Feb. 15, 1944. E. E. ELLIS 2,341,860

METHOD OF MAKING CHAMBERED METALLIC ARTICLES

Filed Feb. 9, 1942

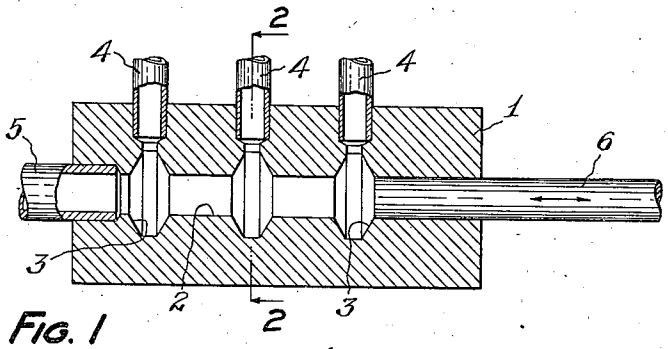


FIG. 1

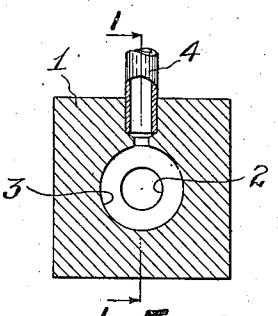


FIG. 2

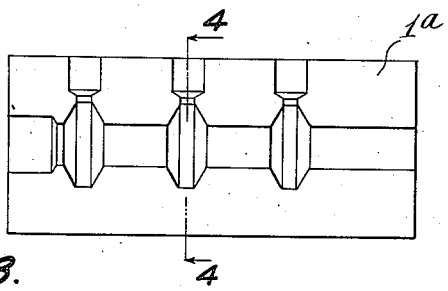


FIG. 3.

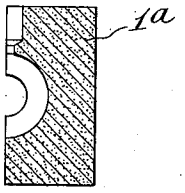


FIG. 4.

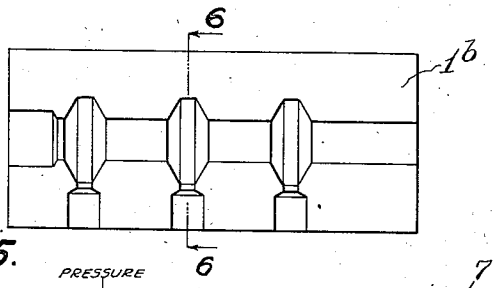


FIG. 5.

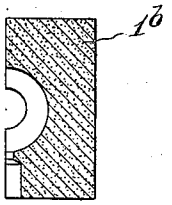


FIG. 6.

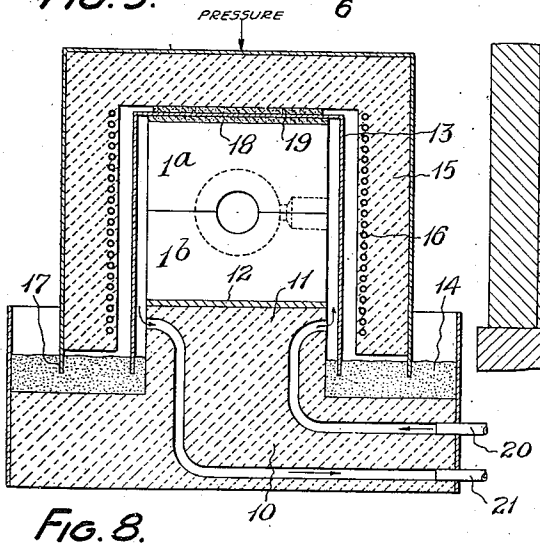


FIG. 8.

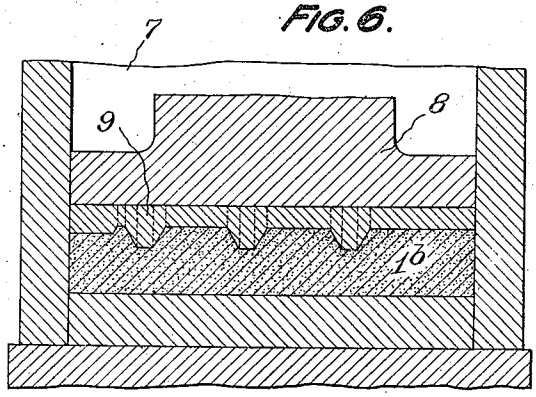


FIG. 7.

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METHOD OF MAKING CHAMBERED METALLIC ARTICLES

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Application February 9, 1942, Serial No. 429,996

1 Claim. (Cl. 75—22)

This invention relates to a method for making metal articles having internal cavities and/or external contours of intricate configuration.

Various articles such as valve bodies, engine pistons, and like hollow articles have been made in the past by casting molten metal about suitably shaped cores by the processes generally known as permanent mold casting or die casting. Some articles of the type described are of such configuration, however, that the core which is used cannot be removed readily from the casting except by breaking it apart. Sand and plaster cores predominate for such articles, soft or "green" cores being used generally. Casting processes, however, sometimes fail to meet the requirements of a production plan which involves a high rate of production at low cost. This difficulty, so far as hollow articles are concerned, has heretofore been avoided to some extent by parting the article in such a manner that it may be built up from a number of different pieces corresponding to different parts of the finished article. Under such a plan the various pieces are formed separately from each other by casting in sand, by die-casting, by permanent-mold casting, or otherwise, and are subsequently machined, where necessary, and assembled together by bolting, riveting or otherwise so as to form a composite article having the desired configuration. It will be appreciated, however, that a built-up or composite article made in this latter manner necessarily includes a number of joints which ordinarily would not be liquid or gas tight. Where such fluid tight joints are required, it is customary and usually necessary to finish the matching surfaces of the separate pieces by a lapping process or by other similar fine finishing process. Such finishing operations are apt to be expensive and, even when employed, may not produce a joint which can be relied upon to remain gas or liquid tight over prolonged periods of use in service.

The present invention is directed to a process for making built-up or composite articles of the type described which are free from such joints and which therefore avoid the unreliability and expense mentioned above. According to the invention, an article such as a low pressure valve body having a rather intricate series of cavities within it is formed by powder metallurgical processes. In practicing the invention, a number of different work pieces, each of which corresponds to a different part of the desired article, are formed by briquetting metal powders. These individual briquettes are then assembled together so as to form a composite briquette having substantially the configuration desired in the finished article. The composite briquette is then sintered with or without the application of pressure and at a temperature which is sufficiently high to bond the individual briquettes together into an integrated whole. By giving adequate consideration to the briquetting pressures, the sintering temperature, and sintering pressure (when used), the joints between the various briquettes can be almost wholly effaced, and the porosity of the article may be made so low that the finished article compares favorably with cast metals so far as liquid or gas tightness at low pressures is concerned.

The objects and features of merit of the invention may be explained more fully through reference to the accompanying drawing:

Fig. 1 is a longitudinal sectional view of a valve structure, the body of which may be made in accordance with the invention, the section being taken on the line 1—1 of Fig. 2.

Fig. 2 is a transverse sectional view of the mechanism taken on the line 2—2 of Fig. 1.

Fig. 3 is an inner side view of one-half of the valve body as made in accordance with the invention.

Fig. 4 is a sectional view taken on the line 4—4 of Fig. 3.

Fig. 5 is an inner side view of the other half of the valve body.

Fig. 6 is a sectional view taken on the line 6—6 of Fig. 5.

Fig. 7 illustrates one mode of briquetting a half of the valve body by using a male die on the compression ram.

Fig. 8 illustrates diagrammatically one manner in which pressure may be applied to the composite briquette during sintering.

The valve structure shown in Fig. 1 consists of a valve body 1 having a central bore 2 extending longitudinally therethrough; a series of concentric grooves 3, 3 is provided in spaced relation along the bore, and each communicates through an outlet tube 4 to the machine or device which is to be controlled by the valve assembly. An inlet tube 5 conducts fluid into the central bore, and a piston 6 is arranged to slide longitudinally in the bore thereby to control the passage of fluid to the various outlet tubes.

In accordance with the present invention, the valve body 1 is made by powder metallurgical processes, the valve halves 1*a* and 1*b*, shown in Figs. 3 and 5 respectively, being formed from metal powders by briquetting the powders in suit-

able molds. Thus each half may be formed by introducing powders of one or more metals, or of one or more alloys, or of one or more metals mixed with one or more alloys, into a rectangular mold cavity 7 as illustrated in Fig. 7. The dimensions of the mold cavity correspond substantially to the length and width of the valve half which is to be formed. The amount of powder which is introduced into the mold should be sufficient to form a briquette of the desired thickness when the powder has been compressed cold to the desired density. The powder layer within the mold is compressed under suitable pressure to form a briquette which may be handled when it is subsequently removed from the mold and which will sinter to the required low porosity. The pressure needed for this purpose will, of course, depend upon the kind and nature of the powder which is being formed, and upon its composition. Where the powder is reduced-oxide iron powder, a pressure of about 66 tons per square inch is suitable.

The bore holes and grooves which are required in the briquette may be provided in several ways. For example, the plunger 8 which is used to effect compression of the powder layer, may carry a suitable male die 9 capable of forming the half-bores and half-grooves in the powder as the latter is being briquetted. This method is illustrated in Fig. 7. Alternatively, the face of the plunger 8 may be flat so that it forms a smooth faced briquette having neither the bore nor the grooves in it. In the latter case, the briquette is removed from the mold and the grooves and bores are then machined into it. It will be understood that the briquette is strong enough before sintering to be handled and to be subjected to machining operations, but that it yet lacks the strength and toughness of a metallic body. Consequently, it may be machined quite easily, behaving much like natural graphite in this respect. The usual rotary routing tools may be used to cut the cavities in the briquette.

After the valve halves have been formed by either of the foregoing processes or by other processes of like nature, they are assembled together with the bores and grooves of each half in register with the bores and grooves of the other half. The assembly is then introduced into a furnace. Preferably the furnace should be capable of subjecting the assembly to moderate pressure while heating it, and preferably it should be constructed to provide a neutral or non-oxidizing atmosphere around the assembly during heating. Such a furnace is indicated diagrammatically in Fig. 8. For a more detailed description of its structure, reference should be made to United States Patent No. 2,258,431, issued to S. K. Wellman. The furnace consists of a base 10 having a central loading stage 11 on which the briquettes are placed. A plate 12 of graphite may be disposed between the stage and the briquette, as illustrated. A sheet metal shell 13 of cup-shaped construction is placed with its open side down so as to surround the briquette and the loading stage, and so that its bottom edges extend into a loose layer 14 of suitable granular sealing material, such as sand. Heat is applied by means of a bell-shaped cover 15 having electric resistors 16 suitably carried on its inner side walls. The bell-shaped cover rests on top of shell 13 so that its weight may be carried by the briquette. The bottom flange 17 on the cover extends into the layer 14 of sealing material. If the weight of the cover is not enough to apply the desired pressure to the briquette, additional pressure may be applied to the top wall of the cover, as indicated. A graphite plate 18 may separate the shell 13 from the top of the briquette, and a suitable bearing plate 19 may be disposed between the shell and the top wall of cover 15. Provision is made for introducing a neutral or non-oxidizing gas into the chamber formed by shell 13 around the briquette. This may be done conveniently by means of inlet tube 20 and outlet tube 21.

The pressure which is applied to the composite assembly of briquettes during sintering should be sufficient to press the two halves firmly together, but of course, should not be so excessive as to deform the briquettes. A pressure of between about 5 and 50 pounds per square inch of the surfaces to be united is usually sufficient, but the pressure which is used depends largely on the kind of powdered metal which is used and its composition. As will be explained below, the pressure which is used is related to the work-hardenability of the metals in the powders, and since this property of metals varies with the kind and composition of the powder, the pressure which is needed varies also. Where the briquettes are formed of iron powder which has been briquetted at pressures ranging from about 44 to 66 tons per square inch, a pressure of about 35 pounds per square inch is sufficient during the sintering step.

During sintering, the temperature should not exceed the melting point of the predominant metal of the briquette, and should preferably be well below the temperature which would cause the briquettes to melt. Where the briquettes are formed of a mixture of metal powders, or of alloy powders mixed or not with single metal powders, the sintering temperature may be sufficiently high to melt one or more of the minor components of the mixture without melting the major components. Where the briquettes are composed of iron, for example, a temperature of 1800° F. is adequate if the briquettes are heated to this temperature for a period of about 5 minutes or more.

As previously indicated, if due regard is given to the temperature and pressure employed in the sintering step, and if the briquettes have been suitably compressed prior to sintering, the sintering operation is effective in uniting the two halves firmly together. Under proper conditions, such as those indicated heretofore for iron powders, the joint may be so completely effaced that microscopic inspection of the assembly after sintering will fail to show that a joint originally existed between the two briquettes. After the assembly has been sintered under such conditions, it exhibits most of the properties of dense metal and may be drilled and tapped, if necessary, and may have the inlet tube 5 and the outlet tubes 4, 4 secured to it by soldering or brazing or otherwise. Due in part to shrinkage which is sometimes apt to occur during sintering, the sintered assembly may need to be subjected to a finishing operation. In valve body 1, this finishing operation would usually consist merely in reaming bore 2 so as to fit piston 6. It will be understood that the dimensions of the briquette may be adjusted so as to compensate at least in part for any shrinkage which may occur during sintering.

I have found that when the valve body is composed of iron, and has been briquetted and sintered in a reducing or non-oxidizing atmosphere under the conditions indicated above, the density is around 90% of that of cast iron. I

have also found that, as would be expected from such a density, the valve body has adequate gas and liquid tightness when tested under such moderate pressures as 50 pounds per square inch.

Without wishing to be limited by the theory here expressed, I wish to indicate the factors which, in my opinion, are responsible at least in part for the low porosity of the assemblies made by my process, and for the effacement of the joints. It is my belief that the cold briquetting step, in which the powders are compressed under relatively high pressures of many tons per square inch, imparts cold working to the individual grains of metal powder. As is well-known, cold worked metals undergo recrystallization when they are subsequently heated to temperatures which impart a somewhat critical amount of atomic mobility to the crystalline metals. When this mobility has been attained, the cold-worked particles of metal undergo grain growth by accretion; that is, the more severely strained particles undergo an atomic rearrangement or recrystallization in which the fundamental crystal structure of the metal is restored, but in undergoing this rearrangement, adjacent particles may also be absorbed into the new structure. The result is that certain fragments of the cold-worked metal increase in size by gradually consuming other adjacent fragments. It is my opinion that such action, which occurs when the cold-pressed briquettes are sintered, unites the particles of powder much more closely than is the case when unstrained powders are sintered together. This closer uniting of the particles is believed to account in part for the reduced porosity. I believe also that the occurrence of recrystallization and grain growth aids materially in effacing the joints between the various briquettes since when conditions are such that grain growth is sufficiently pronounced during the sintering operation, the growth will take place across the various joints of the composite assembly. Such growth accordingly integrates the particles of different briquettes into new grains which are as much a part of one briquette as of another. The result is that the particles of metal lying in the interface between two briquettes recrystallize and grow into solid grains of metal which join the two briquettes into one, thereby effacing the joint.

From the foregoing disclosure of the invention, it will be recognized that the invention is characterized by the joining together of cold pressed, unsintered briquettes by a sintering process carried out at temperatures which utilize the tendency of the cold worked particles of metal in the briquettes to undergo recrystallization and grain growth. It is characterized further by the use of briquettes which are made by process steps which produce cold worked and strained particles within and particularly at the surfaces of the briquettes. It is also characterized by the concept of using such cold pressed and strained briquettes to form an unjointed hollow body by uniting together a plurality of separately formed briquettes. When these characterizing principles are employed, a process is provided which offers numerous advantages over prior art processes. For example, all the well-known advantages of the powder metallurgy art over the casting art are embodied. These include a low unit cost of manufacture, a high production rate, accuracy of details, and the opportunity which is afforded to employ the aggregative characteristics and properties of sintered conglomerate compositions as distinguished from homogeneous compositions. Furthermore, the process makes it possible to produce unjointed articles which might be made only with great difficulty by following conventional casting procedures. The extent to which this latter advantage may be utilized will be apparent to those skilled in the art, who will also realize that the article described above and illustrated in the drawings is but one of a large number of diverse articles which can be made by following the principles of the invention. In view thereof, it should be understood that the foregoing description and the illustrations should not be regarded in a limiting sense.

Having now disclosed the invention, what is claimed is:

The method of making a chambered metallic fitting having one or more cavities therein which are substantially symmetrical about a plane extending through the body, said method comprising the steps of briquetting reduced-oxide iron powder under a pressure between about 44 and 66 tons per square inch to form a pair of briquettes which correspond to the two parts of the said chambered metallic fitting as parted along said plane; assembling said briquettes together with their marginal boundaries and cavities in register with each other; applying pressure of upwards of 35 pounds per square inch to said assembled briquettes on lines perpendicular to the parting plane between them and meanwhile heating said assembled briquettes to a sintering temperature of about 1800° F. to substantially efface visible joints between the said halves.

EDWARD ERNEST ELLIS.