

1

2,823,988

COMPOSITE MATTER

Nicholas J. Grant, Winchester, Mass., and Claus G. Goetzel, Hastings-on-Hudson, N. Y., assignors to Sintercast Corporation of America, Yonkers, N. Y., a corporation of New York

No Drawing. Application September 15, 1955
Serial No. 534,626

14 Claims. (Cl. 75—5)

The present invention relates to finely divided composition of matter having particular utility in the powder metallurgical production of reinforced heat resistant metal products capable of sustaining high strength properties and high resistance to creep at elevated temperatures up to 1000° C. and higher for prolonged periods of time. The invention also contemplates a method for producing heat resistant articles.

It is well known that considerable progress has been made in recent years in the development of wrought and cast nickel-and-cobalt-base "super-alloys" for use in the production of power plant components for high powered thermal engines such as turbines, rockets, jets and the like. While these alloys have added measurably to the scientific development of such engines, increased operating temperatures of the more recently developed thermal engines to improve their power rating have placed considerable burden on these alloys. It was found that these alloys had definite temperature limitations in that they tended to soften and creep appreciably at temperatures above 900° C.

The typical wrought super-alloy usually comprises a wrought solid solution alloy containing chromium and at least one metal of the iron group as essential alloying ingredients together with hardening elements to stiffen the alloy for use at high temperatures. Generally, the stiffening may be achieved in several ways: (1) by hardening the solid solution matrix by employing such matrix hardening elements as molybdenum, tungsten, columbium, etc.; (2) by employing special elements capable of forming compounds of low solubility which precipitation-harden the alloy, for example titanium, aluminum, zirconium, etc.; (3) by employing other elements which form a second phase upon solidification which hardens the alloy, etc. The hardening by the second method is achieved by heat treatment and may be employed to augment the hardening of the first method. The hardening by the third method is achieved by casting. Most of the conventional super-alloys are cast nowadays.

Generally, most of the wrought super-alloys are susceptible to precipitation hardening. The precipitation hardening elements in the alloy are taken into solid solution by heating the alloy to a high solution temperature, for example 1000° C. to 1250° C., followed by rapid cooling to keep the precipitation hardening elements in solution. The precipitation hardening is then achieved by reheating the alloy at a lower temperature, for example within the range of about 550° C. to 850° C., for a time sufficient to produce a critical dispersion of a fine precipitate throughout the matrix which is generally invisible, even at a magnification of 2000 times and higher when achieving maximum benefit. Such alloys in the hardened condition exhibit improved resistance to creep at elevated service temperatures up to about 900° C. However, at higher temperatures, the alloys tend to soften due to two effects. If the service temperature is in the neighborhood of about 850° C. to 900° C. and slightly higher, the alloys tend to soften due to over-aging. This

2

phenomenon is believed to be due to a coalescence of the fine precipitate to large, coarse particles which is generally accompanied by a falling off in hardness and hence lower resistance to creep. Moreover, when the service temperature is in the neighborhood of 1000° C. to 1100° C. and higher, the precipitate begins to go into solid solution and the alloy softens much as a regular high temperature solution treatment softens or anneals a precipitation hardened super-alloy. When the alloy softens because of the foregoing reasons, it loses its ability to sustain high static and/or dynamic stresses and generally deforms. Furthermore, such alloys tend to form abnormally large grains at the high temperatures and generally become embrittled. Because tolerances and clearances of rotating and stationary members of thermal engines must be kept extremely small, any variation from normal creep can be dangerous and lead to serious damage of the power plant, even to the extent where the whole engine may be temporarily stalled or possibly totally destroyed.

In an attempt to overcome the foregoing difficulties, super-alloys were proposed with higher amounts of hardening elements, e. g. carbon, to further stiffen them so as to increase their sustaining power at elevated temperatures. While this was helpful to a certain extent, the stiffened alloys generally had lower ductility which was accompanied by a low resistance to impact. Moreover, the alloys could not be worked easily and generally were subject to cracking during the hot working operations. This was especially true when the super-alloys contained particularly high amounts of matrix hardening elements, e. g. tungsten, molybdenum, etc., and high amounts of precipitation-hardening elements such as titanium, aluminum, zirconium, etc. Although many attempts were made to overcome the foregoing difficulties, none as far as we are aware, was entirely successful when carried into practice commercially.

In copending application U. S. Serial No. 452,595, filed August 27, 1954, and assigned to the same assignee, it was shown that heat resistant super-alloys with improved sustaining power at elevated temperature, especially sustained resistance to creep at elevated temperatures, well above 800° C. and even above 1000° C., in combination with high resistance to impact, could be produced by employing substantial amounts of a hardening constituent which would normally embrittle the alloy. By employing the hardening constituent in a special manner, it was pointed out that heat resistant compositions could be produced capable of maintaining their stiffness at elevated temperatures which normally cause conventional alloys to soften and creep substantially.

It was proposed in the copending case to use a slip inhibiting refractory compound as the hardener having a high melting point and characterized by a low degree of solubility in the solid solution matrix of the heat resistant alloy in which it was contained. The compound had the property of behaving like a recovery inhibitor, that is, it acted as a deterrent to recrystallization and to abnormal grain growth. The compound was stable and was not prone to decompose substantially at elevated temperatures and, when uniformly dispersed throughout the matrix of a heat resistant alloy, the alloy was capable of sustaining its mechanical properties for prolonged periods of time at elevated temperatures that normally caused similar heat resistant alloys to soften and creep appreciably. The slip inhibitors contemplated in the copending case comprised mainly the carbides, borides, silicides and nitrides of titanium, zirconium, columbium, tantalum, hafnium and vanadium, and also the disilicides of molybdenum and tungsten. The compound was incorporated into the matrix by utilizing powder metallurgy techniques. In the copending case this was achieved by

mixing finely divided slip and recovery inhibitor compound with finely divided heat resistant matrix metal and shaped to a desired configuration by pressing the powder mixture in a die mold by employing a pressure varying from the about 30 to 150 tons per square inch. The resulting body was then sintered at an elevated temperature to consolidate it sufficiently so it could be subsequently hot worked, the sintering being conducted at a temperature of at least about 1100° C. but not exceeding about 5° below the point of incipient fusion at a subatmospheric pressure generally not exceeding about 100 microns and preferably not exceeding about 50 microns. The sintered body was then hot worked, for example by hot extrusion, forging, swaging, etc., until its cross-section had been reduced at least 50% and preferably at least 90% to 95% so that substantially all of the voids had been eliminated after which the hot worked body was fabricated into the desired finished product.

The slip inhibitor phase ranged from about 5% to 20% by volume of the total composition, the balance of which was made up of a ductile nickel or cobalt-base heat resistant alloy. The heat resistant alloys comprised about 5 to 30% by weight of chromium and up to about 25% by weight of iron, substantially the balance of the alloy being at least one metal selected from the group consisting of up to about 90% nickel and up to 70% cobalt, the sum of nickel and cobalt contents being at least 40%, and preferably 50%, of the total alloy composition, allowances being made for the presence of optional amounts of other elements commonly employed in heat resisting alloys. In producing the requisite powder mixture in order to obtain as uniform a dispersion of the slip inhibitor compound as possible, finely divided powder of the heat resistant matrix alloy was used, the maximum particle size not exceeding 40 microns and preferably not exceeding about 5 microns. The slip inhibitor was controlled at a particle size not exceeding 10 microns, and preferably not exceeding two or even one micron. It was found that the uniform dispersion of the slip inhibitor throughout the matrix metal was very important and that prolonged mixing times had to be resorted to in order to achieve as uniform a dispersion as possible. Wet mixing times of the order of about 120 hours and higher in a liquid vehicle, such as xylene, trichlorethylene or carbon tetrachloride, in carbide-lined ball mills containing cemented tungsten carbide balls were usually necessary. The results achieved by the reinforced product of the invention described in the copending case indicated a considerable improvement over conventional type wrought "super-alloys." The product was not only stiffer but was also stronger and resisted softening at high operating elevated temperatures.

The primary disadvantage and short coming of the foregoing method was the fact that even when extremely long mixing times were employed, and exceptionally large batches of the powder ingredients were blended in the mixing mills, a perfect mixture could never be obtained. As a result, it was not possible to obtain an ideal dispersion of the slip inhibitor hard phase in the matrix of the ultimate product produced from the mixed powders. Even when the powders were blended under the best possible mixing conditions, there was still the problem of segregation of the mixed powders during storage, handling, processing, pressing and other steps of the manufacture leading to the ultimate reinforced product. For example, if the powders were stored for any length of time and subjected inadvertently to extraneous vibration usually prevailing in buildings containing large presses, reciprocating vacuum pumps, and the like, the powders tended to segregate due to the marked differences in density between the slip inhibitor phase and the matrix metal. Unless this segregation was caught in the nick of time and the powders re-mixed, the resulting product would not have the best attainable dispersion of the slip inhibitor phase. Where the slip inhibitor phase was de-

ficient in a portion of the final product, the product would be soft, and where the phase was unduly concentrated in another portion of the final product, the product would be hard and somewhat brittle. Such non-uniformity tended to result in unpredictable behavior of the product at elevated temperatures. According to the copending case it was important that the spacing of the hard phase be preferably maintained at an average distance ranging from about 0.1 to 0.5 micron. However, it was not always possible to insure such uniform dispersion without taking infinite care and subjecting the powders to prolonged mixing times.

The present invention overcomes the foregoing disadvantages by providing a novel powder composition comprised of composite particles of controlled composition and size which powders, during storage, are substantially non-segregatable with respect to composition.

The composition of matter contemplated by the invention comprises a free flowing mass of finely divided composite particles in which substantially all of the particles each contain as essential constituents a strong high melting point refractory material, for example high melting point refractory oxides, and a relatively high melting point ductile metal, for example a heat resisting alloy, in integral relation therewith, the composite structure of the powder being of the type where one constituent is substantially covered by the other. The composition of the powder is controlled to contain about 0.5% to 25% by volume of the refractory material, substantially the balance being made up of the ductile metal. It is preferred in practicing the invention that the refractory material be employed over a narrow range of 2% to 15% by volume, the most preferred range being 5% to 10%. The size of the composite powder particles should not exceed 40 microns, with the desired size not exceeding 10 microns and preferably not exceeding 5 microns. The most uniform substantially non-segregatable composite powder with respect to composition and dispersion of the refractory material is obtained at sizes at or below 5 microns.

The high melting point refractory material contemplated by the invention as an essential ingredient of the composite powder includes oxides of calcium, beryllium, magnesium, aluminum, titanium, zirconium, silicon, chromium, thorium, cerium, etc. These and similar refractory materials, which also include the silicides, borides, nitrides and carbides of the refractory metals tungsten, molybdenum, chromium, titanium, zirconium, tantalum, columbium, hafnium, etc., are relatively stable at elevated temperatures and have melting or softening points in excess of about 1600° C.

Ductile metals contemplated by the invention as an essential ingredient of the composite particles include metals having melting points in excess of about 1250° C. Such metals include the iron group metals, iron, nickel and cobalt as well as ductile heat resistant alloys based on these and other metals such as chromium. The ductile metals or alloys which have been found preferably suited for the powder composition include a composition comprising about 5 to 30% by weight of chromium and up to about 25% by weight of iron, substantially the balance of the alloy containing up to about 90% nickel and up to 70% cobalt, the sum of the nickel and cobalt contents being at least about 40%, and preferably 50%, of the total alloy composition. The term substantially the balance when applied to the aforementioned composition does not exclude the presence of other elements in amounts which do not adversely affect the basic characteristics of the ductile alloy used in forming the composite powder. Thus, the alloy may contain in addition to chromium, either tungsten or molybdenum, or both, in amounts not inconsistent with maintaining the ductile properties of the matrix metal. This is also true for other elements which may be present in the ductile metal, such as columbium, tantalum, titanium, aluminum, etc., provided these and the other elements are not present in amounts that pro-

duce phases detrimental to the properties of the alloy, such as the brittle sigma phase in chromium-bearing alloys or other phases. As those skilled in the art will readily understand, small amounts of other elements may be present either incidentally or as regular additions such as manganese, silicon, boron, etc. With respect to the carbon and nitrogen contents, these elements generally do not exceed about 0.25% and about 0.1%, respectively, and preferably should be maintained as low as possible.

The structure and the composition and size of the composite particle are important in achieving the results of the invention. In a preferred embodiment, the composite particles comprise a nucleus of the refractory oxide substantially covered by a controlled layer of ductile metal. As stated hereinbefore, the average composition of the refractory oxide by volume making up the particle may range broadly from about 0.5% to 25% with the intermediate range controlled from about 2% to 15% and the preferred range from about 5% to 10%. The sizes of the phases in the composite particles preferably suitable in forming the desired powder composition for composite particle sizes below 5 microns are given in microns as follows:

Range	Diameter of Oxide Phase	Thickness of Metal Coating
Working.....	Up to 3 (preferably not exceeding 1).	0.05 to 1.0
Preferred.....	0.05 to 0.5	0.05 to 0.5
Optimum.....	0.05 to 0.3	0.05 to 0.2

Utilization of the foregoing type of composite powder enables the production of a reinforced wrought product in which the average distance between the oxide nuclei may be maintained relatively uniformly throughout the product, the interparticle distance being maintained less than 2 microns and usually below 1 micron. The preferred interparticle distance between the oxide nuclei ranges from about 0.025 to 0.5 micron with the most preferred distance for optimum combination of properties in the reinforced product ranging from about 0.05 to 0.4 micron.

Composite powder of the foregoing type is particularly advantageous because of its substantially non-segregatable characteristics and does not require the prolonged mixing times mentioned in the copending case. The composite powder of the aforementioned characteristics may be produced by methods well known in the art. For example finely divided aluminum oxide, or other hard phases, may be coated with an appropriate thickness of nickel or cobalt by chemical deposition under controlled conditions from a suitable aqueous solution containing either one of the metals. Or, if desired, the hard phase may be coated with either of these metals by the thermal decomposition of their respective gaseous carbonyls; or by the thermal decomposition of their halides. The hard phase particles may also be coated with a ductile metal by thermal vaporization in a vacuum, for example with a heat resistant alloy comprising 80% nickel and 20% chromium or other similar heat resistant alloys coming within the broad definition of such ductile alloys disclosed herein. In other words any convenient method for coating the hard phase with a ductile metal may be used in producing the novel powder composition of the invention.

Another type of composite powder composition contemplated by the invention is one in which ductile metal particles are each substantially covered with an integral layer of a hard refractory phase, for example a layer of aluminum oxide. Such a layer may be obtained by coating a ductile metal particle with metallic aluminum, for example by vapor deposition, or by the decomposition of an aluminum halide, etc., followed by an oxidizing treatment at an elevated temperature in an atmosphere oxidizing to aluminum. In similar manner other types of integral hard phase layers may be produced on ductile metal particles from such metals as beryllium (to form beryllia),

magnesium (to form magnesia), calcium (to form calcia), silicon (to form silica), titanium (to form titania), zirconium (to form zirconia), chromium (to form chromium oxide), cerium (to form ceria), etc. The foregoing type of oxide coatings are characterized in that they are brittle. This is very important as it is this characteristic that enables the composite powders to be utilized in the production of sintered wrought articles of optimum density. By subjecting such powders to high compacting pressures, the hard phase coating is fractured sufficiently to achieve metal to metal bonding which through high temperature sintering and hot working results in consolidation of the reinforced product.

The sizes of the phases in the foregoing type of composite powder preferably suitable for the production of reinforced metal products are given in microns as follows:

Range	Diameter of Ductile Metal Phase	Thickness of Hard Phase Coating
Working.....	Up to 5 (preferably not exceeding 2).	Up to 0.3 (preferably not exceeding 0.15).
Preferred.....	0.05 to 1.....	0.001 to 0.1.

The hard phase utilized in this manner for the production of reinforced metal articles, i. e. as the surface coating on the ductile metal particle, will generally give rise to a fragmented or lamellar structure as compared to the other type of composite particle in which the hard phase forms a discrete nucleus surrounded substantially completely by ductile metal forming the matrix.

In producing reinforced metal products from either of these composite powder compositions, the powder is briquetted or shaped at room temperature into ingots at pressures ranging from about 30 to 150 tons per square inch. They may also be hot pressed at temperatures where the metal is still solid in which case the pressures can be below 30 tons per square inch. An example of a powder that can be pressed in this manner is one comprising composite particles having a hard phase nucleus of aluminum oxide covered by a layer of a nickel-chromium alloy, e. g. 80% nickel and 20% chromium, the composite particles not exceeding about 5 microns in diameter with the composition of the hard phase amounting to about 5% by volume of the total composition.

The ingots formed are sintered under substantially non-reactive conditions at an elevated temperature to consolidate them sufficiently so they can be subsequently hot worked. The sintering is preferably conducted at a temperature of at least about 1100° C. but not exceeding about 5° below the point of incipient fusion, e. g. at a subatmospheric pressure generally not exceeding about 100 microns and preferably not exceeding about 50 microns. If necessary, sintering may be carried out in two stages, the first stage being carried out at a lower temperature range than the second stage which may employ a sintering temperature range of up to about 5° C. below the temperature of incipient fusion.

The sintered ingots are then hot worked, for example by hot extrusion, forging, swaging, etc., until their cross-sections have been reduced at least 50% and preferably at least 90% to 95% so that substantially all of the voids have been eliminated after which the hot worked ingots are fabricated into the desired finished products.

In evaluating the capability of the reinforced product of the invention to sustain itself under stress at elevated temperatures, high temperature creep rupture tests are employed. The test comprises heating a test specimen to an elevated temperature, say 1000° C., and determining its rupture life and creep resistance at that temperature in the conventional manner. In this way the reinforced product of the invention can be compared to a similar product produced by conventional methods. Tests have shown that an 80-20 nickel-chromium alloy containing no hard phase already softens appreciably above 600° C. and has unsatisfactory resistance to creep. Even if the alloy contains elemental titanium and/or

aluminum as age hardeners, the alloy softens due to over-aging at 800° C. and higher and solution softens at 950° C. and higher when held at these temperatures for prolonged periods of time. In either case the alloy suffers in its creep properties and is unsatisfactory. However, when the alloy is reinforced by at least about 0.5% to 25% by volume, preferably 5% to 10%, of the hard phase material in accordance with the invention, e. g. with aluminum oxide, the alloy exhibits improved resistance to creep and is able to sustain itself under stress at a temperature range between 850° C. and 1050° C. for prolonged periods of time. The novel composite powder composition of the invention insures the obtaining of uniform products because of its ease of handling and its substantially non-segregatable characteristics.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

We claim:

1. A composition of matter suitable for the powder metallurgy production of wrought reinforced products comprising free flowing finely divided composite particles in which substantially each of the particles contain as essential constituents a strong high melting point hard and substantially insoluble refractory material and a ductile metal of melting point above 1250° C. in integral relation therewith in which one constituent is substantially covered by the other, the particles being substantially non-segregatable with respect to composition, the refractory material ranging from about 0.5% to 25% by volume of the total composition for a particle size of the composite powder of up to about five microns for composite powder in which the metal forms a coating on the refractory material and for composite powder in which the refractory material forms a coating on the metal, the thickness of the metal coating on the refractory material ranging from about 0.05 to one micron and the thickness of the refractory material coating on the ductile metal ranging up to about 0.3 micron.

2. A composition of matter suitable for the powder metallurgy production of wrought reinforced products comprising free flowing finely divided composite particles containing a strong high melting point refractory material integrally coated with a ductile metal of melting point above 1250° C., the amount of refractory oxide ranging from about 2% to 15% by volume of the total composition for a particle size of the composite particles of up to about five microns, the thickness of the ductile metal coating on the refractory material ranging from about 0.05 to one micron.

3. The composition of matter as defined in claim 2, characterized in that the thickness of the ductile metal coating on the refractory material ranges from about 0.05 to 0.5 micron.

4. A composition of matter suitable for the powder metallurgy production of wrought reinforced products comprising free flowing finely divided composite particles in which ductile metal particles of melting point above 1250° C. are each substantially coated with a layer of a strong high melting point refractory material, the amount of refractory material in the powder ranging from about 2% to 15% by volume of the total composition for a particle size of the composite particles of up to about five microns, the thickness of the oxide coating on the ductile metal ranging up to about 0.3 micron.

5. A method for producing reinforced metal products capable of sustaining high strength properties at elevated temperatures which comprises providing free flowing, finely divided composite particles not exceeding 40 microns in size containing as essential ingredients a strong

high-melting point hard and substantially insoluble refractory material as a slip and recovery inhibiting phase and a ductile metal of melting point above 1250° C. in integral relation therewith, whereby one constituent is substantially covered by the other, the amount of the hard refractory material ranging from about 0.5% to about 25% by volume of the total powder composition, shaping said composite powder to a coherent body, sintering the shaped body at an elevated temperature under substantially non-reactive conditions to produce a substantially dense body, hot working said sintered body to reduce its cross-sectional area at least about 50% to eliminate substantially the voids in said body, and then fabricating said hot worked body into a heat resistant article of manufacture, said fabricated article being characterized by a microstructure having a substantially discontinuous and random dispersion of the finely divided slip and recovery inhibiting phase throughout the matrix of the reinforced metal.

6. A method for producing reinforced metal products capable of sustaining high strength properties at elevated temperatures which comprises providing free flowing, finely divided composite particles ranging in size up to about five microns containing as essential ingredients a strong high-melting point hard and substantially insoluble refractory material as a slip and recovery inhibiting phase and a ductile metal of melting point about 1250° C. in integral relation therewith, whereby one constituent substantially coats the other so that when the metal coats the refractory material its thickness ranges from about 0.05 to one micron, and when the refractory material coats the ductile metal its thickness ranges up to about 0.3 micron, the amount of the hard refractory material ranging from about 0.5% to about 25% by volume of the total powder composition, shaping said powder mixture to a coherent body, sintering the shaped body at a temperature of at least about 1100° C. to not greater than about 5° below the point of incipient fusion under substantially non-reactive conditions to produce a substantially dense body, hot working said sintered body to reduce its cross-sectional area at least about 50% to eliminate substantially the voids in said body, and then fabricating said hot worked body into a heat resistant article of manufacture, said fabricated article being characterized by a microstructure having a substantially discontinuous and random dispersion of the finely divided slip and recovery inhibiting phase throughout the matrix of the reinforced metal.

7. The method of claim 6, characterized in that the amount of refractory material by volume ranges from about 2% to 15%.

8. The method of claim 7, characterized in that when the ductile metal covers the refractory material its thickness ranges from about 0.05 to 0.5 micron and that when the refractory material covers the ductile metal its thickness ranges up to about 0.15 micron.

9. A method for producing reinforced metal products capable of sustaining high strength properties at elevated temperatures which comprises providing free flowing, finely divided composite particles ranging in size up to about 5 microns containing as essential ingredients a strong high-melting point hard and substantially insoluble refractory material as a slip and recovery inhibiting phase integrally coated with a ductile metal layer of melting point above 1250° C. of thickness ranging from about 0.05 to one micron, the amount of the hard refractory material ranging from about 2% to about 15% by volume of the total powder composition, shaping said powder mixture to a coherent body, sintering the shaped body at a temperature of at least about 1100° C. to not greater than about 5° below the point of incipient fusion under substantially non-reactive conditions to produce a substantially dense body, hot working said sintered body to reduce its cross-sectional area at least about 50% to eliminate substantially the voids in said body, and then fabricating

9

said hot worked body into a heat resistant article of manufacture, said fabricated article being characterized by a microstructure having a substantially discontinuous and random dispersion of the finely divided slip and recovery inhibiting phase throughout the matrix of the reinforced metal.

10. A method for producing reinforced metal products capable of sustaining high strength properties at elevated temperatures which comprises providing free flowing, finely divided composite particles ranging in size up to about 5 microns containing as essential ingredients a strong high melting point hard and substantially insoluble refractory material as a slip and recovery inhibiting phase forming an integral coating on a ductile metal particle of melting point above 1250° C., the thickness of the refractory material coating ranging up to about 0.3 micron, the amount of the hard refractory material ranging from about 2% to about 15% by volume of the total powder composition, shaping said powder mixture to a coherent body, sintering the shaped body at a temperature of at least about 1100° C. to not greater than about 5° below the point of incipient fusion under substantially non-reactive conditions to produce a substantially dense body, hot working said sintered body to reduce its cross-sectional area at least about 50% to eliminate substantially the voids in said body, and then fabricating said hot worked body into a heat resistant article of manufacture, said fabricated article being characterized by a microstructure

10

having a substantially discontinuous and random dispersion of the finely divided slip and recovery inhibiting phase throughout the matrix of the reinforced metal.

11. A wrought reinforced powder metallurgy metal product capable of sustaining high strength properties and high resistance to creep at elevated temperatures up to about 1000° C. and higher for prolonged periods of time which comprises about 0.5% to 25% by volume of discrete substantially insoluble slip and recovery inhibiting refractory material of up to about 3 microns in size dispersed substantially uniformly through a ductile matrix metal of melting point above 1250° C., the distance between the discrete particles being less than 2 microns.

12. The product of claim 11, characterized in that the amount of discrete insoluble refractory material ranges from about 2% to 15% by volume of the total composition.

13. The product of claim 11 wherein the distance between the discrete particles is less than one micron.

14. The product of claim 13 wherein the distance between the discrete particles ranges from about 0.025 to 0.5 micron.

References Cited in the file of this patent

UNITED STATES PATENTS

2,404,598	Sachse	July 23, 1946
2,580,171	Hagglund et al.	Dec. 25, 1951

U. S. DEPARTMENT OF COMMERCE
PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,823,988

February 18, 1958

Nicholas J. Grant et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, line 27, for "of melting point about 1250° C." read
-- of melting point above 1250° C. --.

Signed and sealed this 22nd day of April 1958.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents

U. S. DEPARTMENT OF COMMERCE
PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,823,988

February 18, 1958

Nicholas J. Grant et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, line 27, for "of melting point about 1250° C." read
-- of melting point above 1250° C. --.

Signed and sealed this 22nd day of April 1958.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents