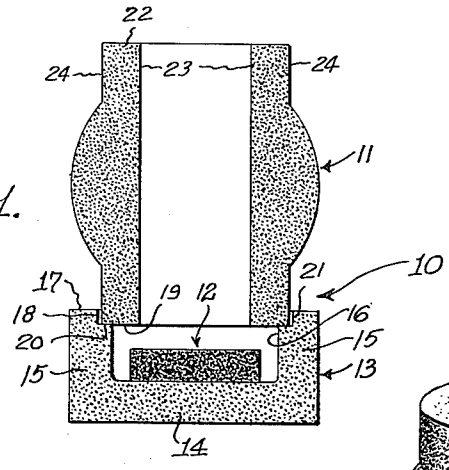
April 19, 1955 J. HALLER 2,706,694

PROCESS OF EXTERNALLY INFILTRATING POWDERED METAL ARTICLES

Filed March 15, 1952

Fig. 1.



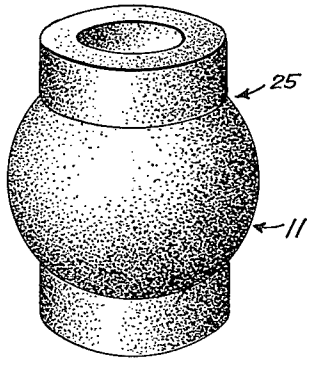
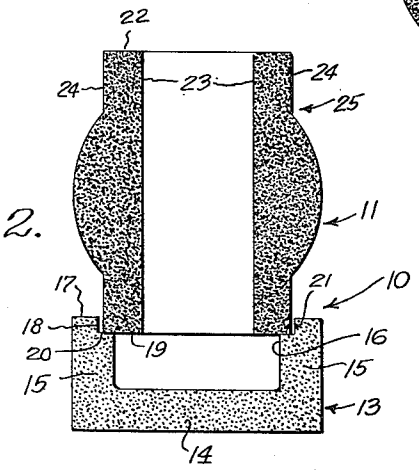


Fig. 3.

Fig. 2.



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PROCESS OF EXTERNALLY INFILTRATING POWDERED METAL ARTICLES

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2 Claims. (Cl. 117—112)

This invention relates to powder metallurgy and, in particular, to processes of infiltrating powdered metal articles with other metals or alloys.

One object of this invention is to provide a process of infiltrating powdered metal articles with a different metal or alloy to strengthen or densify the article whereby the infiltration is accomplished without eroding the surface of the article, as ordinarily occurs during external surface infiltration of such articles.

Another object is to provide a process of infiltrating powdered metal articles wherein the article is infiltrated from the bottom upward, thereby enabling the gases in the article to be expelled upward and out through the top of the article, unimpeded by the infiltration of the metal, as is the case when the infiltration is carried out from the top of the article downward, as in previous processes of infiltration.

Another object is to provide a process of infiltrating powdered metal articles wherein the bottom of the article to be infiltrated rests upon a powdered metal receptacle in which the infiltrating metal or alloy is placed, so that the infiltrating metal or alloy must first travel through the pores of the receptacle before it reaches the article.

Another object is to provide a process of infiltrating powdered metal articles of the foregoing character wherein the receptacle is made of a powdered metal having an affinity for the infiltrating metal so that the erosion tendency or appetite of the infiltrating metal for the metal of the article to be infiltrated is removed as it passes through the pores of the receptacle and reacts with the metal thereof.

Other objects and advantages of the invention will become apparent during the course of the following description of the accompanying drawings, wherein:

Figure 1 is a central vertical section through a powdered metal article to be infiltrated, resting upon the upper edge of a powdered metal receptacle containing a slug of the infiltrating metal, before sintering;

Figure 2 is a view similar to Figure 1, but showing the relationship of the parts after sintering and after the slug of infiltrating metal has passed through the receptacle and into the article; and

Figure 3 is a perspective view of the article after infiltration.

In the manufacture of powdered metal articles as hitherto practised, it has been found beneficial to infiltrate the article with a different metal in order to increase its density and also its strength. In particular, powdered iron articles have been infiltrated by copper or by a copper-zinc alloy for this purpose, but during the infiltration process, the surface of the article becomes eroded at the location where it has been in contact with the slug or lump of infiltrating metal because of an apparent affinity or appetite of the infiltrating metal for the metal being infiltrated. Furthermore, when the infiltration is carried out from the top of the article downward, as by placing the slug or lump of infiltrating metal on top of the article to be infiltrated, it has been found that the flow of the infiltrating metal downward through the article opposes and interferes with the escape of the gases coming out of the article and proceeding upward through its pores as a result of the sintering heat. As a result of this interference, the capillary action of infiltration has been found to be retarded by the rising gases so that full infiltration was not obtained and, as a result, it was necessary to infiltrate the article by a repetition of the process.

The present invention, however, provides a process in

which surface erosion is prevented and at the same time, the escaping gases and the capillary action of the infiltrating metal do not interfere with one another. To accomplish this, the process of the present invention infiltrates the article from the bottom upward, so that the gases escape upward through the pores of the article ahead of the progress upward of the infiltrating metal by the force of capillary attraction. Moreover, the infiltrating metal is also preferably placed out of direct contact with the article by being placed in a porous powdered metal receptacle which is preferably of the same powdered metal as the article to be infiltrated, so as to satisfy the affinity or appetite of the infiltrating metal for the powdered metal before reaching the article. During sintering, therefore, the infiltrating metal melts in the cavity of the receptacle and flows upward through its side walls and enters the bottom of the article which rests upon the side walls of the receptacle, moving upward by capillary attraction without interfering with or being impeded by the escape of the gases upward through the pores of the article.

Referring to the drawing in detail, Figures 1 and 2 show a powdered metal article infiltration assembly, generally designated **10**, according to the present invention before the infiltration has commenced. In Figure 1, the article is stippled light gray before infiltration and in Figure 2, dark gray after infiltration to represent the increase in density resulting therefrom. The infiltration assembly **10** includes the porous powdered metal article or workpiece **11** which is to be infiltrated, the slug or lump **12** of the infiltrating metal, and the powdered metal receptacle **13** containing the slug **12** and interposed between the latter and the article **11**.

The porous powdered metal article **11** to be infiltrated is shown in the form of a sleeve element for a self-aligning bearing, but it will be obvious that any other article which can be similarly arranged may be similarly infiltrated by using the same or a similar process. It is preferable that the receptacle **13** be made from the same kind of powdered metal as the article **11** to be infiltrated, so that any affinity of the infiltrating metal **12** for the powdered metal of the article **11** which is likely to cause erosion will be satisfied before reaching the article **11**. In order to speed up the infiltration, however, the receptacle **13** may be made of coarser porosity than the article **11**, such as of 80 mesh iron powder where the article **11** is made from 100 mesh iron powder, namely iron powder which passes through 80 mesh and 100 mesh screens respectively.

The receptacle **13** is preferably in the form of a cup or boat having a bottom wall **14** and a side wall **15** containing a cavity of recess **16** for receiving the infiltrating metal **12**. The top **17** of the receptacle **13** is preferably provided with a recessed or countersunk portion **18** for receiving the bottom **19** of the article **11** so as to rest upon the annular shoulder **20** thereof which is sunk below the level of the top **17** by an amount equal to the height of the recess side wall **21** (Figure 1).

If the article or workpiece **11** is made from powdered iron, the infiltrating metal slug or lump **12** may consist of pure copper or a copper zinc alloy preferably in the proportion of 85 parts of copper to 15 parts of zinc. Alternatively, an alloy of 70 parts of copper to 30 parts of zinc may be used, especially where the process is carried on out of contact with the atmosphere. If, on the other hand, the article **11** is of powdered bronze, it may be impregnated by the use of a slug or lump **12** of metallic lead, either by itself or with the addition of a small quantity of antimony for raising the melting point of the lead and increasing its compression strength.

In the process of infiltration of the present invention, the infiltrating metal slug **12** is placed in the cavity **16** of the receptacle **13**, the article **11** placed in the recess **18**, and the assembly **10** thus formed placed in a sintering oven and raised to the sintering temperature. Where the article **11** is made of powdered iron and infiltrated with an alloy composed of 85 parts copper to 15 parts zinc, an infiltration temperature of approximately 2020° F. has been found satisfactory.

During the process, as the temperature is raised within the sintering oven, the infiltrating metal lump or slug **12** melts and passes into the pores of the powdered metal

receptacle 13, proceeding upward through the side walls 15 thereof by the force of capillary attraction overcoming the force of gravity. As the infiltrating metal passes through the pores of the powdered metal receptacle 13, its affinity or appetite for the powdered metal which would otherwise cause erosion is satisfied, so that by the time the infiltrating metal reaches the shoulder 20 in the recess 18 near the top 17 of the receptacle 13, the infiltrating metal 12 will cross the boundary shoulder 20 and enter the bottom end 19 of the article 11 without materially eroding the latter. As the sintering continues, the infiltrating metal continues to rise through the pores of the article 11 until it reaches the top thereof, provided that a sufficient amount of the infiltrating metal 12 is employed. Obviously, by varying the amount of infiltrating metal in the slug or lump 12, the density of infiltration of the article 11 may be varied.

Meanwhile, during the infiltration operation, the heating of the powdered metal article 11 causes the gases entrapped therein to be expelled, and these gases move upward through the pores of the article 11 and escape freely from the top 22 and inner and outer sides 23, 24 thereof without their escape being impeded by the passage of the infiltrating metal through the pores of the same article, since both are traveling in the same direction, but one above the other. Moreover, the gases being lighter and more penetrable, will naturally escape through the top and sides 22, 23, 24 faster and the infiltrating metal 12 will rise from the bottom 19 thereof by capillary attraction in the infiltration process of the present invention as ordinarily carried out, for reasons explained more fully below.

During the sintering operation, the infiltrating metal slug or lump 12 completely disappears if the volume of the pores in the article 11 is sufficient to absorb it. When the infiltration has been completed, as shown in Figure 2, the infiltrated article 25 is removed from the recess 18 in the receptacle 13 without difficulty, as there is substantially no adhesion between the article 25 and the receptacle 13. Moreover, it is found that as a result of the process of the present invention, the bottom surface 19 and other surfaces of the finished article 25 are completely free from erosion because of the fact that the affinity or appetite of the infiltrating metal 12 has been satisfied already during its travel through the pores of the receptacle 13.

By employing a smaller quantity of infiltrating metal in the lump or slug 12 than is required to completely impregnate the powdered metal article 11, a partial impregnation or infiltration thereof in a first manner may be accomplished. Partial infiltration may also be accomplished in a second manner by terminating the infiltration before the slug or lump 12 has completely disappeared herein. By partial infiltration in the second manner, the portion of the article 11 nearest the receptacle 13 may be more densely infiltrated than the portions more remote therefrom, such as, for example, the top portion of the article 11. During partial infiltration in the second manner, namely without completely absorbing the entire lump or slug 12, the infiltration is terminated when the infiltrating metal has risen to the level desired, merely by removing the assembly 10 from the sintering oven.

If, instead of the above-mentioned copper-zinc alloy, an infiltrating metal consisting of copper alone is used to infiltrate a powdered iron article in a powdered iron receptacle, the copper melts at 1981° F. and begins to flow over the bottom of the cavity 16 in the receptacle 13, absorbing a quantity of the iron as it passes into the pores thereof and upward through its side walls 15.

It has been found in actual experience that when sintering and infiltration have been terminated before completely and solidly filling the pores of the article 10, the infiltrated article does not ordinarily adhere to the cup 13. It will be obvious, however, that, if infiltration has been carried out to the extent of completely and solidly filling the pores of the article 11, any adhesion of the article to the cup can be prevented by removing the article from the cup while the assembly 10 is still hot and before solidification of the metal sets in.

The reason that under conditions of partial infiltration in the above-mentioned first manner, the article 11 does not adhere to the cup 13, arises from the fact that when the metal in the lump or slug 12 melts, it proceeds through the pores of the cup 13 and thence upward through the article 11 to the top 22 thereof by capillary attraction. Thus, the infiltrating metal first fills the pores nearest the top 22 and then spreads downwardly gradually toward the cup 13, the bottom portion of the article 11 nearest the cup 13 being the least infiltrated, provided of course that the amount of metal in the lump or slug 12 is insufficient in quantity to completely and solidly fill the pores of the article 11. The result is that the bottom portion of the article 11 retains some porosity even though the pores of the upper portion have been filled, and where porosity still exists, adhesion will not occur. Proof of this fact is seen when it is attempted to braze together two powdered metal articles. If the articles have not been completely and solidy infiltrated, the brazing metal will disappear into the pores at the interface and will not cause adhesion. In order to accomplish brazing, each of the articles must be approximately 100% infiltrated so that no pores will occur at the interface into which the brazing metal can disappear.

It will be obvious that other metals may be infiltrated into other powdered metal articles in the same manner described above. For example, a porous powdered bronze article may be similarly infiltrated by means of a pellet or slug of metallic lead in a porous powdered bronze receptacle upon which the bottom of the article rests during sintering. By heating the infiltration assembly 10 to a temperature above the melting point of lead and below the melting point of bronze, the lead becomes molten and makes its way by capillary attraction through the pores of the powdered bronze receptacle upward into the bottom of the powdered bronze article, thereby infiltrating the latter. Similarly also, a powdered aluminum article may be infiltrated with metallic thallium by sintering an infiltration assembly 10 consisting of the porous powdered aluminum article 11 placed on the rim of a porous aluminum cup or receptacle 13 containing the pellet or slug of metallic thallium 12. The sintering is caused to take place at a temperature above the melting point of thallium but below the melting point of aluminum. An article of powdered aluminum alloy, such as Duralumin, may also be similarly infiltrated with metallic thallium. In such instances, the porous powdered bronze of aluminum cup or receptacle 13 is also preferably of a coarser porosity than the porosity of the article to be infiltrated.

What I claim is:

1. A process of externally infiltrating a porous powdered metal article wtih another metal while preventing surface erosion thereof, said process comprising providing a porous article-protecting cup of powdered metal of substantially the same kind as the metal of the article to be infiltrated, placing said article on a higher lever than said cup with the bottom portion of said article disposed in surface contact with the top of the rim of said cup, placing in the bottom of said cup a metal which is infiltratable into the pores of the powdered metal of said article and cup but is of a lower melting point than the melting point of the metal of said article and cup, and melting said infiltratable metal by heating the thus assembled article and cup to a temperature higher than the melting point of said infiltratable metal but lower than the melting point of the metal of said article and cup, whereby to cause the molten infiltratable metal to flow through the pores of said protecting cup upwardly through the side walls of said cup by capillary attraction into the pores at the bottom of said article and simultaneously to expell gases therein upwardly through the upper portion thereof while the protecting cup neutralizes the eroding effect of the infiltrating metal before the infiltrating metal reaches the metal of the article to be infiltrated.

2. A process of externally infiltrating a porous powdered metal article with another metal while preventing surface erosion thereof, said process comprising providing a porous article-protecting cup of powdered metal of substantially the same kind as the metal of the article to be infiltrated, placing said article on a higher level than said cup with the bottom portion of said article disposed in surface contact with the top of the rim of said cup, placing in the bottom of said cup a metal which is infiltratable into the pores of the powdered metal of said article and cup but is of a lower melting point than the melting point of the metal of said article and cup, and melting said infiltratable metal by heating the thus assembled article and cup to a temperature higher than the melting point of said infiltratable metal but lower than the melting point of the metal of said article and cup, whereby to cause the

molten infiltratable metal to flow through the pores of said protecting cup upwardly through the side walls of said cup by capillary attraction into the pores at the bottom of said article and simultaneously to expel gases therein upwardly through the upper portion thereof while the protecting cup neutralizes the eroding effect of the infiltrating metal before the infiltrating metal reaches the metal of the article to be infiltrated, said cup being of powdered metal of a relatively coarser porosity than the porosity of the powdered metal article.

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