooling. The accuracy of this statement is in part evidenced by further characteristics of the alloys disclosed herein which include the characteristics of rapid stabilizing of the face centered cubic austenite phase with increased percentages of the austenite stabilizing and martensite strengthening alloying additions. A further characteristic of the alloys disclosed herein is the martensite transforming characteristics of the austenite formed at higher temperatures when it is continuously cooled through temperatures of 1300° F. or lower. This results in essentially complete suppression of ferrite growth in the parent austenite matrix. This is illustrated in FIGURES 1 and 2 wherein there is shown in FIGURE 1 the martensite transformation temperature ranges for a simple base system iron and manganese and in FIGURE 2 a simple base system iron and nickel.

Upon the basis of this data and in accordance with the metallurgical principles which are cited herein, a family of alloy systems meeting the criteria of sinterability, martensitic transformation and age hardenability have been formulated and have been made and verified in practice. Although many different examples may be furnished, there are set out below three typical examples, in each of which the percentage of alloying elements and the temperatures and duration of time cycles and methods are disclosed. Obviously other examples may be cited and the invention is not limited to the particular examples set out below nor to the precise proportions, temperatures and heating cycles. The specific values given for proportions, temperatures, method steps and heating cycles have all been carried out and verified in practice and the values given are satisfactory and in some cases preferred. Variations are contemplated and the invention is therefore not limited to the precise values given.

Example 1.—An alloy composed of 18% Ni, 8% Co, 0.5% Ti, 4% Mo was prepared by furnace melting, casting and hot rolling. Next this alloy was converted to —100 mesh U.S. Sieve Series powder by means of abrasive wheel comminution, flotation, separation and screening. The powder so prepared was blended with 1.0 weight percent stearic acid lubricant and compacted under 50 t.s.i. to form a cold bonded compact of 5.66 gm./cc. apparent density. This compact was initially sintered for one hour at 2100° F. (1149° C.) temperature under an atmosphere of dissociated ammonia. Next the body was repressed under 70 t.s.i. pressure and resintered once more at 2100° F. (1149° C.) temperature under an atmosphere of dissociated ammonia. Apparent density in this condition was 5.89 gm./cc. Following these procedures the body was next heat treated at 1500° F. (816° C.) for one hour under dissociated ammonia protective atmosphere to attain an austenitic condition. Transformation to martensite was next induced by slow cooling to room temperature at the rate of 1000° F. (538° C.) per hour. In this condition, the compact apparent hardness was found to be Rockwell A 34.3. Next the sintered compact was subjected to an age hardening treatment which consisted of holding at 900° F. (482° C.) under a protective layer of loose iron powder for three hours. After this age hardening treatment, the apparent hardness of the compact was found to have increased to Rockwell A 50.5. Additional compacts were prepared using the same starting powder but with additional repressing and sintering steps to achieve a range of apparent densities. Properties obtained for compacts prepared and sintered under these conditions are listed in Table I.

TABLE I

Sintered compacts prepared using comminuted powder

Apparent Density, gm./cc.	Apparent Rockwell A Hardness After Age Hardening	Tensile Strength
5.89	51	
6.56	60	[1] 45,300
6.62	61	[2] 80,150
6.76	68	[1] 97,200

[1] Converted from Transverse Rupture Test.
[2] Determined in Standard Tensile Test.

From this data it is apparent that an exceptional combination of apparent density, hardness and tensile strength has been achieved with these sintered compacts. By extrapolation of this data, it may be predicted that 150,000 t.s.i. tensile strength should be reached for compacts of between 7.0 and 7.2 gm./cc. apparent density.

Example 2.—Metal powders of the following descriptions were prepared as a mechanical mixture:

	Percent
Titanium hydride (—100 mesh)	2.7
Cobalt powder (reduced, —200 mesh)	4.0
Nickel powder (carbonyl —325 mesh)	20.0
Molybdenum powder (reduced, —200 mesh)	8.0
Lithium stearate lubricant (—200 mesh) of total	1.0

A uniform mixture of these powders was obtained by means of tumbling the mixture for forty-five minutes while held in a double cone blender. The blended powder mixture was next compacted under 50 t.s.i. pressure and then sintered thirty minutes at 2100° F. (1149° C.) under dissociated ammonia atmosphere. During sintering thermal decomposition of titanium hydride occurred with the accompanying formation of metallic titanium capable of rapid alloying with the iron matrix phase.

Following this initial sintering treatment the compacts were repressed, again under 50 t.s.i. pressure and then resintered, again under the initial conditions.

The resulting sintered compacts were found to be of 7.07 gm./cc. density and of 52.7 Rockwell A apparent hardness. The compacts were next heat treated and age hardened according to the same procedures followed in Example 1 preceding. Following the heat treatment and age hardening the compacts were found to be of 58.5 Rockwell A apparent hardness and to exhibit 93,300 t.s.i. tensile strength.

From this example it is apparent that this age hardenable powder metallurgy alloy exhibits a most useful combination of sinterability, strength and hardness. Further, it is anticipated that these properties are capable of greater enhancement by refinement and further perfection of the blending, compaction, sintering and heat treatment procedure.

Example 3.—Metal powders of the same description and in the same percentages cited in Example 2, and blended according to the same procedures as cited for Example 2 were prepared as a mechanical mixture. Following blending, the mechanically mixed powders were next melted and atomized in order to yield a fully prealloyed powder having the same composition as the starting mechanical mixture. Melting and atomization were carried out by means of passing the mechanically mixed powders through an oxygen-acetylene metal spraying gun, Metco Type 2P. During passage through this metal spray gun, the mechanically mixed powder blend was heated to approximately 3270° F. (1800° C.) whereupon melting and homogenization occurred. Simultaneously with melting, the alloy was subjected to the disruptive forces of the high velocity gas flow in the flame produced by the gun and was consequently atomized to produce an alloy metal powder. The powder so produced was directed into a water trough to cause solidification and to minimize air oxidation. In final preparation for use, the collected powder was alcohol rinsed, dried and placed through a 100 mesh screen to remove oversized material.

The resulting prealloyed powder was annealed for one hour at 1800° F. (982° C.) temperature in dissociated ammonia atmosphere and again placed through a 100 mesh screen. In this condition, 1.0% weight lithium stearate lubricant was blended with the powder and compacts were pressed under 70 t.s.i. pressure

The compacts were next sintered for thirty minutes at 2100° F. (1149° C.) temperature under an atmosphere of dissociated ammonia. Following sintering the apparent density of these compacts was determined as 7.02 gm./cc. Apparent hardness was 38.2 Rockwell A. Heat treatment and age hardening procedures were next carried out using the same time and temperature sequence described in Example 1. Following heat treatment and age hardening, the apparent hardness of compacts was found to be Rockwell A 45.6. Tensile strength was determined to be 45,000 p.s.i.

It is apparent from these examples that there is produced a powder metallurgy age hardening alloy using (1) comminuted powder metals, (2) mechanically blended powders and (3) atomized prealloyed powder materials. It is also apparent that these same alloys could be produced using powders manufactured by other methods. One example of such an alternative method of powder manufacture would be to reduce a granular mixture of metallic oxides proportioned and blended to yield the desired alloy composition under dry hydrogen atmosphere at high temperature. It is further apparent that halogen salts of the metals selected could in this example be substituted for all or part of the oxides in the mixture. Another example of such an alternative method of manufacture would consist of the thermal decomposition of metal oxides or halogen salts in an electric arc plasma in such proportions as to yield an alloy powder of the desired composition.

The general phenomenon of age hardening referred to in this invention consists of a physical change which takes place in the subject alloys with a resultant increase in the internal cohesiveness. Outwardly this is evident by increased hardness and increased tensile strength which are the effects desired to be produced. The age hardening reaction is induced by a prior solution heat treatment, followed by cooling, followed by an age hardening heat treatment at a second temperature lower than the solution heat treating temperature. The solution heat treatment temperature should consist of a one hour holding period at a temperature not lower than 1400° F. or over 2100° F. Cooling should be at a rate not greater than 4000° F. per hour and should be carried to room temperature. The age hardening treatment should be at between 600° F. and 1000° F. for between one and six hours. A 900° F. age hardening treatment for three hours is preferred.

The expression "protective atmosphere" has been used above. There are many commonly accepted compositions for protective atmospheres suitable to perform the sintering operations described above. For example, there are reducing endothermically generated gases which may appear in suitable formulae of which three appear below:

(a) Nitrogen, carbon monoxide and hydrogen with traces of carbon dioxide and water vapor,

(b) Nitrogen and hydrogen with a trace of water vapor,

(c) Hydrogen alone with a trace of water vapor.

There are neutral protective atmospheres which may appear in a variety of formulae as follows:

(a) Nitrogen associated with carbon monoxide, carbon dioxide and hydrogen. The three latter being present in relatively small quantities together with traces of methene and water vapor.

(b) Combusted ammonia comprising nitrogen and hydrogen in which the nitrogen predominates and there is present a trace of water vapor.

(c) Prepared nitrogen comprising a mixture of substantially all nitrogen with small quantities of carbon monoxide and hydrogen with a trace of water vapor.

Suitable protective atmospheres may include inert atmospheres such as:

(a) Vacuum,

(b) Argon with a trace of water vapor and possibly other elements.

The above listed examples of protective atmospheres are merely illustrative of commonly accepted compositions of suitable protective atmospheres and not exclusive of other possible protective atmospheres and the invention is limited to none of them.

Whereas a preferred manner of carrying out the invention has been described herein, it should be realized that there are many modifications, substitutions and alterations thereto, within the scope of the following claims.

I claim:

1. The method of producing an alloy which comprises the steps of mixing metallic powders of the following metals in the proportions stated, approximately 18% Ni, approximately 8% Co, approximately 0.5% Ti, approximately 4% Mo, approximately 70% Fe; mixing the metallic powders, adding approximately 1% by weight stearic acid lubricant; compacting the mixture of metallic powders and acid and forming a cold bonded compact mass on the order of 6.5 to 7.5 gm./cc.; sintering the compacted mass for approximately one-half to two hours at a temperature of approximately 2100° F. under an atmosphere of dissociated ammonia; thereafter reheating the mass at a temperature of 1500° F. for approximately one hour under an atmosphere of dissociated ammonia; thereafter cooling the mass at room temperature at the approximate rate of 100° F. per hour; and finally age hardening the mass by reheating it at a temperature of approximately 900° F. and maintaining it at that temperature for about three hours under a layer of loose iron powder.

2. The method of producing an alloy which comprises the steps of mixing metallic powders of the following metals in the proportions stated, approximately 18% Ni, approximately 8% Co, approximately 0.5% Ti, approximately 4% Mo, approximately 70% Fe; mixing the metallic powders; adding approximately 1% by weight stearic acid lubricant; compacting the mixture of metallic powders and acid and forming a cold bonded compact mass on the order of 6.5 to 7.5 gm./cc.; sintering the compacted mass for approximately one-half to two hours at a temperature of approximately 2100° F. under an atmosphere of dissociated ammonia; thereafter recompacting the mass and resintering it at approximately the same temperature and in approximately the same atmosphere; thereafter reheating the mass at a temperature of 1500° F. for approximately one hour under an atmosphere of dissociated ammonia; thereafter cooling the mass at room temperature at the approximate rate of 1000° F. per hour; and finally age hardening the mass by reheating it at a temperature of approximately 900° F. and maintaining it at that temperature for about three hours under a layer of loose iron powder.

3. The method of producing an alloy which comprises the steps of mixing metallic powders of the following metals in the proportions stated, approximately 18% Ni, approximately 8% Co, approximately 0.5% Ti, approximately 4% Mo, approximately 70% Fe; mixing the metallic powders; adding approximately 1% by weight stearic acid lubricant; compacting the mixture of metallic powders and acid and forming a cold bonded compact mass on the order of 6.5 to 7.5 gm./cc.; sintering the compacted mass for approximately one-half to two hours at a temperature of approximately 2100° F. under an atmosphere of dissociated ammonia; thereafter recompacting the mass and resintering it at approximately the same temperature and in approximately the same atmosphere; thereafter reheating the mass at a temperature of 1500° F. for approximately one hour under an atmosphere of dissociated ammonia; thereafter cooling the mass at room temperature at the approximate rate of 1000° F. per hour; and finally age hardening the mass by reheating it at a temperature of approximately 900° F. and maintaining it at that temperature for about three hours in air.

4. The method of producing an alloy which comprises the steps of mixing metallic powders of the following metals in the proportions stated, approximately 18% Ni, approximately 8% Co, approximately 0.5% Ti, approximately 4% Mo, approximately 70% Fe; mixing the metallic powders; adding approximately 1% by weight stearic acid lubricant; compacting the mixture of metallic powders and acid and forming a cold bonded compact mass of the order of 6.5 to 7.5 gm./cc.; sintering the compacted mass for approximately one-half to two hours at a temperature of approximately 2100° F. under an atmosphere of dissociated ammonia; thereafter, recompacting the mass and resintering it at approximately the same temperature and in approximately the same atmosphere; thereafter reheating the mass at a temperature of 1500° F. for approximately one hour under an atmosphere of dissociated ammonia; thereafter cooling the mass at room temperature at the rate of 1000° F. per hour; and finally age hardening the mass by reheating it at a temperature of approximately 900° F. and maintaining it at that temperature for about three hours under a non-oxidizing atmosphere.

5. The method of producing an alloy which comprises the steps of mixing metallic powders of the following metals of no more than 80 mesh in the proportions stated, approximately 18% Ni, approximately 8% Co, approximately 0.5% Ti; approximately 4% Mo, approximately 70% Fe; mixing the metallic powders; adding approximately 1% by weight stearic acid lubricant; compacting the mixture of metallic powders and acid and forming a cold bonded compact mass of the order of 6.5 to 7.5 gm./cc.; sintering the compacted mass for approximately one-half to two hours at a temperature of approximately 2100° F. under an atmosphere of dissociated ammonia; thereafter recompacting the mass and resintering it at approximately the same temperature and in approximately the same atmosphere; thereafter reheating the mass at a temperature of 1500° F. for approximately one hour under an atmosphere of dissociated ammonia; thereafter cooling the mass at room temperature at the approximate rate of 1000° F. per hour; and finally age hardening the mass by reheating it at a temperature of approximately 900° F. and maintaining it at that temperature for about three hours.

6. The method of producing an alloy which includes the steps of preparing by any suitable method metallic powders of a variety of metals of not more than 80 mesh size and lubricant in the following proportions, Titanium Hydride—approximately 2.7%, Nickel—approximately 20%, Cobalt—approximately 4%, Molybdenum—approximately 8%, Lithium Stearate—approximately 1%, Iron —approximately 65%; mixing the said metal powder and lithium stearate uniformly; compacting the metal powder into a cohesive mass; sintering the compacted mass for approximately thirty minutes at 2100° F. in an atmosphere of dissociated ammonia; resintering the metal for approximately thirty minutes at approximately 2100° F.; heat treating the compacted and sintered mass at a temperature of approximately 1500° F. for approximately one hour under an atmosphere of dissociated ammonia; and finally age hardening the mass by holding it a a temperature of approximately 900° F. under a layer of loose iron powder for approximately three hours.

7. The method of preparing an alloy which includes the steps of preparing by any suitable method metallic powders of no more than 80 mesh size and lubricant in the following proportions, Titanium Hydride—approximately 2.7%, Nickel—approximately 20%, cobalt—approximately 4%, Molybdenum—approximately 8%, Lithium Stearate—approximately 1%, Iron—approximately 65%; mixing the said metal powder and lithium stearate uniformly; compacting the metal powder into a cohesive mass; sintering the compacted mass for approximately thirty minutes at 2100° F. in an atmosphere of dissociated ammonia; repeating the compacting after the completion of sintering; resintering the metal after the second compacting for approximately thirty minutes at approximately 2100° F.; heat treating the twice compacted and twice sintered mass at a temperature of approximately 1500° F. for approximately one hour under an atmosphere of dissociated ammonia; and finally age hardening the mass by holding it at a temperature of approximately 900° F. under a layer of loose iron powder for approximately three hours.

8. The method of producing an alloy which includes the steps of preparing by any suitable method metallic powders of a variety of metals and lubricant in the following proportions, Titanium Hydride—approximately 2.7% Nickel—approximately 20%, Cobalt—approximately 4%, Molybdenum—approximately 8%, Lithium Stearate—approximately 1%, Iron—approximately 65%; mixing the said metal powder uniformly with the lithium stearate; compacting the metal powder into a cohesive mass; sintering the compacted mass for approximately thirty minutes at 2100° F. in an atmosphere of dissociated ammonia; resintering the metal for approximately thirty minutes at approximately 2100° F.; heat treating the compacted and sintered mass at a temperature of approximately 1500° F. for approximately one hour under an atmosphere of dissociated ammonia; and finally age hardening the mass by holding it at a temperature of approximately 900° F. under a layer of loose iron powder for approximately three hours.

9. The method of producing an alloy which includes the steps of preparing by an suitable method metallic powders of a variety of metals and lubricant in the following proportions, Titanium Hydride—approximately 2.7%,

Nickel—approximately 20%, Cobalt—approximately 4%, Molybdenum—approximately 8%, Lithium Stearate—approximately 1%, Iron—approximately 65%; mixing the said metal powder uniformly with the lithium stearate; compacting the metal powder into a cohesive mass; sintering the compacted mass for approximately thirty minutes at 2100° F. in an atmosphere of dissociated ammonia; resintering the metal for approximately thirty minutes at approximately 2100° F.; heat treating the compacted and sintered mass at a temperature of approximately 1500° F. for approximately one hour under an atmosphere of dissociated ammonia; and finally age hardening the mass by holding it at a temperature of approximately 900° F. in air.

10. The method of producing an alloy which includes the steps of preparing by any suitable method metallic powders of a variety of metals and a lubricant in the following proportions, Titanium Hydride—approximately 2.7%, Nickel—approximately 20%, Cobalt—approximately 4%, Molybdenum—approximately 8%, Lithium Stearate—approximately 1%, Iron—approximately 65%; mixing the said metal powder uniformly; compacting the metal powder into a cohesive mass; sintering the compacted mass for approximately thirty minutes at 2100° F. in an atmosphere of dissociated ammonia; resintering the metal for approximately thirty minutes at approximately 2100° F.; heat treating the compacted and sintered mass at a temperature of approximately 1500° F. for approximately one hour under an atmosphere of dissociated ammonia; and finally age hardening the mass by holding it at a temperature of approximately 900° F. under a non-oxidizing atmosphere.

11. As an article of manufacture, a sintered iron base powder metallurgy age hardened martensitic alloy containing nickel within the range of 9% to 20% and containing also within a range of 2% to 9% at least one of the elements from the group comprising molybdenum, cobalt, vanadium, tungsten and niobium and also containing at least one of the elements within the range of 0.5% to 2.5% from the group of elements comprising hafnium, zirconium, titanium, and containing optionally 7% copper, the complete alloy containing not more than 0.2% carbon.

12. The method of producing a high strength ferrous base powder alloy which includes mixing a relatively large proportion of powdered iron and a relatively smaller proportion of hard metal powder, compacting the materials into a cohesive mass, sintering the mass in a protective atmosphere, cooling it in a manner to produce a martensitic phase substantially free of internal stresses, and thereafter age hardening it through reactions occurring within the martensitic phase contained in the sintered alloy mass.

13. The method of producing a high strength ferrous base powder alloy which includes mixing a relatively large proportion of powdered iron and a relatively smaller proportion of hard metal powder selected from the fourth, fifth or sixth periods of the periodic chart of elements, compacting the materials into a cohesive mass, sintering the mass in a protective atmosphere, cooling it at a non-stressing rate of cooling in a manner to produce martensite, and thereafter age hardening the sintered alloy mass.

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