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D. L. WOOD ET AL
METHOD FOR HARDENING METALS

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Fig. 1.

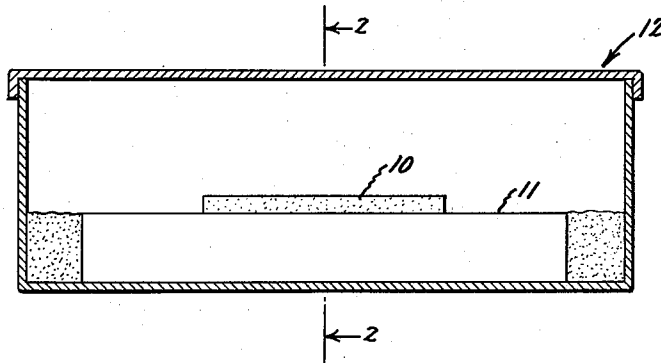
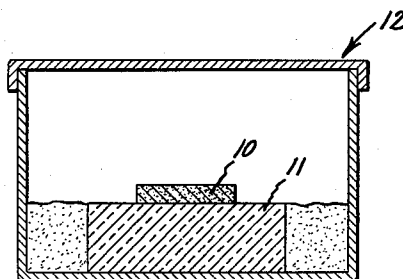


Fig. 2.



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METHOD FOR HARDENING METALS

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5 Claims. (Cl. 75—201)

One method of hardening metals and alloys is by forming a second hardening phase which is preferably dispersed as uniformly as possible throughout the matrix material. A second phase can be formed in many ways, for example, by quenching from high temperatures to set up stress concentrations, or by precipitation hardening and other related methods, the particular method used being more or less dependent upon the type of metal to be hardened.

Hardening phases can also be formed by subjecting the selected metal or alloy to a chosen atmosphere so that the atmosphere will diffuse inwardly into the body and react with one of the components thereof. However, this method is subject to distinct limitations. First, the hardening phases are formed at the gas-metal or reaction interface which moves progressively toward the center of the metal body as long as it is subjected to the presence of the selected atmosphere. Thus, the rate of inward movement of the reaction front is controlled by the gas diffusion rate and long times are needed to form intermediate hardening phases to any appreciable depth.

To achieve the full benefit of the intermediate phase, it must be dispersed throughout the matrix metal as finely divided particles. The smaller particle sizes give greater resistance to recrystallization after deformation of the matrix, as well as increased yield strength. When the previously discussed gas diffusion process is used, the size of the particles depends upon the rate of inward movement of the reaction front, which moves according to a parabolic law. After certain depth has been reached the particles that form exceed optimum size and the full potential of the phase is not attained.

Heretofore, attempts to overcome these problems have generally been inadequate to obtain optimum results. For example powdered metal has been mixed with a suitable amount of a second phase compound and the mixture sintered into an integral body. While the resulting body was acceptable in many instances, the hardening phase was generally too large and too poorly dispersed.

Another method attempted was to prepare a powder mixture compact consisting of a matrix metal and a second metal to form the hardening phase, and to subject the second metal to the conditions necessary to form the hardening phase. Unfortunately, at temperatures necessary to formation of the hardening phase, the powders quickly sintered and the technique operated essentially the same as the gas diffusion method mentioned earlier. It is, therefore, a principal object of this invention to provide a process for forming a second phase which is of proper size and location to strengthen the matrix metal and which is quickly and readily accomplished.

It is another object of this invention to provide a method for forming a metal body having improved mechanical properties by combining a powdered matrix metal alloy containing a more reactive metal in solid solution,

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with a matrix metal compound, and heating the mixture to form a dispersed hardening phase.

Other objects and advantages will be in part obvious and in part explained by reference to the accompanying specification and drawings.

Fig. 1 is a section through a closed container showing one way in which the present process is effected; and

Fig. 2 is a cross section through the container of Fig. 1.

Briefly, the present invention comprises a method for forming a metal body having second phase dispersion to increase the strength and resistance to recrystallization thereof. The body is made by preparing a powder mixture consisting of a compound of a desired matrix metal with a suitable inorganic non-metal and an alloy of the matrix metal containing additions of a second metal having greater affinity for the non-metallic part of the matrix metal compound than the matrix metal. The mixture is then heated to dissociate the matrix metal compound or react the non-metallic part thereof with the second metal and to sinter the powders into an integral body.

More specifically, the present process is effected by preparing a powder mixture of an alloy including a desired matrix metal such as nickel, iron or copper and a predetermined amount of a somewhat more reactive metal, such as aluminum, titanium, zirconium, beryllium, silicon or manganese in solid solution therewith, with suitable additions of a matrix metal compound. The matrix metal compound is composed of the selected metal and non-metal, such as oxygen, carbon, nitrogen, silicon or sulfur. For example, with an iron matrix, an iron oxide, carbide or nitride would be used as the matrix metal compound. In selecting the components, two conditions must be met. First, the non-metal used must diffuse through the matrix metal more rapidly than does the solid solution addition and second, the affinity of the non-metal must be greater for the addition than for the matrix metal. As long as these conditions are met, any combination of metals and non-metals is acceptable.

After the mixture is prepared, it is mechanically compacted, in accordance with usual powder metallurgy techniques, to place the particles in closely associated relationship. The resulting body is then heated to a temperature sufficiently high to cause dissociation of the matrix metal compound and to sinter the compacted particles into an integral body. Dissociation of the compound frees the non metal part and it diffuses into the matrix metal alloy and combines with the more reactive second metal, forming the hardening, second phase. This reaction is preferably effected in a neutral atmosphere or an atmosphere containing a partial pressure of the matrix metal compound. Sintering of the matrix metal powder occurs simultaneously with the formation of the hardening phase so that formation time of the final product is reduced from that needed in existing procedures.

The amount of the matrix metal compound is preferably equal to the amount required to change all of the second, solid solution metal to the hardening phase, although an excess can be used and the remainder removed by reduction with a suitable atmosphere.

Referring to Figs. 1 and 2 of the drawings, a sintered body 10 consisting of a nickel matrix containing an alumina second phase was produced by preparing a mixture of finely divided nickel containing 2 weight percent aluminum in solid solution therewith, with sufficient nickel oxide to provide enough oxygen to oxidize all the solid solution aluminum. The mixture was compacted at about 20 tons per square inch to place all of the particles in contacting relationship. The resulting compact was then placed on the alumina block 11 in closed container 12 and the alumina block surrounded by powdered

nickel oxide, the nickel oxide producing a partial pressure of the matrix metal compound when heated. Sintering at 1200° C. was then effected, dissociating the nickel oxide, and causing the free oxygen to oxidize the solid solution aluminum. Since the oxygen is dispersed throughout the body, it diffuses into the surrounding matrix alloy as sintering takes place. The body was then heated in a hydrogen atmosphere for a period of time sufficient to reduce any remaining matrix metal compound.

A second sample was prepared in a manner similar to that just discussed, except that copper replaced the nickel and copper oxide the nickel oxide. Aluminum was the second metal once again, so that a dispersion of aluminum oxide was formed when the compacted mixture was heated to 1000° C. for one hour.

While the two examples are both directed to oxidation of the second metal, carburizing or nitriding procedures can also be used. For example, a powder compact of an iron-titanium alloy with iron carbide can be used to form a titanium carbide dispersion in an iron matrix.

In describing this invention, it is our intention to cover all changes and modifications of the examples of the invention herein chosen for purposes of disclosure, which do not constitute departures from the spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A method for forming a metal body comprising a matrix having a second phase dispersion to increase the strength and resistance of the body to recrystallization, comprising preparing a powder mixture consisting of a

compound of a matrix metal with a non-metal selected from the group consisting of oxygen, nitrogen, carbon, silicon and sulfur, and an alloy containing a major proportion of the matrix metal having a second metal in solid solution therewith which has a greater affinity for the non-metallic part of the matrix metal compound than does the matrix metal, compacting the mixture to form a body, sintering the compacted body, and thermally dissociating the matrix metal compound and diffusing the non-metallic part thereof through the matrix metal for reaction with the solid solution metal to form the second phase dispersion within the matrix metal, said sintering and said dissociation and diffusion being effected in an atmosphere selected from the group consisting of neutral atmospheres and atmospheres containing a partial pressure of the matrix metal compound.

2. The method recited in claim 1 wherein the matrix metal is selected from the group consisting of iron, nickel and copper.

3. The method recited in claim 1 wherein the body is sintered in a neutral atmosphere.

4. The method recited in claim 1 wherein the body is sintered in an atmosphere having a partial pressure of the matrix metal compound.

5. The method recited in claim 1 wherein the amount of matrix metal compound present is equal to that required to change all of the solid solution metal to the second phase.

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