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(54) SUPERDEFORMABLE/HIGH STRENGTH METAL ALLOYS

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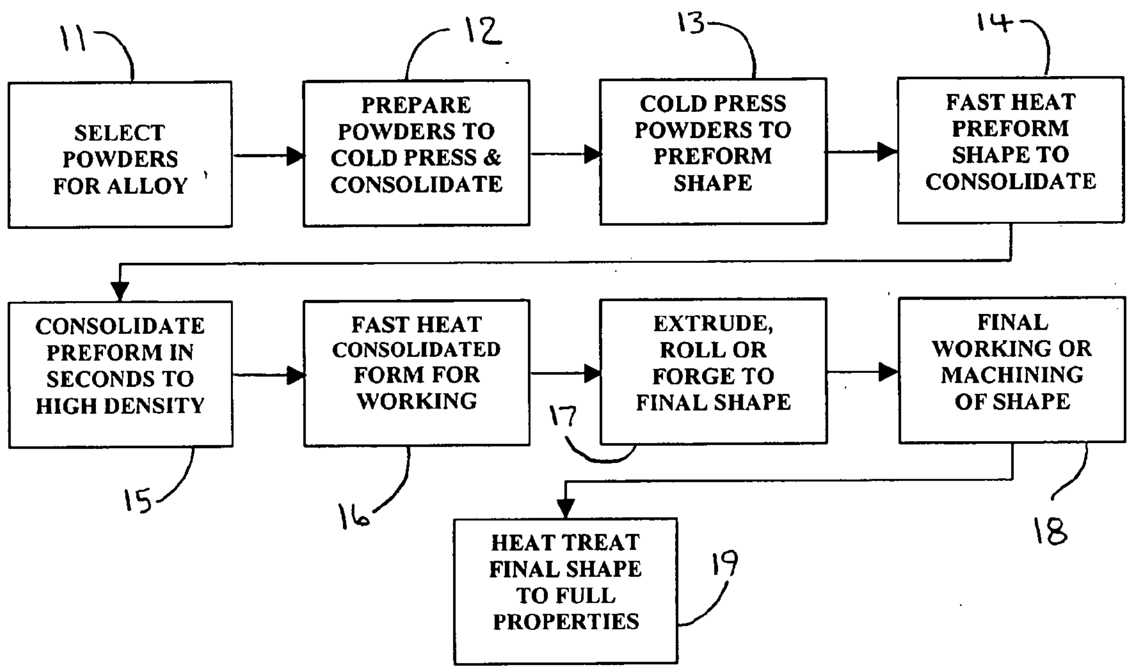
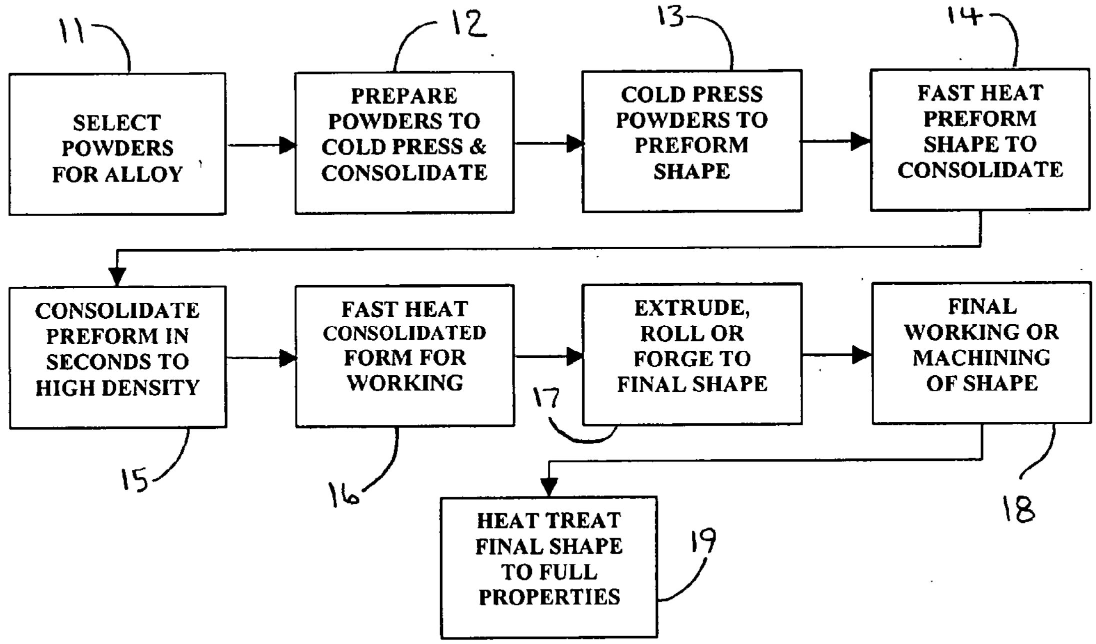
(57) ABSTRACT

A method for forming superdeformable metal alloy preforms that have high strength alloy compositions by selecting metal powders which will define the desired alloy, mixing the selected metal powders, performing either one of cold pressing the metal powders or fast heating the metal powders to define a desired preform shape, and fast heating the metal powder preform shape so as to consolidate it to a desired form.

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SELECT POWDERS FOR ALLOY
12
PREPARE POWDERS TO COLD PRESS & CONSOLIDATE
13
COLD PRESS POWDERS TO PREFORM SHAPE
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FAST HEAT PREFORM SHAPE TO CONSOLIDATE
CONSOLIDATE PREFORM IN SECONDS TO HIGH DENSITY
15
FAST HEAT CONSOLIDATED FORM FOR WORKING
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17
EXTRUDE, ROLL OR FORGE TO FINAL SHAPE
FINAL WORKING OR MACHINING OF SHAPE
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HEAT TREAT FINAL SHAPE TO FULL PROPERTIES
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FIG. 1

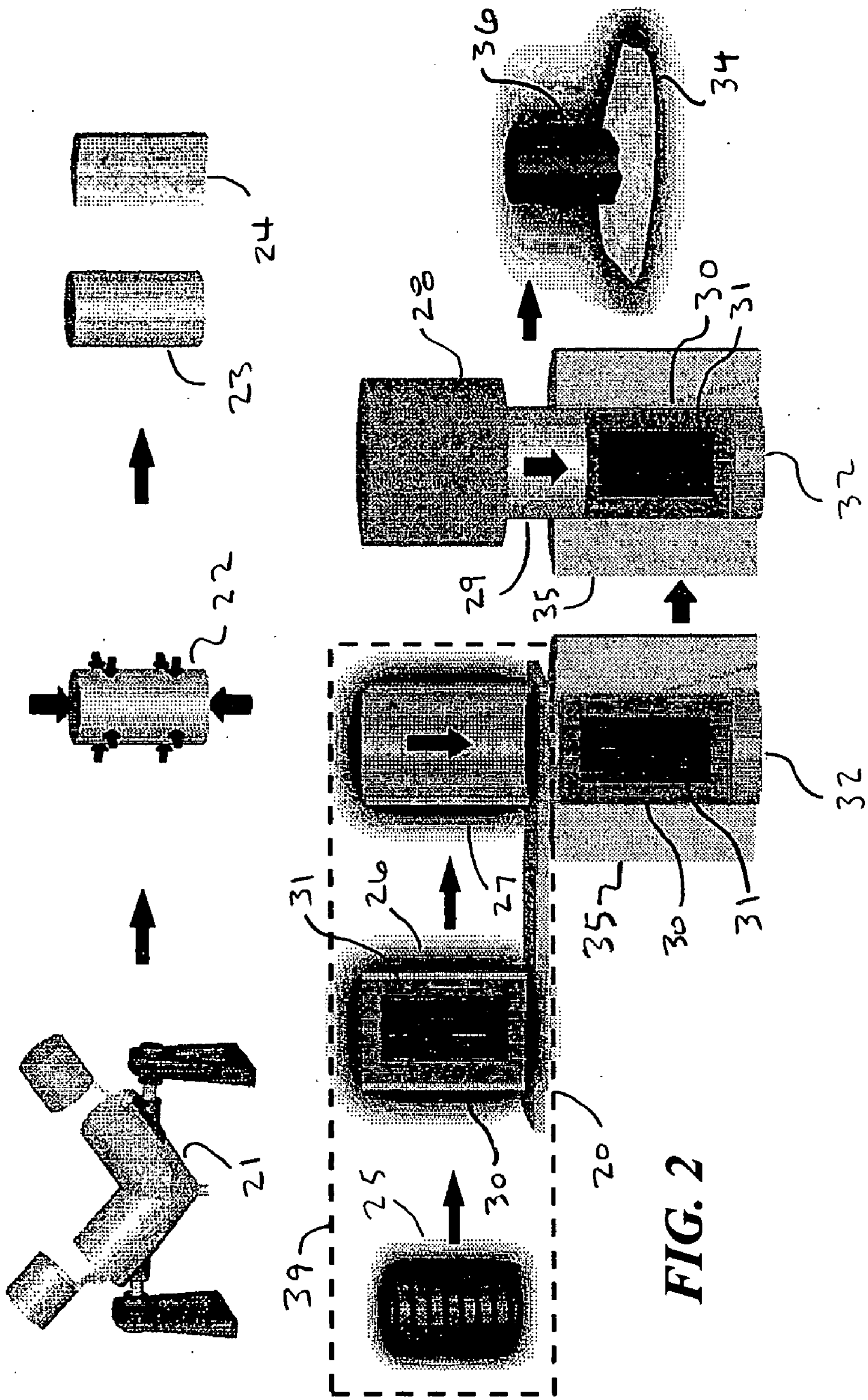


FIG. 2

FIG. 3 A

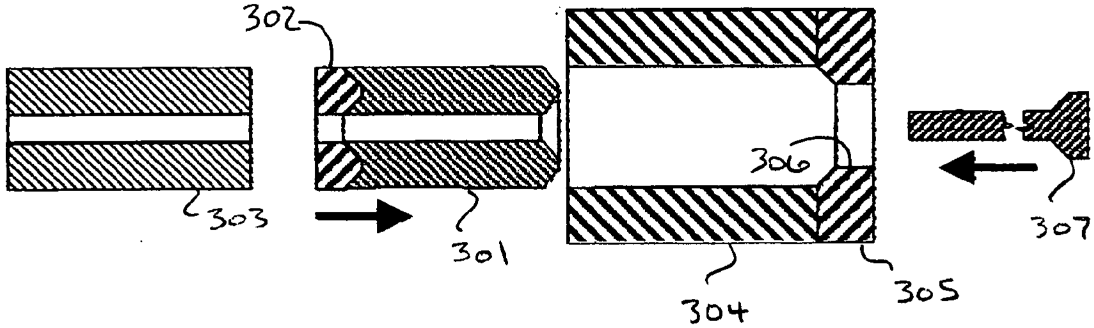


FIG. 3B

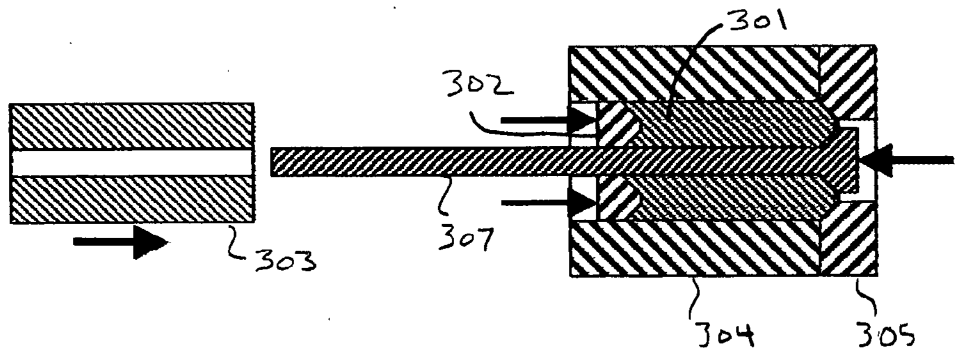


FIG. 3C

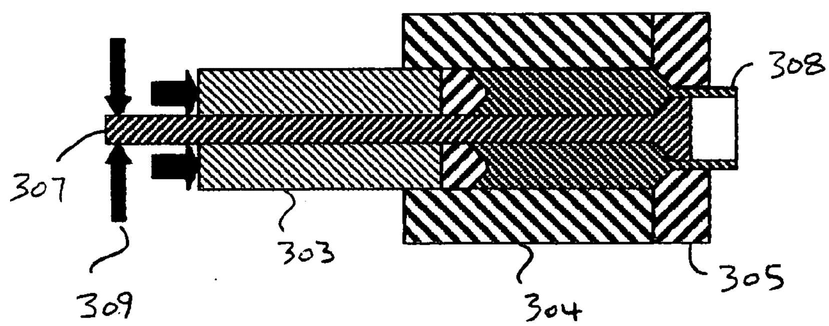


FIG. 4C

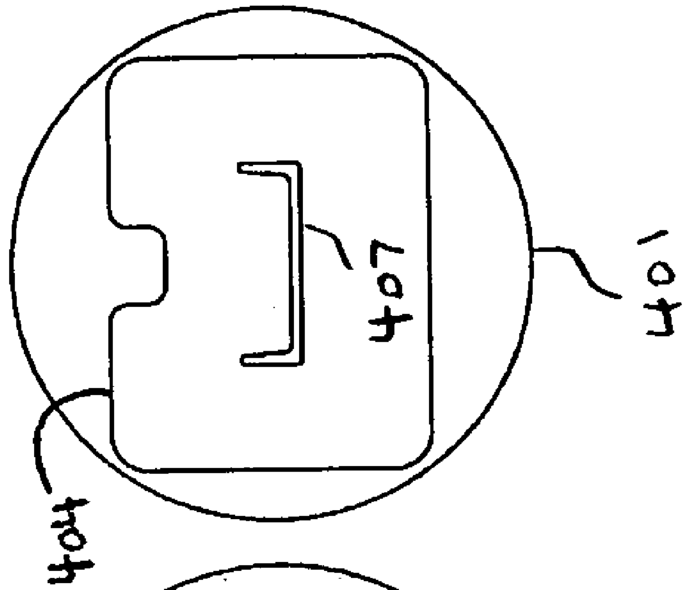


FIG. 4B

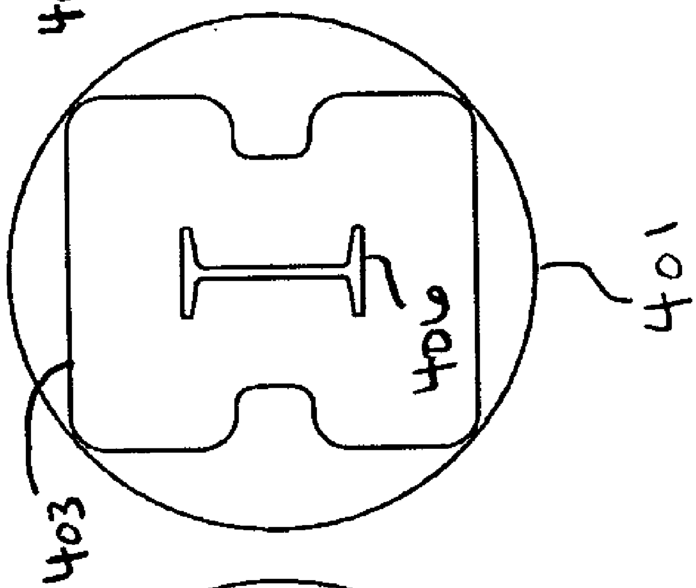
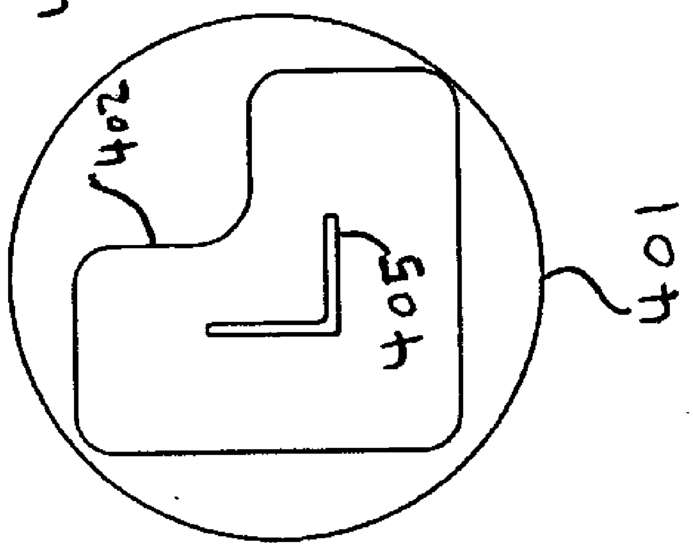


FIG. 4A



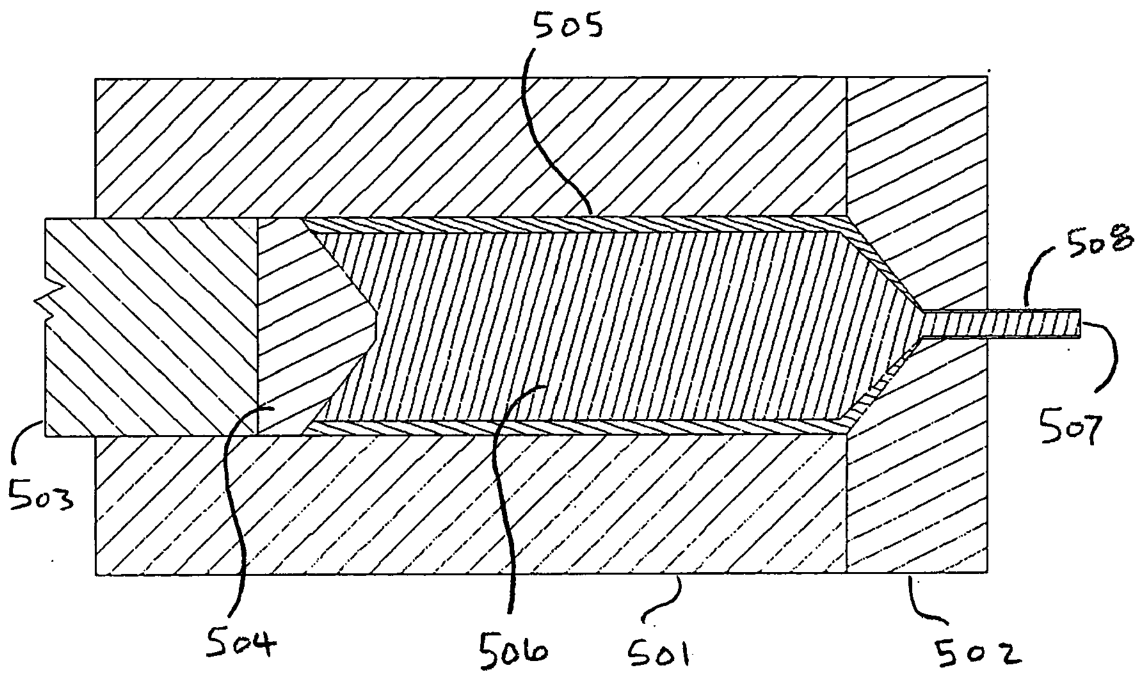


FIG. 5

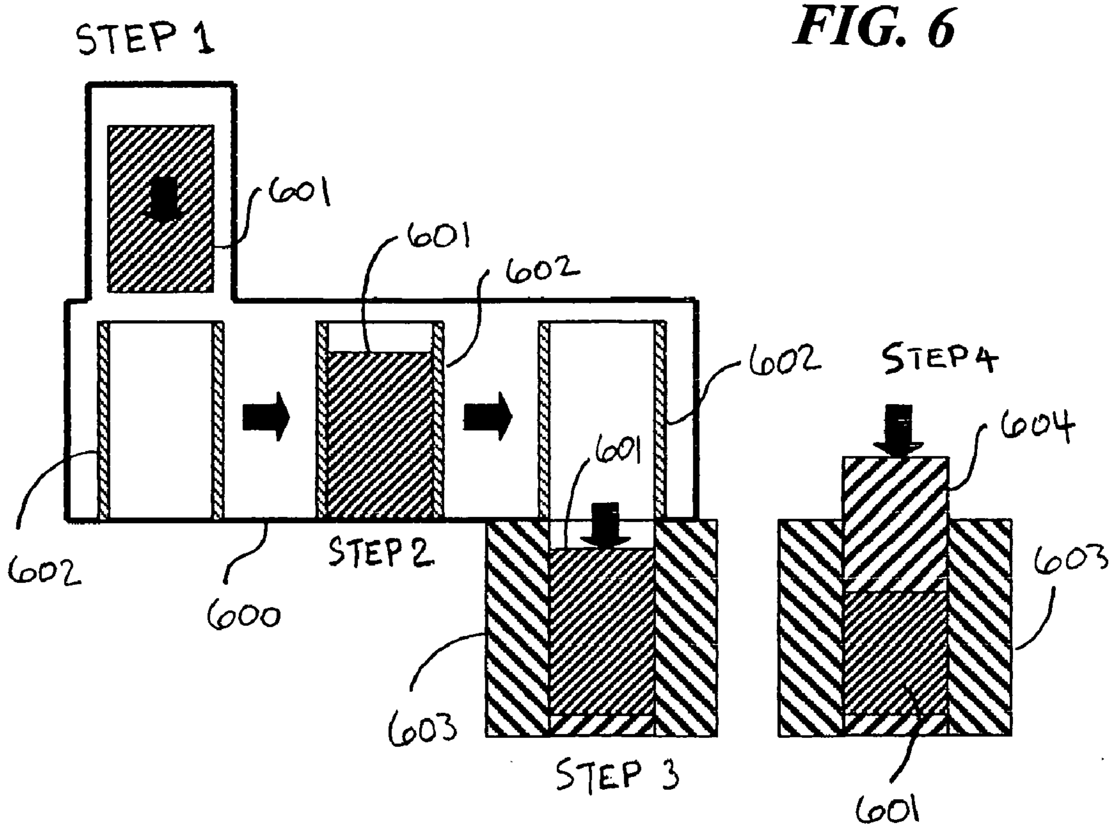

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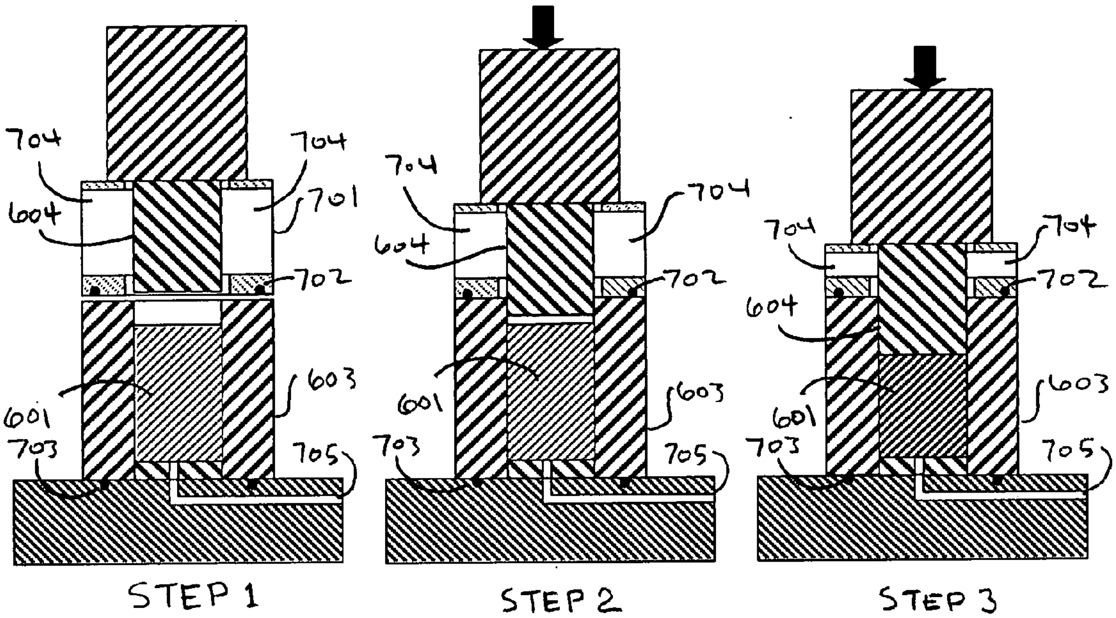
FIG. 6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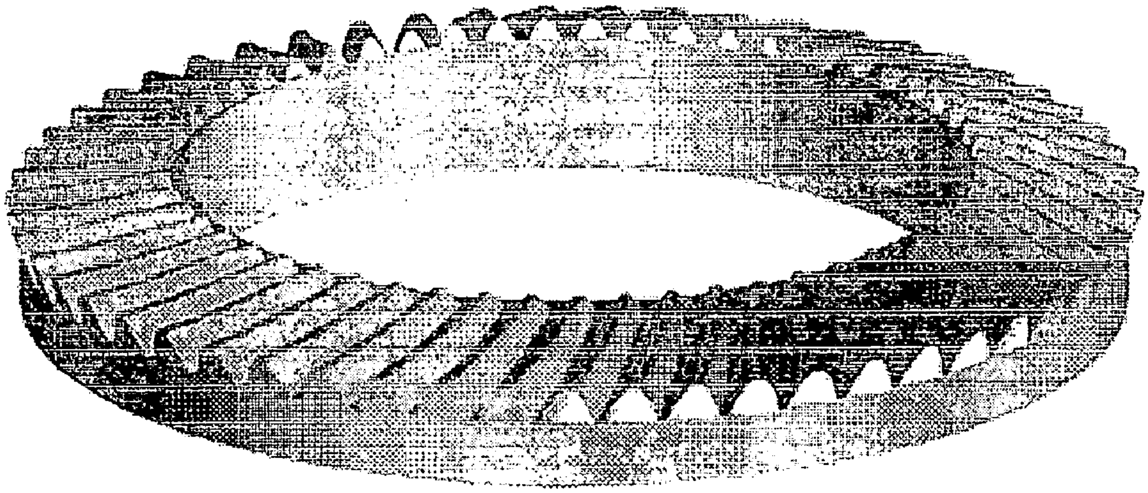
STEP 3

FIG. 7

FIG. 8



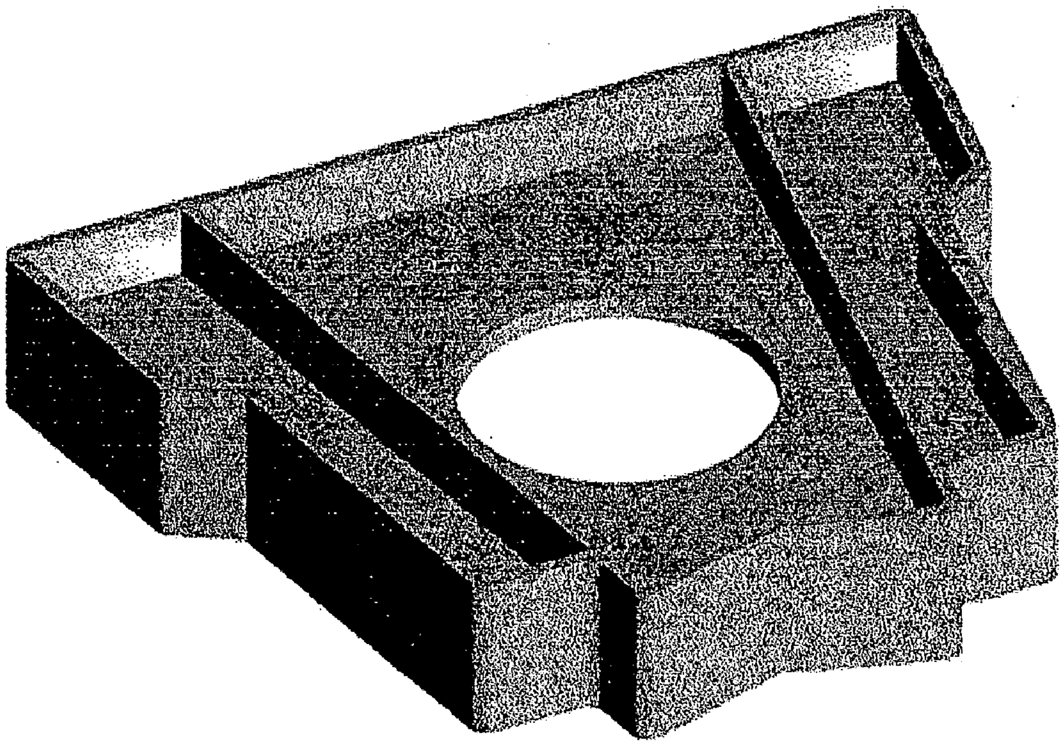


FIG. 9

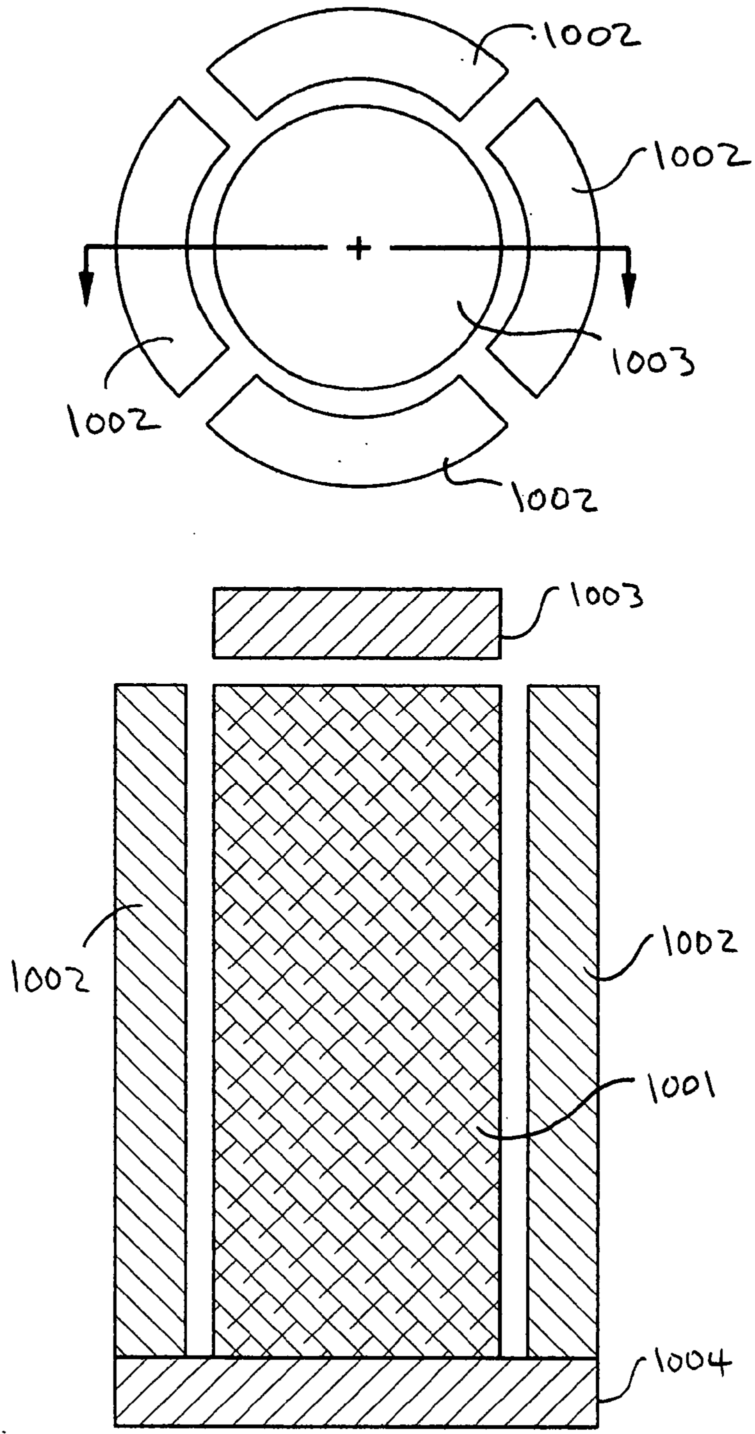


FIGURE 10A

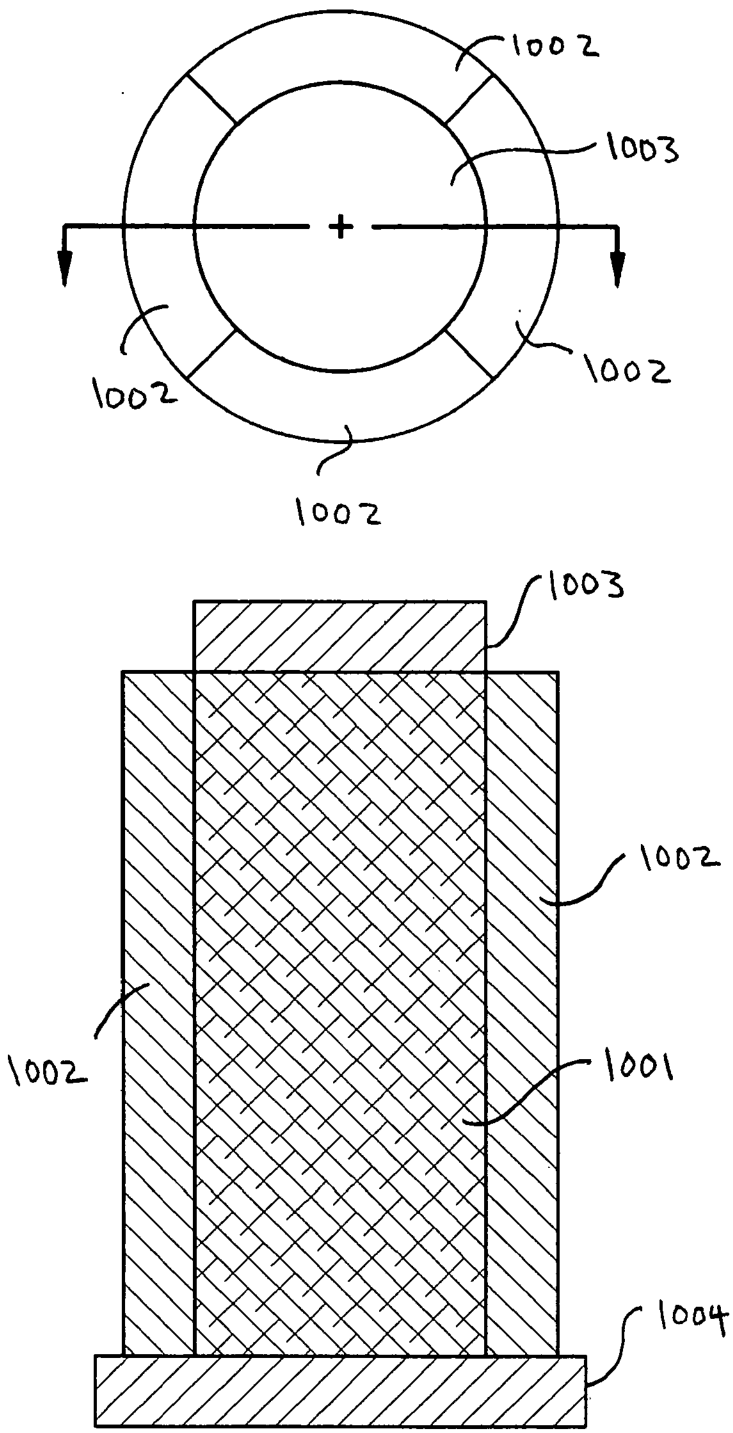


FIGURE 10B

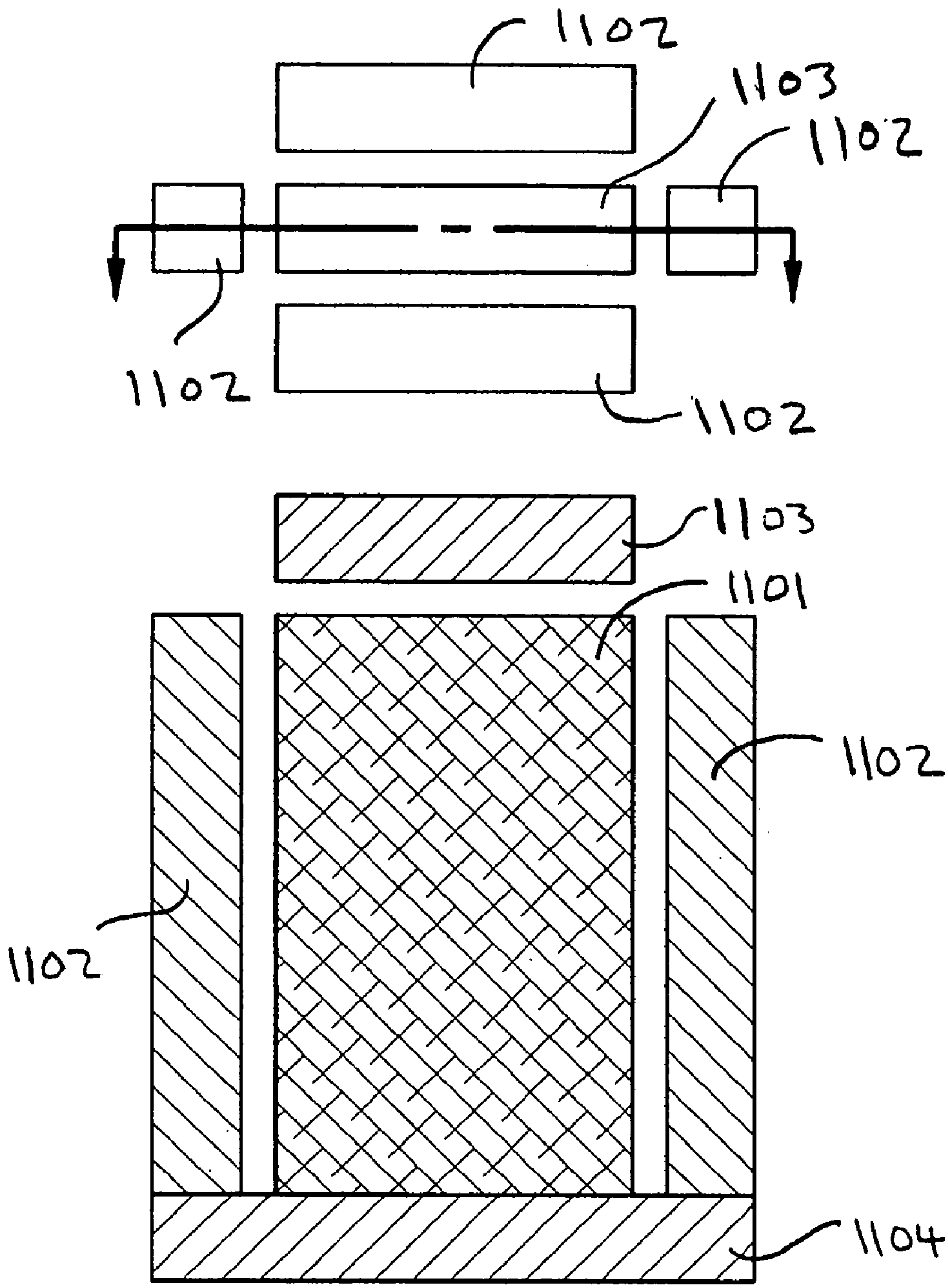
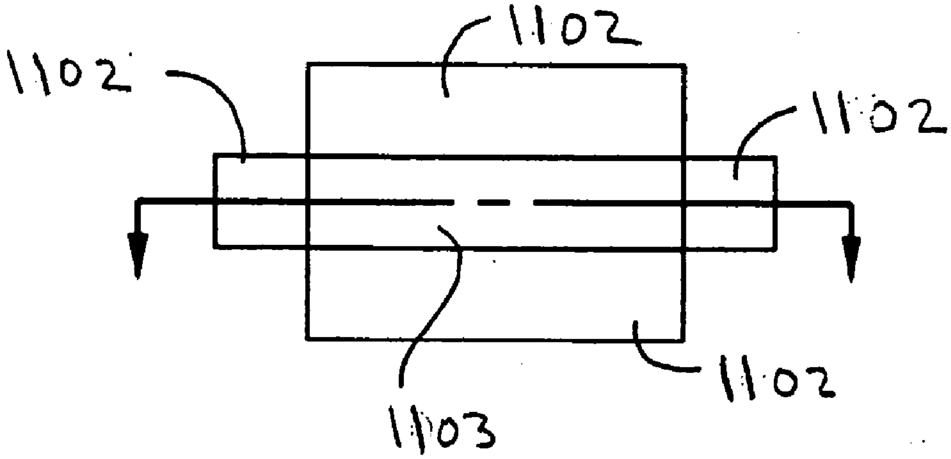


FIGURE 11A



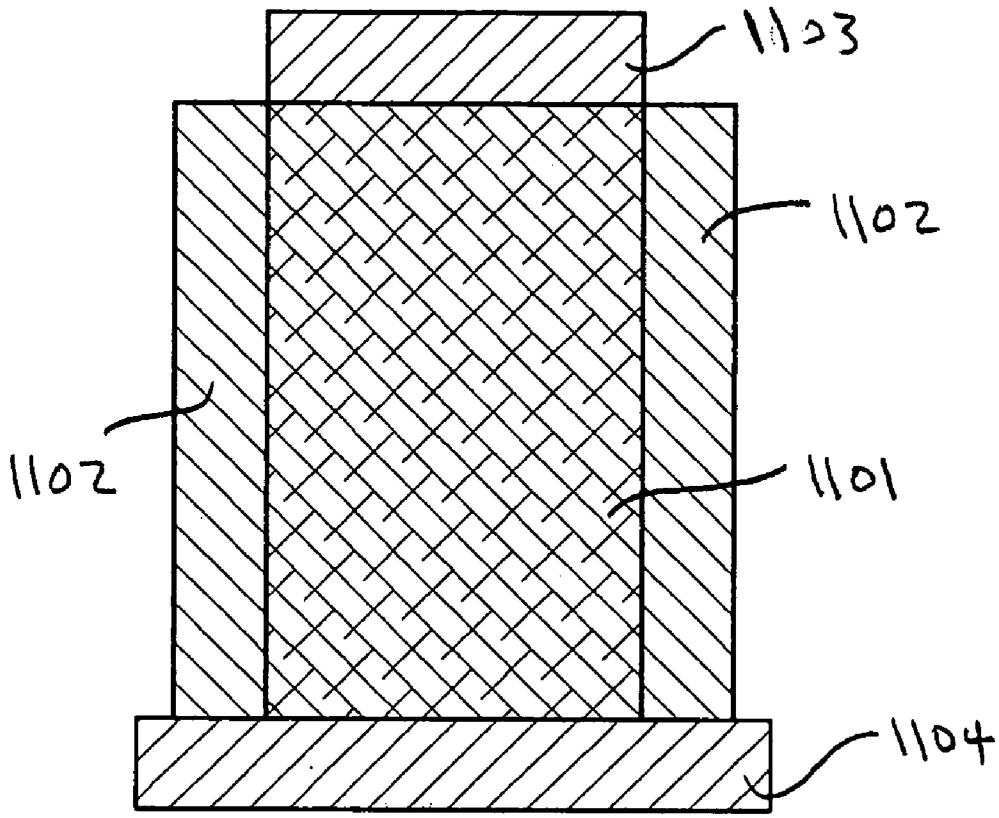


FIGURE 11B

SUPERDEFORMABLE/HIGH STRENGTH METAL ALLOYS

PRIORITY CLAIM

[0001] This patent application claims the benefit of the priority date of U.S. Provisional Patent Application Ser. No. 60/466,626, filed on Apr. 29, 2003 and entitled SUPERDEFORMABLE/HIGH STRENGTH METAL ALLOYS (Myers, Dawes, Andras & Sherman docket no. ADV-.PAP.01) pursuant to 35 USC 119. The entire contents of this provisional patent application are hereby expressly incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates generally to the field of metallurgy. The present invention relates more particularly to a method for forming superdeformable metal alloy preforms and the like by mixing metal powders that define a desired alloy and then cold pressing the powders and/or heating the powders so as to consolidate them into a desired shape with only partial solid diffusion of the powders relative to their fully diffused final alloy condition. Such preforms are softer and more easily worked than are fully alloyed metals and can be heat treated so as to become the stronger, fully alloyed metals after such working.

BACKGROUND OF THE INVENTION

[0003] The United States metals industry historically has depended on melted and cast alloys as raw material for billions of pounds of final products each year. At the same time, they have recognized the urgent need for innovative new methods that would increase production efficiencies and provide improved products for worldwide markets.

[0004] One of the methods that seemed to have great promise was powder metallurgy. According to the practice of contemporary powder metallurgy, pre-alloyed metal powder is pressed and/or heated to form a desired metal part.

[0005] Contemporary powder metallurgy methods are cost-effective, but they also suffer from severe limitations in achieving the full densities and properties required for high performance applications. Additionally, contemporary powder metallurgy methods suffer from substantial limitations in product sizes and shapes. For example, contemporary methodology does not facilitate the manufacture of larger items such as billets.

[0006] Using hot isostatic pressing (HIP), superior properties can be obtained with hot pressed metal powder alloys and composites. However, the standard HIP method has proved to be too inefficient and costly for manufacturing most commercial metal products. HIP is a batch method that has major size limitations and that normally uses inefficient heating and limited pressures that result in long and costly cycle times.

[0007] In view of the foregoing, it is desirable to provide a method for forming larger parts, for forming parts having comparatively complex shapes, and for providing metal products having superior strength. It is also desirable to facilitate the working, machining or forming of metal before the metal has acquired such superior strength and subsequently treating the metal such that superior strength is imparted to the already worked, machined or formed part.

BRIEF SUMMARY OF THE INVENTION

[0008] While the apparatus and method has or will be described for the sake of grammatical fluidity with functional explanations, it is to be expressly understood that the claims, unless expressly formulated under 35 USC 112, are not to be construed as necessarily limited in any way by the construction of "means" or "steps" limitations, but are to be accorded the full scope of the meaning and equivalents of the definition provided by the claims under the judicial doctrine of equivalents, and in the case where the claims are expressly formulated under 35 USC 112 are to be accorded full statutory equivalents under 35 USC 112.

[0009] The present invention specifically addresses and alleviates the above mentioned deficiencies associated with the prior art. More particularly, according to one aspect the present invention comprises a method for forming superdeformable metal alloy preforms that have high strength alloy compositions, wherein the method comprises selecting metal powders which will define the desired alloy, mixing the selected metal powders, cold pressing the metal powders and/or fast heating the metal powders, optionally in a heated container, to define a desired preform shape, and fast heating the metal powder preform shape so as to consolidate it rapidly to a desired form.

[0010] As one example, selecting the metal powders may comprise selecting aluminum as a matrix material and selecting at least one alloy metal such as copper, magnesium, chromium, titanium, iron, lithium, nickel, vanadium, silicon, manganese, and zinc.

[0011] As another example, selecting the metal powders may comprise selecting iron as a matrix material and selecting at least one alloy material from the group consisting of nickel, manganese, silicon, chromium, molybdenum, vanadium, cobalt, carbon, and metal carbides.

[0012] Preferably, selecting the metal powders comprises selecting metal powders having particle sizes between approximately 1 micron and approximately 100 microns.

[0013] As used herein, the term mixing is defined to include blending, preferably with agitation, as well as optionally milling, the selected powders.

[0014] Preferably, the method further comprising mechanically alloying surfaces of the metal powders, such as by performing at least one process such as hammer milling, ball milling, and impact milling.

[0015] Preferably, fast heating the cold pressed metal powder preform shape or the heated metal powder preform shape to a temperature where it can be consolidated under pressure comprises heating the metal powder preform shape to the desired consolidation temperature in the shortest time possible, with minimum hold time.

[0016] Preferably, the heated metal powder preform is consolidated under pressure, such as under pressure of between approximately 20,000 pounds per square inch and approximately 100,000 pounds per square inch.

[0017] Preferably, the heated metal powder preform is consolidated at a temperature between approximately 40% and 75% of the melting point of the matrix metal of the metal powders, with the metal powder preform under pressure of between approximately 20,000 pounds per square inch and approximately 100,000 pounds per square inch.

[0018] According to one aspect, the present invention comprises a method for forming superdeformable metal alloys that have high strength alloy compositions, wherein the method comprises selecting metal powders which will define the desired alloy, mixing the selected metal powders, cold pressing the metal powders and/or fast heating the metal powders, optionally in a heated container, to define a desired preform shape, fast heating the metal powder preform shape so as to consolidate it to a desired form, fast heating the consolidated preform to prepare the consolidated preform for working, working the consolidated preform to a desired shape, and heat treating the worked product to define a metal alloy having the desired shape and properties.

[0019] For example, working the consolidated preform to a desired shape may comprise performing extruding, rolling, forging, and/or machining.

[0020] Preferably, heat treating the worked product to define a metal alloy having the desired shape and properties comprises heating the product at a temperature and for a length of time that provides diffusion of the alloying elements and the matrix metal to give the desired properties.

[0021] The amount of diffusion, and consequently the physical properties of the final product, can be controlled by varying the heating time, as well as by varying the particle size of the metal powders or other additives (such as carbon and boron).

[0022] According to one aspect, the present invention comprises a superdeformable metal alloy with a high strength alloy composition formed by a method comprising selecting metal powders which will define the desired alloy, mixing the selected metal powders, performing cold pressing of the metal powders and/or fast heating the metal powders, optionally in a heated container, to define a desired preform shape, and fast heating the metal powder preform shape so as to consolidate it to a desired form.

[0023] According to one aspect, the present invention comprises a superdeformable metal alloy with high strength alloy composition formed and worked by a method comprising selecting metal powders which will define the desired alloy, mixing the selected metal powders, performing cold pressing of the metal powders and/or fast heating the metal powders, optionally in a heated container, to define a desired preform shape, fast heating the metal powder preform shape so as to consolidate it to a desired form, fast heating the consolidated preform to prepare the consolidated preform for working, working the consolidated preform to a desired shape, and heat treating the worked product to define a metal alloy having the desired shape and properties.

[0024] According to one aspect, the present invention comprises a method for extruding materials, wherein the method comprises providing a dummy block which has a surface that is complimentary in shape to a die and/or a mandrel, such that the dummy block fits into an extrusion container generally flush with the die, and having a front end that is complimentary in shape to the back end of a billet. The dummy block is placed behind a hot billet during an extrusion process, such that an efficiency of the extrusion process is enhanced as the billet is extruded.

[0025] The dummy block may thus have a cross-section that is generally similar to that of the die and which is also generally similar to that of the extrusion. For example, a dummy block having an L-shaped cross-section may be used with a die having an L-shaped cross-section to form an L-channel.

[0026] Preferably, the method further comprises removing the dummy block from the container after an extrusion process and placing the dummy block behind another hot billet and reusing the dummy block in a subsequent extrusion process.

[0027] According to one aspect, the present invention comprises a method for extruding a clad material, wherein the method comprises forming a superdeformable metal alloy preform having a high strength alloy composition that is formed by selecting metal powders which will define the desired alloy, mixing the selected metal powders, and cold pressing the mixed metal powders to define a desired preform shape, and forming a cladding upon the superdeformable metal alloy preform by selecting metal powders which will define the desired cladding, mixing the selected metal powders as needed for a desired cladding alloy, and cold pressing the mixed metal powder cladding against the preform to define a desired clad preform shape, fast heating the cold pressed clad preform shape so as to consolidate the metal powders and bond the cladding to the preform, and heating and extruding the clad superdeformable metal alloy to a desired form.

[0028] According to one aspect, the present invention comprises a method for forming a superdeformable metal alloy preform having a high strength alloy composition, wherein the method comprises selecting metal powders which will define the desired alloy, mixing the selected metal powders, cold pressing the mixed metal powders and/or fast heating the metal powders, optionally in a heated container, to define a desired preform shape, fast heating the preform shape to a desired consolidation temperature, and applying mechanical pressure thereto at reduced atmospheric pressure, so as to consolidate the metal powders in a manner which mitigates an occurrence of voids therein.

[0029] Preferably, the heated preform shape is substantially surrounded with a ceramic grain or the like prior to applying mechanical pressure thereto at a reduced atmospheric pressure. The ceramic grain transmits pressure to the preform and also readily facilitates the escape of gasses from the preform as pressure is applied thereto. More particularly, the use of ceramic grain facilitates the generally uniform application of pressure to preforms having irregular shapes, openings, cavities and the like.

[0030] According to one aspect, the present invention comprises a method for forming a preform which facilitates working of metal, wherein the method comprises selecting metal powders which will define a desired alloy, mixing the selected metal powders, performing cold pressing of the mixed metal powders and/or fast heating of the metal powders, optionally in a heated container, to define a desired preform shape, and fast heating the metal powder preform shape and applying pressure so as to consolidate the metal powders. The desired preform shape is generally similar to a desired shape of a final, worked product.

[0031] For example, the desired preform shape may be tubular, L-channel, I-beam, or U-channel. Various other preform shapes and configurations are likewise possible.

[0032] According to one aspect, the present invention comprises a preform formed by a method comprising selecting metal powders which will define a desired alloy, mixing the selected metal powders, cold pressing the mixed metal powders and/or fast heating the metal powders, optionally in a heated container, to define a desired preform shape, and fast heating the metal powder preform shape and applying pressure so as to consolidate the metal powders. The desired preform shape is generally similar to a desired shape of a final, worked product.

[0033] According to one aspect, the present invention comprises a method for working metals, wherein the method comprises forming a superdeformable/high strength metal alloy preform by selecting powdered metals which will define the desired alloy, mixing the selected powdered metals, cold pressing the mixed metal powders and/or fast heating the metal powders, preferably in a heated container, to define a desired preform shape, and fast heating the cold pressed powdered metals so as to consolidate the powdered metals.

[0034] The desired preform shape is generally similar to a desired shape of a final, worked product. After the superdeformable/high strength metal alloy is formed, then the preform is worked to the desired final shape, such as a tubular shape, an L-channel shape, an I-beam shape, a U-channel shape, a plate-like shape or any other desired shape. Working the preform to the desired final shape may comprise extruding, rolling, or forging. Working the preform to the desired final shape may comprise machining or any other method of metal forming.

[0035] According to one aspect, the present invention comprises a method for extruding metals, wherein the method comprises forming a superdeformable metal alloy preform having a high strength alloy composition by selecting metal powders which will define the desired alloy, mixing the selected powdered metals, cold pressing the mixed metal powders and/or fast heating the metal powders, optionally in a heated container, to define a desired preform shape, and fast heating the preform shape and applying pressure so as to consolidate the metal powders. The desired preform shape is generally similar to a desired shape of a final, worked product. The preform is extruded to the desired final shape.

[0036] According to one aspect, the present invention comprises a metal extrusion preform shape formed by a method comprising forming a superdeformable/high strength metal alloy preform by selecting powdered metals which will define the desired alloy, mixing the selected powdered metals, cold pressing the mixed metal powders and/or fast heating the metal powders, optionally in a heated container, to define a desired preform shape, and fast heating the preform shape so as to consolidate the metal powders.

[0037] The desired preform shape is generally similar to a desired shape of a final, worked product. The preform is extruded to the desired final shape. Optionally, this process further comprises fast heating the preform shape to a consolidation temperature and applying at least a partial vacuum to the heated preform shape while simultaneously applying mechanical pressure thereto, so as to increase the density thereof, and so as to mitigate an occurrence of voids therein.

[0038] These, as well as other advantages of the present invention, will be more apparent from the following description and drawings. It is understood that changes in the specific structure shown and described may be made within the scope of the claims, without departing from the spirit of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] The invention and its various embodiments can now be better understood by turning to the following detailed description of the preferred embodiments which are presented as illustrated examples of the invention defined in the claims. It is expressly understood that the invention as defined by the claims may be broader than the illustrated embodiments described below.

[0040] **FIG. 1** is a flow chart of the basic powder processing steps used to produce metal alloys with greatly improved formability and with ultimate high strengths;

[0041] **FIG. 2** is a schematic illustration of the process steps that produce a consolidated product;

[0042] **FIGS. 3A-3C** represent schematically the steps used for extruding a tubular billet form;

[0043] **FIGS. 4A-4C** represents schematically the types of preform shapes that can be used in extrusion to provide more uniform plastic deformation to a final product form, together with improved control of cladding thickness and increased size capacity;

[0044] **FIG. 5** is a schematic illustration of a cylindrical extrusion billet with front and back end shapes that give maximum material yield efficiency and increased uniformity of cladding in the extrusion process;

[0045] **FIG. 6** is an alternative method to that shown in **FIG. 2** for consolidating powders to preform billet shapes for extrusion without using hot ceramic grain in the hot consolidation process;

[0046] **FIG. 7** shows schematically a method for removing gases from a powder form as it is consolidated;

[0047] **FIG. 8** shows a net shape steel alloy product, i.e., a gear, made according to the present invention;

[0048] **FIG. 9** shows a net shape aluminum alloy product, i.e., an elevator rib fitting for aircraft, according to the present invention;

[0049] **FIG. 10A** shows a method and apparatus for heating a cylindrical billet, wherein the heating units are movable so as to provide fast conductive heating to the billet and the side and top heating units are shown spaced apart from the billet;

[0050] **FIG. 10B** shows a method and apparatus for heating a cylindrical billet, wherein the heating units are movable so as to provide fast conductive heating to the billet and the side and top heating units are shown contacting the billet;

[0051] **FIG. 11A** shows a method and apparatus for heating a rectilinear billet, wherein the heating units are movable so as to provide fast conductive heating to the billet and the side and top heating units are shown spaced apart from the billet;

[0052] **FIG. 11B** shows a method and apparatus for heating a rectilinear billet, wherein the heating units are movable so as to provide fast conductive heating to the billet and the side and top heating units are shown contacting the billet;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0053] Many alterations and modifications may be made by those having ordinary skill in the art without departing from the spirit and scope of the invention. Therefore, it must be understood that the illustrated embodiment has been set forth only for the purposes of example and that it should not be taken as limiting the invention as defined by the following claims. For example, notwithstanding the fact that the elements of a claim are set forth below in a certain combination, it must be expressly understood that the invention includes other combinations of fewer, more or different elements, which are disclosed herein even when not initially claimed in such combinations.

[0054] The words used in this specification to describe the invention and its various embodiments are to be understood not only in the sense of their commonly defined meanings, but to include by special definition in this specification structure, material or acts beyond the scope of the commonly defined meanings. Thus if an element can be understood in the context of this specification as including more than one meaning, then its use in a claim must be understood as being generic to all possible meanings supported by the specification and by the word itself.

[0055] The definitions of the words or elements of the following claims therefore include not only the combination of elements which are literally set forth, but all equivalent structure, material or acts for performing substantially the same function in substantially the same way to obtain substantially the same result. In this sense it is therefore contemplated that an equivalent substitution of two or more elements may be made for any one of the elements in the claims below or that a single element may be substituted for two or more elements in a claim. Although elements may be described above as acting in certain combinations and even initially claimed as such, it is to be expressly understood that one or more elements from a claimed combination can in some cases be excised from the combination and that the claimed combination may be directed to a subcombination or variation of a subcombination.

[0056] Insubstantial changes from the claimed subject matter as viewed by a person with ordinary skill in the art, now known or later devised, are expressly contemplated as being equivalently within the scope of the claims. Therefore, obvious substitutions now or later known to one with ordinary skill in the art are defined to be within the scope of the defined elements.

[0057] The claims are thus to be understood to include what is specifically illustrated and described above, what is conceptionally equivalent, what can be obviously substituted and also what essentially incorporates the essential idea of the invention.

[0058] Thus, the detailed description set forth below in connection with the appended drawings is intended as a description of the presently preferred embodiments of the invention and is not intended to represent the only forms in which the present invention may be constructed or utilized. The description sets forth the functions and the sequence of steps for constructing and operating the invention in connection with the illustrated embodiments. It is to be understood, however, that the same or equivalent functions may be accomplished by different embodiments that are also intended to be encompassed within the spirit of the invention.

[0059] The present invention relates to metal alloys which normally are difficult to work, but that can be made as billets or preform shapes by this invention so as to have low yield strengths and high deformability, which allows faster, much easier and therefore lower cost working to a smaller cross-section or final shape.

[0060] After working the alloys to a desired shape, they can be heat treated to high tensile properties for high performance use. The invention also provides special preform shapes that allow more efficient working to a final form, as well as composite billet shapes that incorporate special combinations of materials, including external and internal cladding.

[0061] The advantages of the invention over standard metal alloys and standard billet shapes thus include increased sizes of final product forms, increased ability to form products from higher alloys, the ability to form higher strength, corrosion resistant products from clad higher alloys, greatly increased tooling and die life, increased material yields in working billets to final product forms, increased billet size capacity for existing equipment, thinner wall sections in final products, cladding capabilities not possible before, material combinations not possible before, lower energy costs to produce final products, and improved machinability of alloy products.

[0062] The metals industries use several important working methods to supply billions of pounds of metal alloys each year to industrial and commercial markets in forms such as plate, sheet, bars, tubing and other shapes. Extrusion and rolling methods are widely used as metal working processes to convert metal ingots or billets of a large cross-section to long lengths of a uniform, smaller cross-section. In metal extrusion, the reduction is accomplished by forcing the metal preform shape to flow plastically through a smaller cross-section of the die orifice.

[0063] In metal rolling, such reduction in cross-section is accomplished through the use of rotating rolls that are set to force the metal to flow plastically to a smaller thickness of plate or sheet. In forging, large cross-section metal forms are plastically deformed to final shapes at high pressures, using shaped dies. Spinning is another method used to form and work metal plate and sheet to a final shape by applying roller pressure against the metal surface as it is held and rotated on a rotating mandrel. All of these methods normally use elevated metal preform temperatures to reduce the forces necessary for plastic deformation of a high strength metal alloy to a final desired form.

[0064] A metal alloy's resistance to deformation in the above working processes normally is in proportion to the type and amount of alloying elements in the alloy. For instance, a 7075 high strength aluminum alloy for aircraft contains about 13% of copper, magnesium, chromium, titanium, iron, manganese and zinc as alloying element content. These alloying elements give the 7075 alloy the high strength needed for aircraft structures, but they also give this alloy a high resistance to deformation that makes it a difficult and costly alloy to work to final forms. In comparison, a widely used 6063 alloy with under 3% of alloying element content has only half the strength of a 7075 alloy, but its extrudability is more than 10 times greater than the more difficult 7075 alloy.

[0065] The result is that working processes for standard high alloys of most metals normally require heavier, larger equipment with higher pressure capacity than is needed for lower alloys, with subsequent increased costs. The high resistance to deformation of standard high alloys also significantly limits the size of extruded shapes that can be made with any specific equipment capacity in addition to making final machining difficult and costly.

[0066] At the present time, standard metal alloys are made primarily by melting a base metal and adding to it alloying elements that dissolve and are uniformly dispersed in the base metal to provide a full alloy composition. The molten alloy then is cast to solid forms that can be worked or formed to final product forms. Such fully alloyed metals generally have up to two times or more higher resistance to working or forming than the unalloyed base metal because of the strengthening effect of the alloying elements in the metal.

[0067] This invention uses a new combination of powder metallurgy methods to provide preform shapes which have the alloying element content for full alloy compositions, but which also have special processing that restrains diffusion of the alloying elements into the base metal so that they are easier to work to final forms. Such preform shapes, because they are not fully alloyed prior to working, will have a softness more like the base metal, and therefore a low resistance to working by extrusion, rolling, drawing, forging or other similar methods.

[0068] After working these preform shapes to final product forms, the products then can be heat treated to a desired alloy condition that can include a heat treatment to develop desired machining properties, and a following heat treatment to develop the optimum high strengths and other properties that normally are possible with the alloy compositions. It allows larger products to be made at low cost, with less equipment capacity and energy input than would normally be required. It also makes possible the ability to extrude, roll or otherwise work a whole new range of higher strength products faster, in larger sizes and at lower costs, for industrial and commercial use.

[0069] The present invention provides means to blend or mix alloying element powders and base metal powders that are chosen to give minimum diffusion of the alloying elements into the base metal as the powders are consolidated to a preform shape and worked to a final shape, and also to give rapid diffusion of the alloying elements by a heat treatment after working to produce full alloy properties. It also provides means for producing shapes and composite forms of cold pressed powder billets that can be consolidated to provide more efficient working to final shapes and improved final properties; methods to rapidly consolidate the powder forms in just seconds to a high density, satisfactory condition for following working, with minimum solid diffusion of alloying elements into the base metal; and fast heating and working of the consolidated forms to final product shapes that also minimizes diffusion of alloying elements into the base metal.

[0070] This unique combination of processing allows products with high alloy compositions to be processed as readily as lower alloys of the base metal. It provides easier working or forming by a factor of up to two or higher, in comparison with a fully alloyed product. After working or forming is completed, the end product can be heat treated readily to an intermediate alloy condition for machining or to a full alloy condition that provides the full strength and other properties required for the product's end use.

[0071] Standard preform shapes for metal extrusion, rolling or forging normally are limited to simple shapes such as cylinders or rectangular forms with square ends, because of the increased labor costs and decreased material yields that result from machining or forming special preform shapes. However, the powder metallurgy methods of this invention can economically produce special preform shapes such as heavy wall channels, angle, I-beams, tube forms or similar shapes that have cross-sections that can be worked to final forms much more efficiently than is possible with standard cylindrical or rectangular billets.

[0072] These special preform shapes make it possible to form final products with thin wall sections and complex shapes at much lower pressures and with much greater efficiency than is possible with standard starting forms. Additionally, the powder metallurgy methods of this invention can be used to make preforms economically that have internal and/or external cladding, as well as special nose and back end shapes, to provide improved properties in the final product and increased material yields.

[0073] The present invention is illustrated in **FIGS. 1-7**, which depict (a) presently preferred embodiment(s) thereof.

[0074] Referring now to **FIG. 1**, this flow chart shows the steps for making an alloy that will initially be low in strength and highly deformable as it is worked or machined to a desired shape, and that can subsequently be heat treated to provide the full properties of the alloy once it is in the final or near final product shape.

[0075] The first step in preparing an alloy with these desirable properties is to select powders for the base metal and the alloying elements as shown in block **11**. These powders will have particle sizes and properties that will provide minimum diffusion of the alloying element powders into the base metal in initial heating and processing steps prior to extrusion, rolling or working; which will prevent significant diffusion of alloying elements into the base metal as the alloy is worked to final shape by extrusion, rolling, forging or the like; and which will be capable of full diffusion of alloying elements into the base metal after it has been worked to final shape, through a subsequent nominal heat treatment that will provide full alloy properties. The net result will be a low strength, highly deformable alloy for working to final shape, and a final product shape with high strength, full alloy properties.

[0076] Thus, a cost savings is realized in working or machining the metal, since it can be worked faster, since less energy is needed to work or machine the softer metal and since working or machining tools are less subject to undesirable wear.

[0077] The principle factors involved in the diffusion of alloying element powders into base metal matrix powders include particle size, temperature and time at temperature, They also include blending with agitation, the contact areas between powder surfaces and milling and mechanical alloying of powder surfaces.

[0078] Metal powders generally are available in particle sizes ranging from less than one micron in average diameter up to 50-100 microns diameter or more. The finer particle sizes allow alloying element powders to be more favorably dispersed in a base metal powder. When the powders are consolidated to form a billet or preform shape, as described in this invention, the dispersed alloying element powders are restrained from diffusing significantly into the matrix metal. Thus, the metal tends to maintain physical properties similar to the base metal and is thus softer and more readily worked or machined.

[0079] After working the billet or preform shape to a final desired form by rolling, extrusion, forging or other methods, the alloying elements can be rapidly diffused into the matrix metal and the alloy brought to desired properties through a standard form of heat treatment. In this manner, a fully alloyed or nearly fully alloyed metal product is provided.

[0080] Solid diffusion of one metal into another is dependent to a large extent on the temperature of the metals and the time at temperature. Diffusion rates generally increase with increasing temperature.

[0081] For example, magnesium is one of the important alloying elements used to strengthen alloys of aluminum, which has a melting point of about 660C. The diffusion coefficient for magnesium into aluminum at a temperature of 365C. has been shown to be in the order of 3.9×10^{-8} cm^2 per hour. At 450C., the coefficient is shown to increase to 6.84×10^{-6} cm^2 per hour, more than 175 times the diffusion rate at 365C.

[0082] Other alloying elements such as copper and zinc follow a similar pattern. The heating and handling system for metals consolidation described in U.S. Pat. No. 4,634,375, the entire contents of which are hereby expressly incorporated by reference, makes it possible to heat powder preforms in minutes of time to a temperature where they can be consolidated under high pressure to a controlled form and high density in just seconds of time. High pressures up to 80,000 pounds per square inch or more can be applied in the consolidation step, so that consolidation and metallurgical bonding of the powders in the preform can be accomplished at relatively low temperatures, down to 50% of the melting point of the powder preform or lower.

[0083] This allows high alloy billets or preforms to be made by the unique powder metallurgy methods of this invention with minimum diffusion of alloying elements into the matrix metal and a resultant high workability when they are rolled, extruded, forged or otherwise worked in following process steps to a desired product form. After working, alloys made by this invention can be brought to intermediate or full properties through a standard form of heat treatment.

[0084] Solid diffusion of alloying element powders into a matrix metal powder proceeds at a relatively slow rate at lower temperatures in the range of 50% of an alloy's melting point), and more rapidly at higher temperatures in the range of 90% of an alloy's melting point).

[0085] The fast heating and consolidation of powder preforms that is possible with the heating and handling system and consolidation process described in U.S. Pat. No. 4,634,375, together with the advantage of being able to use lower consolidation temperatures as a result of the high pressures available with the process, provides for minimum diffusion of alloying elements into the matrix metal during the consolidation process. This allows high alloy billets to be made with workability properties similar to that of low alloy billets, to provide high workability for extrusion, rolling, forging or other working processes.

[0086] The present invention thus facilitates the provision of a highly uniform dispersion of alloying element powders in a base metal matrix powder, so that a low cost heat treatment after the working operations can provide full properties in the final product.

[0087] Solid diffusion rates increase in proportion to increased contact area between adjoining powder particles, particularly as the powder particles are plastically deformed during cold pressing to a preform shape and then are forged together during consolidation at elevated temperatures to a solid billet shape. Solid diffusion rates also increase with finer grain sizes and increased grain boundaries that result from the present invention, but can be kept low by the lower temperatures and short cycle times of the invention until final products are heat treated to develop the full properties.

[0088] Various hammer milling, ball milling and impact milling methods can be used to mechanically alloy powder surfaces so that diffusion mechanisms are enhanced and the segregation of alloying element powders is minimized.

[0089] The present invention employs effective combinations of the above factors to provide minimum diffusion of the alloying elements into the matrix metal as the powders are brought to a form and condition suitable for subsequent extrusion, rolling, forging or other forming processes, using the lowest temperature and shortest time at temperature needed to accomplish this form and condition. Minimum diffusion of the alloying elements into the matrix metal also occurs as the consolidated powder forms are extruded, rolled, forged or otherwise formed, using the lowest temperature and shortest time at temperature needed to accomplish this processing.

[0090] Final diffusion of the alloying elements into the matrix metal of the extruded, rolled, forged or otherwise formed products later occurs so as to produce the desired metallurgical properties of the product. This final diffusion is accomplished by the use of standard methods of heat treatment.

[0091] As shown in block **12** of **FIG. 1**, the selected powders are processed to prepare them for the subsequent cold pressing and consolidation steps. This processing can include blending the powders, as in a V-blender (such as item **21** of **FIG. 2**, which also can use agitation during the blending), to establish a preliminary uniform distribution of the alloying element powders in the base metal powder; hammer milling the powders to break down powder agglomerates and make possible more intimate mixing of the powders; and/or ball milling the powder mixture to provide increased dispersion of the powders and increased uniformity of the powder mix. The milling processes may produce some light surface alloying of the powder particles, but these processes can be controlled to produce the intimate mixing and uniformity of the alloy mixture desired for this invention.

[0092] As shown in block **13** of **FIG. 1**, the prepared powders are cold pressed to a desired preform shape (such as item **22** of **FIG. 2**) and density by standard methods or by any other desired method.

[0093] For example, the shapes can be made as simple cylinders, with circular cross-sections, as shown by the outer circle **401** in **FIGS. 4A-4C**, or in more complex cross-sections that provide improved flow of the billet to a final shape as the billet is extruded, as shown by the inner forms **402**, **403**, and **404** in **FIGS. 4A, 4B**, and 4C, respectively.

[0094] The more complex shapes of billets can reduce the pressures required to make a final shape such as L-channel **405**, I-beam **406**, and U-channel **407** shown in **FIGS. 4A, 4B**, and 4C, respectively, and can also help to establish a more uniform flow of billet material relative to the final shape. These more complex shapes also can help assure a more uniform, controlled cladding thickness on the outer and inner surfaces of a final part, as discussed in detail below.

[0095] Various forms of extrusion billets or other shaped products can be made at low cost in the cold pressing process of block **13**, to provide increased material yields and increased uniformity of extruded properties from end to end in the finished product.

[0096] Fast heating is performed as shown in block **14** to consolidate the preform to cause consolidation of the metal powders. The preform is quickly, preferably in a matter of seconds, consolidated to a high density, as shown in block **15** (also shown in item **22** of **FIG. 2**). The density of the preform is preferably the same as, or nearly the same as, the density of the final product.

[0097] Consolidation occurs when the heated metal powder preform is pressurized and plastically deforms to cause the metal powders to diffusion bond to each other and thus retain a desired shape. Consolidation is not the complete alloying of the metal powders, but may include some, preferably small, degree of alloying.

[0098] The consolidated form is optionally fast heated for working as shown in block **16**. Such fast heating is typically required for forming operations such as extruding, rolling, and forging, generally to a final shape as shown in block **17**. Optionally, final working or machining of the shape may be performed as shown in block **18**.

[0099] Once the working of block **17** and/or the final working/machining of bock **18** has been performed, then the final shape or near final shape of the product may be heat treated so as to achieve its full metallurgical properties, as shown in block **19**. The full metallurgical properties typically include enhanced tensile strength, enhanced hardness, and/or other enhanced physical or metallurgical properties of the alloy.

[0100] After heat treating to full properties, the product is substantially fully alloyed, and thus has the full properties or approximately the full properties of an alloy.

[0101] Referring now to **FIG. 2**, the process for forming a preform is shown in a semi-schematic fashion. This preform may be used in subsequent metal working and/or machining processes, as described above.

[0102] Metal powders are selected so as to provide the constituents and the concentrations of a final desired alloy. These metal powders are combined and blended (block **12** of **FIG. 1**), such as in V-blender **21**. It is important that the different metals be thoroughly mixed, so as to achieve properly alloying thereof in the final heat treating process (block **19** of **FIG. 1**).

[0103] The mixed powders are cold pressed (block **13** of **FIG. 1**) as shown in item **22**, so as to provide the preform shape **23**. As shown in cross-section **24**, the application of substantially uniform pressure results in substantially uniform pressed properties in the preform shape.

[0104] The powder preform shape is heated (block **14** of **FIG. 1**) as shown by item **25** of **FIG. 2**. The hot preform shape **31** is then preferably enclosed in hot ceramic grain **26**. Next, this hot charge **27** (which comprises the hot preform shape **31** combined with the hot ceramic grain **26**), is transferred to a consolidation die **35**.

[0105] The preform **31** is consolidated (block **15** of **FIG. 1**) by applying pressure to the ceramic grain via ram **29** from hydraulic actuator **28** thereto. The pressure applied to the ceramic grain **30** is transmitted to the preform shape **31**, which plastically deforms and distributes the pressure uniformly within the preform shape **31**, so as to effect substantially uniform consolidation thereof.

[0106] The charge **27** is removed from the die **35** and the ceramic grain **34** is removed from consolidated preform **36**. Typically, the ceramic grain **34** will maintain its form and adhere to the preform **36** after the charge **27** is removed from the die **35**. Typically, the ceramic grain can be removed from the consolidated preform **36** by hitting the charge **27** with a hammer or other hard object, so as to cause the ceramic grain **34** to break up, as shown at the end of the process in **FIG. 2**.

[0107] Referring now to **FIGS. 3A-3C**, a tube billet **301** is formed with front and back end configurations that are designed to give maximum yields and uniform flow of the billet from end to end in the extruded shape.

[0108] The extrusion tooling, comprising extrusion ram **303**, extrusion die **304** having extrusion head **305**, and mandrel **307**, provides a unique means for extruding tube forms with maximum material yields and with maximum control of cladding uniformity, both internal and external. An opening **306** is formed in the die head **305**. The opening **306** cooperates with the mandrel **307** to define the shape of the extrusion. A hot tube billet **301** with shaped front and back ends is entered into the extrusion die as shown in **FIG. 3B**, together with dummy block **302** at the back end thereof.

[0109] The dummy block facilitates proper application of pressure from the extrusion ram **303** to the billet **301**, while allowing the back end of the billet **301** to have a shape that enhances material usage efficiency and also enhances desirable material flow characteristics, particular when the billet **301** is clad.

[0110] The mandrel **307**, typically having a shaped front end, is inserted through the billet to a position aligned with the extrusion die opening **306**, as shown in **FIG. 3B**. The extrusion ram **303** then moves forward over the mandrel **307** to contact the dummy block **302**, and the mandrel **307** is clamped and held in position by transverse side clamps **309** (**FIG. 3C**) that operate through side slots in the ram **303** and are fixed in position outside the ram **303**. The side slots are long enough to allow movement of the ram to provide complete extrusion of the billet **301**. The die head **305** is designed for fast separation from the die **304** after extrusion, so that the extruded tube **308** can be disengaged from both the die **304** and mandrel **307** with minimum material end loss.

[**0111**] Referring now to **FIGS. 4A-4C**, examples of the types of preform shapes that can be used in extrusion processes to provide more uniform plastic deformation to a final product form, together with improved control of cladding thickness and increased size capacity is shown. The outer circles **401** of **FIGS. 4A-4C** represent the cross-sections of simple contemporary cylindrical extrusion chambers, within which the material to be extruded is place so that it can be forced through the extrusion head by a ram.

[**0112**] Thus, the cross-sectional shapes of the extrusion chamber can be simple cylinders, with circular cross-sections as shown by the outer circle **401** in **FIGS. 4A-4C**. Alternatively, more complex cross-sections can provide improved flow of the billet to a final shape, as shown by the intermediate forms **402**, **403**, and **404** in **FIGS. 4A**, **4B**, and **4C**, respectively. This is particularly important when it is desired to maintain an even thickness of cladding on the extrusion. The intermediate forms **402**, **403**, and **404** represent both the billet cross-section and the complimentary extrusion die or chamber cross-section.

[**0113**] Thus, an L-shaped (in cross-section) billet, for example, may be extruded using an L-shaped extrusion die (having an L-shaped chamber in cross-section), so as to more efficiently produce an L-shaped extrusion and/or so as to provide more uniform cladding on the extrusion.

[**0114**] Thus, more complex cross-sections are filled with more complex billets having complimentary shapes. The more complex shapes of billets can reduce the pressures required to make a final shape such as L-channel **405**, I-beam **406**, and U-channel **407** shown in **FIGS. 4A**, **4B**, and **4C**, respectively, and can also help to establish a more uniform flow of billet material relative to the final shape. These more complex shapes also can help assure a more uniform, controlled cladding thickness on the outer and inner surfaces of a final part, as discussed in detail below.

[**0115**] **FIG. 5** shows a solid billet **506** form with shaped front and back end configurations like those of **FIGS. 3A-3C** and which serve the same purposes. The cold pressing methods used with the present invention can produce reasonably uniform transverse and longitudinal densities in a billet, with average densities normally in the order of 60-85%. The factors that establish the most desirable density in a cold pressed billet are the strength needed for heating and handling in the following consolidation step; maintenance of open channel porosity that allows gas to escape from internal pore spaces during consolidation; and obtaining thermal conductivity that allows fast, uniform heating for consolidation.

[**0116**] An extrusion die **501** has an extrusion head **502**. An extrusion ram **503** forces the metal billet **506** through an opening in the extrusion head **502** to form the extrusion **507**. A dummy block **504** mates the extrusion ram **503** to the irregular shape of the back of the billet **506**, as described above.

[**0117**] The billet has a cladding **505** formed thereon. According to one aspect of the present invention, it is desired to form a cladding **508** of substantially uniform thickness upon the extrusion **507**. The enhanced extrudability of the billet **506** of the present invention, in combination with the use of specifically shaped (in cross-section and/or on the front and back ends) billets facilitates more uniform plastic flow of the billet **506** into the extrusion **507**, such that a more uniform thickness of the cladding **508** results.

[**0118**] In the fourth step of **FIG. 1** (block **14**), the cold pressed extrusion billet is entered into the inert atmosphere preheat chamber indicated schematically by dashed lines **39** of **FIG. 2**. The billet is heated to a selected temperature, such as by induction, radiation or conduction heating, as shown in item **25** of **FIG. 2**.

[**0119**] The heating and transfer units in this chamber can use both radiation and conduction heating from their side and end heating surfaces to provide fast heating of an enclosed billet and minimum diffusion between the alloying element powders and the matrix metal powder. This can be accomplished by using side wall and top heating units that can be moved in to contact the billet surfaces for heating, and moved out to allow convenient loading, as shown in **FIGS. 10 and 11**.

[**0120**] As shown in **FIG. 10A**, a plurality of side heater units **1002** and a top heater unit **1003** are spaced apart from a cylindrical billet **1001** to facilitate loading and unloading of the billet **1001** into the heating units, such as with tongs.

[**0121**] As shown in **FIG. 10B**, the side heater units **1002** and the top heater unit **1003** have been moved so as to be in contact with the billet **1001** so as to heat the billet to a desired temperature. A base heater **1004** heats the bottom of the billet **1001**. In this manner, the billet **1001** is rapidly heated by conduction to the desired temperature.

[**0122**] As shown in **FIG. 11A**, a plurality of side heater units **1102** and a top heater unit **1103** are spaced apart from a rectilinear billet **1101** to facilitate loading and unloading of the billet **1101** into the heating units, such as with tongs.

[**0123**] As shown in **FIG. 11B**, the side heater units **1102** and the top heater unit **1103** have been moved so as to be in contact with the billet **1101** so as to heat the billet to a desired temperature. A base heater **1104** heats the bottom of the billet **1101**. In this manner, the billet **1101** is rapidly heated by conduction to the desired temperature.

[**0124**] The temperature to which the billet is heated should be low enough to minimize alloying of powders in the billet, and high enough to allow plastic deformation and consolidation of the billet to a satisfactory strength for following working, and to a desired high density, normally in the range of 95-100% of theoretically. Fast heating of the billets to controlled temperatures in a protective atmosphere is accomplished most effectively by using the heating and transfer system of U.S. Pat. No. 4,634,375, which provides for continual production with a circular heating chamber.

[**0125**] The fifth step (block **15**) of **FIG. 1** is the consolidation of a heated preform to a high density, high strength form suitable for following working operations. When a cold pressed billet has been heated in a protective atmosphere to a selected temperature, as shown in step **4** of **FIG. 2**, it then can be consolidated to a strength and density that will allow following working by extrusion, rolling, forging or like processes.

[0126] One option is to enclose the hot billet in hot ceramic grain **30**, as shown in **FIG. 2**, so that the billet and the enclosing grain can be transferred to a consolidation die (**35** of **FIG. 2**). The entire charge **27** then can be pressurized in the die to a high density and a controlled form. A thin sheet metal liner optionally is used in the die to prevent contact of the hot grain with the die wall while the grain and enclosed part are consolidated as in step **6**. After consolidation by this option, the ceramic grain and enclosed billet are ejected from the die, the grain is broken away from the billet, and the billet surface is cleaned and finished as needed for the following working and finishing operations shown in blocks **16** through **19** of **FIG. 1**.

[0127] Another option for consolidating a cold pressed billet to a high density form is shown schematically in **FIG. 6**. The billet is first loaded into a heating unit in an enclosed protective atmosphere chamber, as shown in step **1** of **FIG. 6**. It then is heated to a selected temperature in the protective atmosphere, as shown in step **2** of **FIG. 6**.

[0128] Finally, the hot billet form is transferred directly to the consolidation die, as in step **3** of **FIG. 6**, and consolidated to a desired density without the use of enclosing ceramic grain. This option can be most practical with the lower melting point base metal powders such as aluminum, magnesium and the like, particularly for simple cylindrical or rectilinear shapes. The consolidation die can be maintained at an elevated temperature to obtain uniform consolidation and bonding of the billet materials across the billet cross-section during consolidation. For this option, the consolidation die would have an inside cross-section that would produce the consolidated dimensions required for following working operations, and the billet cross section would be designed for efficient transfer into the die.

[0129] Referring now to **FIG. 6**, a thin sheet metal liner can be used in the die **603** to prevent contact of the hot billet **601** with the wall of the die **603** while the billet is consolidated, thus eliminating the ceramic grain **30** of **FIG. 2**.

[0130] In step **1**, the billet is placed within a heated container **602**. In step **2**, the billet **601** is brought to temperature within the heated container **602**. In step **3**, the billet is transferred from the container **602** to a consolidation die **603**. In step **4**, pressure is applied to the billet **601** in the consolidation die **603** by consolidation ram **604**.

[0131] If the thin sheet metal liner is not used in die **603** in this option, the outer surface of the billet or the inner wall of the die may alternatively be lubricated with a solid lubricant such as MoS_2 or with other lubricants that will be compatible with the billet **601** and die **603** during consolidation.

[0132] The die **603** itself may be made with a split inside sleeve which has an inside cross-section that will produce the desired consolidated billet form, and an outside diameter that is tapered longitudinally for a close fit with the inside surface of the die wall, which has the same taper. This construction will allow the inner cross-section of the sleeve to open when it is moved up in the die, and thus free the consolidated charge for easy removal from the die. Tube forms made with this option can use a cast ceramic grain core or a core consisting of packed ceramic grain held in place within the tube inside diameter by cast ceramic plugs at one or both ends.

[0133] An additional option can be used that will provide high density, consolidated billet forms by going directly from powder to the consolidation step, without cold pressing a powder preform shape and without using ceramic grain. This can be most practical with the lower melting point base metal powders of aluminum, magnesium and the like. With this option, the powders are loaded and packed lightly into the heating and transfer units such as shown in step **1** of **FIG. 6**, within a protective atmosphere preheat chamber shown schematically by line **600**.

[0134] The powders then are heated rapidly to a desired temperature for consolidation, during which time the powder mass will shrink slightly in diameter and in length and bond lightly so that the powder mass can be transferred readily to the consolidation die as a coherent body.

[0135] This option requires the consolidation of a longer length of powder form than would be required with a cold pressed powder form, since the density of packed powder is much lower than the density of a cold pressed form. It therefore requires longer heating and transfer units, longer dies and larger press openings than would be required with cold pressed forms. It also has limitations as to cladding and special end configurations, and presents handling problems with pyrophoric or highly combustible powders as they are loaded at high temperatures into the heating and transfer units.

[0136] In all three of these options, maximum densities and properties can be obtained in the consolidated powder forms by the use of an additional invention that provides for fast removal of gases in the billet in the consolidation step. This invention is particularly important in consolidating product forms without enclosing them in solid grain, since the grain acts to allow the escape of most of the contained gases during consolidation, through the open porosity in the grain that is maintained as the grain is compacted.

[0137] Referring now to **FIG. 7**, a billet **601** has been loaded into the consolidation die **603**, as in step **3** of **FIG. 6**, and the die **603** has been moved to a position below the punch as shown in step **1** of **FIG. 7**.

[0138] An enclosure **701**, which may be in the form of a bellows, surrounds the punch or consolidation ram **604**, with an optional O-ring seal **702** at its bottom that preferably moves down with the consolidation ram **604** to create a gas-tight seal against the top of the die **603**. At the same time, an optional O-ring seal **703** at the bottom of the die **603** preferably completes a gas-tight seal of the die cavity as the punch moves down in step **2** of **FIG. 7**. The die cavity then can be quickly evacuated, either by a high capacity pump or by a vacuum tank opened to the die cavity.

[0139] The vacuum can be applied either at the top of the assembly via ports **704** or bottom of the die cavity via port **705** to provide the necessary gas removal during consolidation. A porous, expendable ceramic plug may optionally be used in the bottom punch vacuum port **705** to control extrusion of the billet into the port during the consolidation step.

[0140] Thus, in step **1** the hot billet or metal powders are loaded into the die and the die is moved under the press punch. In step **2** the punch or consolidation ram move down to seal the die so that gases in the billet or powder can be removed by vacuum. In step **3**, the billet or powder are consolidated by downward pressure of the consolidation ram to achieve the desired density and physical properties.

[0141] The hot grain consolidation of a cold pressed form provides the most versatile and controlled means for processing a wide range of alloys with special or unusual shapes, particularly end shapes, and/or with unusual internal configurations, as well as with cladding or other composite combinations such as fiber reinforced and dispersion strengthened materials.

[0142] The present invention uses an advanced hot isostatic pressing (HIP) method that provides new and more efficient heating methods, high pressures, and short cycle times to give fast, continual processing at greatly lowered costs. These developments now make possible the production, at lower costs, of an extended range of improved, high strength metal alloy products for high performance applications, in large size billets or other forms, and with forged quality.

[0143] It is understood that the exemplary apparatus and methods described herein and shown in the drawings represents only presently preferred embodiments of the invention. Indeed, various modifications and additions may be made to such embodiments without departing from the spirit and scope of the invention.

[0144] Thus, these and other modifications and additions may be obvious to those skilled in the art and may be implemented to adapt the present invention for use in a variety of different applications.

1. A method for forming superdeformable metal alloy preforms that have high strength alloy compositions, the method comprising:

selecting metal powders which will define the desired alloy;

mixing the selected metal powders;

performing either one of cold pressing the metal powders or fast heating the metal powders to define a desired preform shape; and

fast heating the metal powder preform shape so as to consolidate it to a desired form.

2. The method as recited in claim 1, wherein selecting the metal powders comprises selecting aluminum as a matrix material.

3. The method as recited in claim 1, wherein selecting the metal powders comprises selecting aluminum as a matrix material and selecting at least one alloy metal from the group consisting of:

copper;

magnesium;

chromium;

titanium;

iron;

lithium;

nickel;

vanadium;

silicon;

manganese; and

zinc.

4. The method as recited in claim 1, wherein selecting the metal powders comprises selecting iron as a matrix material.

5. The method as recited in claim 1, wherein selecting the metal powders comprises selecting iron as a matrix material and selecting at least one alloy material from the group consisting of:

nickel;

manganese;

silicon;

chromium;

molybdenum;

vanadium;

cobalt;

carbon; and

metal carbides.

6. The method as recited in claim 1, wherein selecting the metal powders comprises selecting metal powders having particle sizes between approximately 1 micron and approximately 100 microns.

7. The method as recited in claim 1, wherein mixing the selected metal powders comprises blending the selected metal powders with agitation.

8. The method as recited in claim 1, further comprising mechanically alloying surfaces of the metal powders.

9. The method as recited in claim 1, further comprising mechanically alloying surfaces of the metal powders by performing at least one process selected from the group consisting of:

hammer milling;

ball milling; and

impact milling.

10. The method as recited in claim 1, wherein fast heating the cold pressed metal powder preform shape or the heated metal powder preform shape so as to consolidate the preform shape comprises heating the metal powder preform shape to the desired consolidation temperature in the shortest time possible, with minimum hold time.

11. The method as recited in claim 1, wherein the heated metal powder preform is consolidated under pressure.

12. The method as recited in claim 1, wherein the heated metal powder preform is consolidated under pressure of between approximately 20,000 pounds per square inch and approximately 100,000 pounds per square inch.

13. The method as recited in claim 1, wherein the heated metal powder preform is consolidated at a temperature between approximately 40% and 75% of the melting point of the matrix metal of the metal powders, with the metal powder preform under pressure of between approximately 20,000 pounds per square inch and approximately 100,000 pounds per square inch.

14. A method for forming superdeformable metal alloys that have high strength alloy compositions, the method comprising:

selecting metal powders which will define the desired alloy;

mixing the selected metal powders;

performing either one of cold pressing the metal powders or fast heating the metal powders to define a desired preform shape;

fast heating the metal powder preform shape so as to consolidate it to a desired form;

fast heating the consolidated preform to prepare the consolidated preform for working;

working the consolidated preform to a desired shape; and

heat treating the worked product to define a metal alloy having the desired shape and properties.

15. The method as recited in claim 14, wherein selecting the metal powders comprises selecting aluminum as a matrix material.

16. The method as recited in claim 14, wherein selecting the metal powders comprises selecting aluminum as a matrix material and selecting at least one alloy metal from the group consisting of:

copper;

magnesium;

chromium;

titanium;

iron;

lithium;

nickel;

vanadium;

silicon;

manganese; and

zinc.

17. The method as recited in claim 14, wherein selecting the metal powders comprises selecting iron as a matrix material.

18. The method as recited in claim 14, wherein selecting the metal powders comprises selecting iron as a matrix material and selecting at least one alloy material from the group consisting of:

nickel;

manganese;

silicon;

chromium;

molybdenum;

vanadium;

cobalt;

carbon; and

metal carbides.

19. The method as recited in claim 14, wherein selecting the metal powders comprises selecting metal powders having particle sizes between approximately 1 micron and approximately 100 microns.

20. The method as recited in claim 14, wherein mixing the selected metal powders comprises blending the selected metal powders With agitation and milling the selected powders to obtain desired dispersion of the powders.

21. The method as recited in claim 14, further comprising mechanically alloying surfaces of the metal powders.

22. The method as recited in claim 14, further comprising mechanically alloying surfaces of the metal powders by performing at least one process selected from the group consisting of:

hammer milling;

ball milling; and

impact milling.

23. The method as recited in claim 14, wherein fast heating the cold pressed metal powder preform shape or the heated metal powder preform shape so as to consolidate the preform shape comprises fast heating the metal powder preform shape to the desired consolidation temperature, with minimum hold time.

24. The method as recited in claim 14, wherein the heated metal powder preform is consolidated under pressure.

25. The method as recited in claim 14, wherein the heated metal powder preform is consolidated under pressure of between approximately 20,000 pounds per square inch and approximately 100,000 pounds per square inch.

26. The method as recited in claim 14, wherein the heated metal powder preform is consolidated at a temperature between approximately 40% and 75% of the melting point of the matrix metal of the powdered metals, and at a pressure of between approximately 20,000 pounds per square inch and approximately 100,000 pounds per square inch.

27. The method as recited in claim 14, wherein fast heating the consolidated preform to prepare the consolidated preform for working comprises fast heating the consolidated preform to the desired working temperature, with minimum hold time.

28. The method as recited in claim 14, wherein working the consolidated preform to a desired shape comprises performing at least one process selected from the group consisting of:

extruding;

rolling;

forging; and

machining.

29. The method as recited in claim 14, wherein heat treating the worked product to define a metal alloy having the desired shape and properties comprises heating the product at a temperature and for a time that provides diffusion of the alloying elements and the matrix metal to give the desired properties.

30. A superdeformable metal alloy with high strength alloy composition formed by a method comprising:

selecting metal powders which will define the desired alloy;

mixing the selected metal powders; performing either one of cold pressing the metal powders or fast heating the metal powders to define a desired preform shape; and

fast heating the metal powder preform shape so as to consolidate it to a desired form.

31. The method as recited in claim 30, wherein selecting the metal powders comprises selecting aluminum as a matrix material.

32. The method as recited in claim 30, wherein selecting the metal powders comprises selecting aluminum as a matrix material and selecting at least one alloy metal from the group consisting of:

copper;

magnesium;

chromium;

titanium;

iron;

lithium;

nickel;

vanadium;

silicon;

manganese; and

zinc.

33. The method as recited in claim 30, wherein selecting the metal powders comprises selecting iron as a matrix material.

34. The method as recited in claim 30, wherein selecting the metal powders comprises selecting iron as a matrix material and selecting at least one alloy material from the group consisting of:

nickel;

manganese;

silicon;

chromium;

molybdenum;

vanadium;

cobalt;

carbon; and

metal carbides.

35. The method as recited in claim 30, wherein selecting the metal powders comprises selecting metal powders having particle sizes between approximately 1 micron and approximately 100 microns.

36. The method as recited in claim 30, wherein mixing the selected metal powders comprises blending the selected metal powders with agitation and milling the selected powders to obtain desired dispersion of the powders.

37. The method as recited in claim 30, further comprising mechanically alloying surfaces of the metal powders.

38. The method as recited in claim 30, further comprising mechanically alloying surfaces of the metal powders by performing at least one process selected from the group consisting of:

hammer milling;

ball milling; and

impact milling.

39. The method as recited in claim 30, wherein fast heating the cold pressed metal powder preform shape or the heated metal powder preform shape so as to consolidate the preform shape comprises heating the metal powder preform shape to the desired consolidation temperature in the shortest time possible, with minimum hold time.

40. The method as recited in claim 30, wherein the heated metal powder preform is consolidated under pressure.

41. The method as recited in claim 30, wherein the heated metal powder preform is consolidated under pressure of between approximately 20,000 pounds per square inch and approximately 100,000 pounds per square inch.

42. The method as recited in claim 30, wherein the heated metal powder preform is consolidated at a temperature between approximately 40% and 75% of the melting point of the matrix metal of the metal powders, with the metal powder preform under pressure of between approximately 20,000 pounds per square inch and approximately 100,000

43. A superdeformable metal alloy with high strength alloy composition formed and worked by a method comprising:

selecting metal powders which will define the desired alloy;

mixing the selected metal powders;

performing either one of cold pressing the metal powders or fast heating the metal powders to define a desired preform shape;

fast heating the metal powder preform shape so as to consolidate it to a desired form;

fast heating the consolidated preform to prepare the consolidated preform for working;

working the consolidated preform to a desired shape; and

heat treating the worked product to define a metal alloy having the desired shape and properties.

44. The method as recited in claim 43, wherein selecting the metal powders comprises selecting aluminum as a matrix material.

45. The method as recited in claim 43, wherein selecting the metal powders comprises selecting aluminum as a matrix material and selecting at least one alloy metal from the group consisting of:

copper;

magnesium;

chromium;

titanium;

iron;

lithium;

nickel;

vanadium;

silicon;

manganese; and

zinc.

46. The method as recited in claim 43, wherein selecting the metal powders comprises selecting iron as a matrix material.

47. The method as recited in claim 43, wherein selecting the metal powders comprises selecting iron as a matrix material and selecting at least one alloy material from the group consisting of:

nickel;

manganese;

silicon;

chromium;

molybdenum;

vanadium;

cobalt;

carbon; and

metal carbides.

48. The method as recited in claim 43, wherein selecting the metal powders comprises selecting metal powders having particle sizes between approximately 1 micron and approximately 100 microns.

49. The method as recited in claim 43, wherein mixing the selected metal powders comprises blending the selected metal powders with agitation and milling the selected powders to obtain desired dispersion of the powders.

50. The method as recited in claim 43, further comprising mechanically alloying surfaces of the metal powders.

51. The method as recited in claim 43, further comprising mechanically alloying surfaces of the metal powders by performing at least one process selected from the group consisting of:

hammer milling;

ball milling; and

impact milling.

52. The method as recited in claim 43, wherein fast heating the cold pressed metal powder preform shape or the heated metal powder preform shape so as to consolidate the preform shape comprises fast heating the metal powder preform shape to the desired consolidation temperature, with minimum hold time.

53. The method as recited in claim 43, wherein the heated metal powder preform is consolidated under pressure.

54. The method as recited in claim 43, wherein the heated metal powder preform is consolidated under pressure of between approximately 20,000 pounds per square inch and approximately 100,000 pounds per square inch.

55. The method as recited in claim 43, wherein the heated metal powder preform is consolidated at a temperature between approximately 40% and 75% of the melting point of the matrix metal of the powdered metals, and at a pressure of between approximately 20,000 pounds per square inch and approximately 100,000 pounds per square inch.

56. The method as recited in claim 43, wherein fast heating the consolidated preform to prepare the consolidated preform for working comprises fast heating the consolidated preform to the desired working temperature, with minimum hold time.

57. The method as recited in claim 43, wherein working the consolidated preform to a desired shape comprises performing at least one process selected from the group consisting of:

extruding;

rolling;

forging; and

machining.

58. The method as recited in claim 43, wherein heat treating the worked product to define a metal alloy having the desired shape and properties comprises heating the product at a temperature and for a time that provides diffusion of the alloying elements and the matrix metal to give the desired properties.

59. A method for extruding materials, the method comprising:

forming a dummy block which has a surface which is complimentary in shape to at least one of a die and a mandrel, such that the dummy block fits into an extrusion container generally flush with the die; and

placing the dummy block behind a hot billet during an extrusion process, such that efficiency of the extrusion process is enhanced as the billet is extruded.

60. The method as recited in claim 59, further comprising:

removing the dummy block from the container after an extrusion process; and

placing the dummy block behind another hot billet and reusing the dummy block in a subsequent extrusion process.

61. A method for extruding a clad material, the method comprising:

forming a superdeformable metal alloy preform having a high strength alloy composition, according to the method comprising:

selecting metal powders which will define the desired alloy;

mixing the selected metal powders; and

cold pressing the mixed metal powders to define a desired preform shape; and

forming a cladding upon the superdeformable metal alloy preform according to the method comprising:

selecting metal powders which will define the desired cladding;

mixing the selected metal powders; and

cold pressing the mixed metal powder cladding against the preform to define a desired clad preform shape; and

fast heating the cold pressed clad preform shape so as to consolidate the metal powders and bond the cladding to the preform; and

heating and extruding the clad superdeformable metal alloy to a desired form.

62. A method for forming a superdeformable metal alloy preform having a high strength alloy composition, the method comprising:

selecting metal powders which will define the desired alloy;

mixing the selected metal powders;

performing one of either cold pressing the mixed metal powders or fast heating the metal powders to define a desired preform shape;

fast heating the preform shape to a desired consolidation temperature;

applying mechanical pressure thereto at reduced atmospheric pressure, so as to consolidate the metal powders in a manner which mitigates an occurrence of voids therein.

63. The method as recited in claim 62, further comprising substantially surrounding the heated preform shape with a ceramic grain prior to applying mechanical pressure thereto at a reduced atmospheric pressure.

64. A method for forming a preform which facilitates working of metal, the method comprising:

selecting metal powders which will define a desired alloy;

mixing the selected metal powders;

performing one of either cold pressing the mixed metal powders or fast heating the metal powders to define a desired preform shape;

fast heating the metal powder preform shape so as to consolidate the metal powders; and

wherein the desired preform shape is generally similar to a desired shape of a final, worked product.

65. The method as recited in claim 64, wherein the desired preform shape is selected from the group consisting of:

tubular;

L-channel;

I-beam; and

U-channel.

66. A preform formed by the method comprising:

selecting metal powders which will define a desired alloy;

mixing the selected metal powders;

performing one of either cold pressing the mixed metal powders or fast heating the metal powders to define a desired preform shape; and

fast heating the metal powder preform shape so as to consolidate the metal powders;

wherein the desired preform shape is generally similar to a desired shape of a final, worked product.

67. The preform as recited in claim 66, wherein the desired preform shape is selected from the group consisting of:

tubular;

L-channel;

I-beam; and

U-channel.

68. A method for working metals, the method comprising:

forming a superdeformable/high strength metal alloy preform, according to the method comprising:

selecting powdered metals which will define the desired alloy;

mixing the selected powdered metals;

performing one of either cold pressing the mixed metal powders or fast heating the metal powders to define a desired preform shape; and

fast heating the cold pressed powdered metals so as to consolidate the powdered metals;

wherein the desired preform shape is generally similar to a desired shape of a final, worked product; and

working the preform to the desired final shape;

69. The method as recited in claim 68 wherein the desired preform shape is selected from the group consisting of:

tubular;

L-channel;

I-beam; and

U-channel.

70. The method as recited in claim 68, wherein working the preform to the desired final shape comprises a least one process selected from the group consisting of:

extruding;

rolling; and

forging.

71. A method for extruding metals, the method comprising:

forming a superdeformable metal alloy preform having a high strength alloy composition, according to the method comprising:

selecting metal powders which will define the desired alloy;

mixing the selected powdered metals;

performing one of either cold pressing the mixed metal powders or fast heating the metal powders in a to define a desired preform shape; and

fast heating the preform shape so as to consolidate the metal powders;

wherein the desired preform shape is generally similar to a desired shape of a final, worked product; and

extruding the preform to the desired final shape.

72. The method as recited in claim 71, wherein the desired preform shape is selected from the group consisting of:

tubular;

L-channel;

I-beam; and

U-channel.

73. A metal extrusion formed by the method comprising:

forming a superdeformable/high strength metal alloy preform, according to the method comprising:

selecting powdered metals which will define the desired alloy;

mixing the selected powdered metals;

performing one of either cold pressing the mixed metal powders or fast heating the metal powders to define a desired preform shape; and fast heating the preform shape so as to consolidate the metal powders;

wherein the desired preform shape is generally similar to a desired shape of a final, worked product; and

extruding the preform to the desired final shape.

74. The metal extrusion as recited in claim 73, wherein the desired preform shape is selected from the group consisting of:

tubular;

L-channel;

I-beam; and

U-channel.

75. The metal extrusion as recited in claim 1, further comprising:

fast heating the preform shape to a consolidation temperature;

applying at least a partial vacuum to the heated preform shape while simultaneously applying mechanical pressure thereto, so as to increase the density thereof, and so as to mitigate an occurrence of voids therein.

76. A method for forming metal, the method comprising:

combining at least two different metals such that they are less fully alloyed and such that they have less strength;

working the combined metals; and

more fully alloying the metals such that they are more fully alloyed have more strength.

77. A metal alloy formed by a process comprising:

combining at least two different metals such that they are less fully alloyed and such that they have less strength;

working the combined metals; and

more fully alloying the metals such that they are more fully alloyed have more strength.

78. A method for forming metal products, the method comprising combining at least two different metals such that they are not fully alloyed and may thus be more easily worked.

79. A method for forming metal products, the method comprising combining at least two different metals such that they are not fully alloyed and may thus be more easily worked, wherein at least a portion of the forming is performed using the consolidation equipment described in U.S. Pat. No. 4,634,375.

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