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[54] LOW ENERGY FORMING OF METALS
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[50] Field of Search ..... 29/420, 420.5, 527.5, 180 CH, 192 R, DIG. 47; 164/76; 148/11.5; 72/60, 364

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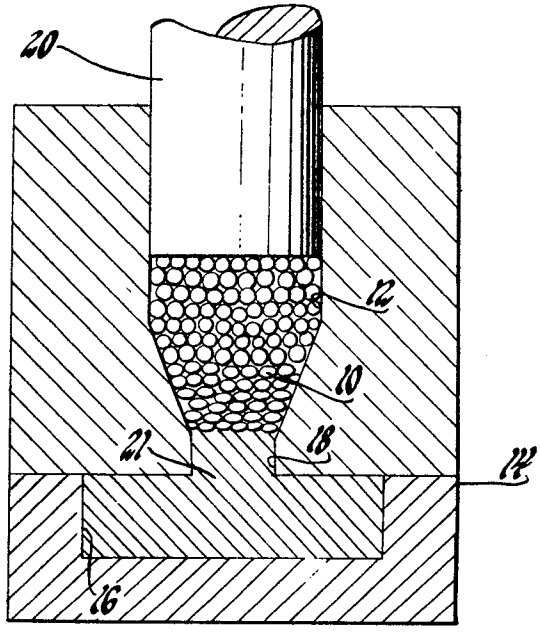
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ABSTRACT: A method of forming bulk metallic articles with relatively little energy input is disclosed. A molten solution of a metal alloy conditionable to exhibit enhanced plasticity is quenched in a manner and at a rate effective to produce pellets having a nonequilibrium, uniform cast structure which on mechanical working bond together and recrystallize to form a homogeneous mass having a fine grain structure required for enhanced plasticity. The mass is then formed at a temperature immediately below the phase transformation temperature of the alloy with relatively little energy input into an article of predetermined configuration.



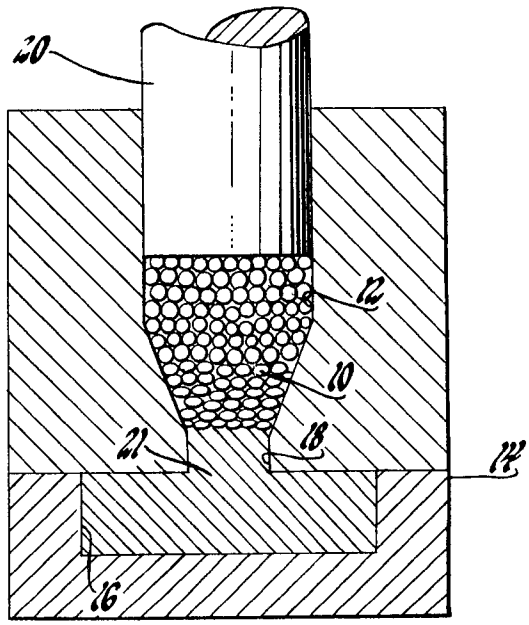


Fig. 4

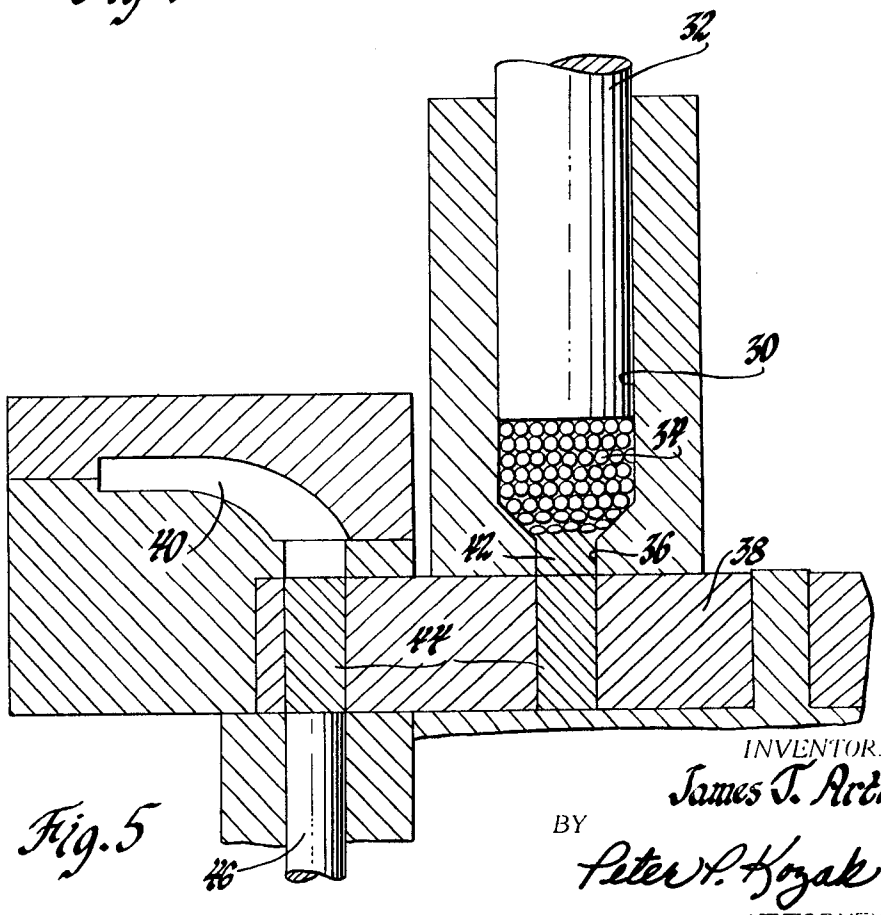


Fig. 5

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LOW ENERGY FORMING OF METALS

This invention relates to the forming of certain metal alloys with a relatively low energy input. More particularly, it relates to a method of efficiently conditioning certain metal alloys to exhibit enhanced plasticity and to a method of forming the alloy by compressive loading with a relatively low energy input into a bulk article of predetermined configuration.

It is known that under certain conditions some metal alloys may be drastically deformed with relatively little energy input. This anomalous behavior not ordinarily exhibited by metals or metal alloys was first observed in certain lead-tin, bismuth-tin, and zinc-aluminum alloy systems and was regarded as so remarkable that alloys exhibiting this phenomenon became known as "superplastic" alloys. Several laboratory investigations of the superplastic phenomenon have shown elongations in tensile test specimens of alloys exhibiting this phenomenon in excess of 1,000 percent as an indication of the degree of deformation attainable.

Superplastic alloys have been characterized as having "especially low values of resistance to deformation and extremely high plasticity as compared with other alloys and pure components of a system," and, thus, are referred to as exhibiting enhanced plasticity. Another characteristic of superplastic alloys is that they are strain-rate sensitive unlike most metals which do not exhibit any significant strain-rate sensitivity. That is, the change in strain rate or speed of deformation of a superplastic alloy with a change in the stress causing deformation is under initial loading much greater than that in most alloys and, as a general proposition, the greater the strain-rate sensitivity of an alloy the greater is the degree of superplasticity and the less is the stress required for deformation. However, superplastic alloys are strain hardenable, i.e., at increasing strain rates the alloys exhibit increased resistance to deformation and, as a consequence, there exists an inverse relation between the rate of deformation and the applied stress-inducing deformation, i.e., the slower the deformation process the less is the load required for deformation.

Because of the low load requirements in forming superplastic alloys, a more efficient method of fabricating metals on a commercial scale has become available. However, a major inefficiency in any fabricating process lies in the fact that before fabrication the alloy must first be conditioned to exhibit sufficient strain-rate sensitivity to have enhanced plasticity. This step is critical and methods known to the art are very time consuming and inefficient. Therefore, an efficient method of conditioning the alloy to exhibit enhanced plasticity or the superplastic phenomenon is highly desireable. Furthermore, in addition to conditioning the alloy to exhibit the superplastic phenomenon, it is also desireable during conditioning to place the alloy in a physical state readily workable in a desired fabricating process.

Accordingly, it is an object of this invention to provide an efficient method of conditioning certain alloys capable of exhibiting sufficient strain-rate sensitivity to have enhanced plasticity to a state whereby enhanced plasticity is achieved.

A further object of this invention is to provide a process for conditioning certain alloys to exhibit enhanced plasticity whereby during conditioning of the alloy, the alloy is placed in a physical state readily workable in a forming process.

More specifically, it is an object of this invention to provide a process for forming bulk metallic articles wherein the alloy being formed is conditioned to exhibit sufficient strain-rate sensitivity to have enhanced plasticity whereby the alloy may be formed with relatively little energy input.

These and other objects and advantages are accomplished in accordance with the invention by heating and melting a metal alloy having the ability to exhibit enhanced plasticity under the proper conditions, dispersing the molten alloy into small droplets, quenching these droplets at a rate effective to form pellets having a nonequilibrium, uniform cast structure which on mechanical working recrystallizes to form a fine grain structure having sufficient strain-rate sensitivity to exhibit enhanced plasticity, and severely mechanically working the pellets by the application of a compressive stress thereto with a relatively low energy input at a temperature immediately below the phase transformation temperature of the alloy and in such a manner that the pellets bond together to form a homogeneous mass which is forced against, and into intimate contact with, a die having a surface formed complementary to the shape desired to be formed. The process is characterized by the relationship that the lower the forming rate the lower is the stress required for forming.

Other objects and advantages will be apparent from the following detailed description of the invention reference being had to the accompanying drawings of which:

FIG. 1 is the zinc-aluminum phase diagram;

FIG. 2 is a photomicrograph at a magnification of 100X illustrating a nonequilibrium, uniform cast structure of a 78 percent zinc-22 percent aluminum alloy;

FIG. 3 is a photomicrograph at a magnification of 100X illustrating the microstructure of the zinc-aluminum alloy of FIG. 2 when conditioned to exhibit enhanced plasticity;

FIG. 4 is a schematic representation of an apparatus suitable for forming an alloy having enhanced plasticity in accordance with one embodiment of the invention; and

FIG. 5 is a schematic representation of a forming apparatus similar to FIG. 4, in accordance with another embodiment of the invention.

A few general comments may first be made concerning factors which control or influence the superplastic phenomenon and the inherent limitations in conditioning an alloy to the superplastic state. Although the phenomenon of superplasticity in certain metal alloys is not completely understood, various investigations have shown that in order for an alloy to exhibit superplasticity it must have two phases and have a fine grain structure. Thus, the critical step of any process utilizing the superplastic phenomenon lies in creating a fine grain structure.

The phase diagram for zinc-aluminum alloy phase transformations, FIG. 1, which was prepared from data published by A. A. Presnyakov, Yu. A. Gorban, and V. V. Chervyakova in *Zhur, Fiz. Khem*, Volume 35 (1961), p. 1,289, shows that when an alloy of 78 percent zinc and 22 percent aluminum, which is known to be conditionable to the superplastic state, is heated above 527° F., a transformation occurs from two phases, an α-aluminum-rich solid solution and a β-zinc-rich solid solution, to a single phase, γ. If this single phase solid solution is now cooled below the eutectoid transformation temperature, 527° F., slowly so as to approximate the equilibrium cooling rate, the resulting structure will be a coarse-grained structure. This structure does not exhibit any special ductility because it is not fine grained. However, if the single solid phase, γ, is quickly cooled from above the eutectoid temperature to room temperature or lower, a nonequiblibrium cooling rate is achieved and at the quenching temperature the single γ phase is retained in the two-phase region as a metastable phase which then quickly decomposes into the equilibrium two phases. However, at this low temperature the rate of diffusion and redistribution of the atoms is drastically decreased as compared to that at higher temperatures and, as a result, a very fine-grained mixture of the two phases is formed. This structure consists of an aluminum-rich matrix having the zinc-rich phase distributed therein and is sufficiently fine grained for the alloy to be superplastic.

It may be observed then that homogenized and slowly cooled alloys do not exhibit superplasticity while alloys quenched to the metastable state or, in other words, quenched at a rate sufficient to prevent immediate decomposition to the equilibrium two-phase state do exhibit superplasticity. Further investigations have shown that the greater the quenching rates achieved, which causes a greater deviation from the equilibrium condition, the greater is the proportion of alloy in the metastable state and the greater is the degree of superplasticity.

As previously stated, the major drawback in utilizing the superplastic phenomenon in commercial processes is that relatively timemconsuming and inefficient processing schedules are involved in conditioning alloys to form the required fine grain structure. In a typical operation, a quantity of metal alloy consisting of 78 percent zinc-22 percent aluminum is heated to the molten state after which the molten solution is cast into ingots which are allowed to slowly cool to room temperature. The ingots are then heated and rolled to a desired thickness after which blanks suitable for forming are punched out of the rolled sheet. These blanks must then be homogenized or solution-treated for a relatively long time above the phase transformation temperature in the γ-region prior to quenching in order to achieve the desired microstructure which is a serious limitation to an efficient forming process. A limitation exists not only in the time required for treatment but also in the size or cross section of the material that may be treated. That is, when material having substantial bulk or a relatively thick cross section is quenched, the outside of the material cools much faster than the inside and in a given quenching procedure for material of a critical cross section and cross sections thicker than the critical, the inner portions will not achieve the cooling rates necessary to form the fine grain structure, and thus will not be superplastic. This limitation is not particularly important in sheet-forming processes where blanks of a relatively thin cross section are used, but in forming processes where materials of substantial cross section are forced into a die to form bulk articles this factor limits the amount of material which may be conditioned for forming and, consequently, places a stringent limitation on the size of the articles which may be formed. Accordingly, this invention provides both an improved and more efficient method of conditioning the alloy to the superplastic state in which the size of the article desired to be formed is not limited by the conditioning process.

In accordance with my process, a batch of zinc is heated to the molten state and aluminum is added to bring the proportion of the molten mixture to 78 percent zinc and 22 percent aluminum. Although this composition is not critical, it is preferred in the process because experience has shown that superplastic properties diminish as the metallic composition varies from this proportion. When the molten solution is thoroughly melted and mixed, it is passed through a centrifugal screen made from a metal with a higher melting point than the solution whereby the solution is dispersed in the form of discrete droplets which fall by gravity into a quenching medium and quickly solidify into pellets. As a result of the quench, a nonequilibrium cooling rate is achieved and the resulting structure, rather than being the metastable structure produced on quenching from the γ-region, is a uniform cast structure having a distribution of the low-temperature phases, the α-aluminum-rich solid solution (light phase) and the β-zinc-rich solid solution (dark phase), as shown in FIG. 2. Although this cast structure exhibits a small amount of strain-rate sensitivity, the sensitivity is not sufficient for the alloy to exhibit enhanced plasticity because the structure is not sufficiently fine grained. However, the fine grain structure required for enhanced plasticity can be achieved by drastic mechanical deformation which bonds the pellets together to form a homogeneous mass and which increases the energy of the structure by deformation of the grains. The stored energy of the deformed grains is dissipated by recrystallization in which simultaneously with the release of the stored energy occurs the growth of a new set of strain-free crystals which grow at the expense of the deformed crystals and form the fine-grained microstructure of the low-temperature phases, as shown in FIG. 3, required for enhanced plasticity. In accordance with the preferred embodiments of this invention as will be more fully explained later, the mechanical deformation and recrystallization of the cast pellets takes place simultaneously with the forming process thereby increasing the efficiency of the process. However, the cast pellets may be mechanically deformed by any of a number of processes involving mechanically compacting particulate material such as powder metallurgy forming techniques and allowed to recrystallize prior to forming, if desired. The conditioning process embodied by this invention thus requires the formation of a nonequilibrium, uniform cast structure which on mechanical working recrystallizes to form the required fine-grained microstructure.

The size of the pellets formed is not critical and may be of any size suitable for convenient working at a later time. However, in the preferred process, the size of the pellets range from approximately 0.06 to 0.12 inch in diameter. In the preferred process the quenching medium is water, however, any quenching medium including liquid nitrogen may be employed as long as the quenching rate is fast enough for the uniform, cast structure to form.

It may be seen then, that although the conditioning process embodied by this invention differs from conventional homogenizing and quenching procedures wherein the fine grain structure is produced directly on quenching, the fine grain structure is more efficiently produced by the processes embodied by this invention and the limitations in conditioning processes heretofore available in the art are eliminated. That is, by quenching directly from the molten state rather than from the single phase γ region the time-consuming process of casting, rolling, and then treating the alloy for substantial periods of time above the phase transformation temperature has been eliminated. Furthermore, since the pellets have a small cross section, it is ensured that each pellet will have the uniform, cast structure and the fine grain structure formed by recrystallization. Another important advantage of the "pelletizing" technique is that as many pellets as required can be used in the forming process to form a desired article, thus eliminating the limitation in conventional techniques of the size of the article which may be formed due to the limitation of the size of the material which can be conditioned to the superplastic state.

The pellets are then removed from the quenching medium and since the uniform, cast structure is stable, they may be either stored or immediately used in the forming process. In one embodiment of the invention, as shown in FIG. 4, the pellets **10** are placed in a cylinder **12** of a forming apparatus **14** which consists also of a die cavity **16** corresponding to the article desired to be formed, a restricted orifice **18** communicating between the cylinder **12** and the die cavity **16**, and a hydraulic ram **20** operable within the cylinder **12**. The maximum strain-rate sensitivity or maximum amount of superplasticity is known to occur at a temperature immediately below the phase transformation temperature of the alloy which for a 78 percent zinc-22 percent aluminum alloy composition is 527° F. and, in addition, it is known that the time for recrystallization to be completed decreases with increasing temperature. Accordingly, the pellets and the extrusion apparatus are heated and maintained at a temperature of about 525° F. throughout the forming process. The pellets are then forced through the orifice **18** at a suitable rate by the compressive action of the ram **20** wherein they undergo severe mechanical deformation and recrystallize forming the desired fine-grained microstructure as previously described. The deformation in the orifice also bonds the pellets together to form a homogeneous mass **21** which then flows into the die cavity **16** and against and into intimate contact with the die **16** to form a desired article. As previously stated, the rate at which the pellets can be extruded is inversely related to the load applied, i.e. the greater the rate of extrusion, the greater is the load required. My investigation has shown that a simple part can be formed at an extrusion speed of 3½ inches per minute under a load of 34,000 p.s.i. and at slower extrusion speeds only a few pounds per square inch load is required.

In a second embodiment of this invention as shown in FIG. **5**, the previously described embodiment of the invention is slightly modified to comprise a "two-step" forming process. The forming apparatus generally includes a cylinder **30** having a hydraulic it **32** operable therein, for receiving the cast pellets **34**, a restricted orifice **36**, a tubular die **38** communicating

with the orifice **36**, and a die cavity **40** corresponding to the article desired to be formed. In operation, the cast pellets are forced through the orifice **36** by the compressive action of the ram **32** wherein they are severely deformed and bonded together to form a homogeneous mass **42**, and wherein recrystallization takes place to form the desired fine-grained microstructure. As the forming process continues the mass **42** enters the tubular die **38** forming a homogeneous, superplastic rod **44**. The rod **44** is then transferred to a second forming apparatus wherein it flows under the action of a second hydraulic ram **46** into the die cavity **40** to form the desired article. The forming process is characterized by the relation, the greater the rate of forming, the greater is the load required. The resulting article has excellent structural integrity and a wrought structure or preferred orientation which increase the mechanical properties of the article. This process is particularly applicable when forming more complex shapes or articles requiring superior mechanical properties.

Another feature of the embodiment shown in FIG. **5** which may be characterized as a "two-step" forming process wherein the pellets are first formed into a rod and the rod is then forced into the die cavity is that it is not necessary that the rod be immediately worked. Where commercial practice dictates the pellets may be formed into a rod which is then stored for later use. Because the fine-grained microstructure produced on recrystallization within the orifice is stable the rod may be held indefinitely and still retain its superplastic properties.

It will be appreciated by those skilled in the art that the performance of the process embodied in this invention is not dependent on any specific configuration of the die cavity nor is the pellet size or configuration or the size of the orifice critical and, accordingly, the preferred embodiments have been presented with reference to schematic representations, FIGS. **4** and **5**, without limitation thereto. The only critical steps in the process are that the pellets be quenched in a manner and at a rate effective to completely form the uniform, cast structure and that this structure be sufficiently mechanically deformed for the pellets to bond together into a homogeneous mass and for recrystallization to proceed to form the fine-grained microstructure required for superplasticity.

Although the foregoing discussion of the invention has been directed to low energy forming in a closed die process, it will be further appreciated by those skilled in the art that the process herein described is not limited thereto but includes other well-known forming processes wherein deformation takes place through inducing compressive stresses on the material being formed. In accordance with the embodiment previously described and shown in FIG. **5**, after the pellets have been formed into a rod, the rod being superplastic may then be formed into a desired article with relatively little energy input in such processes as swagging drop forging, upset forging, press forging, rolling, tube forming, roll threading, and the like which conventionally are high energy forming processes involving loads of several tons and more. Moreover, as previously stated it is not necessary that the pellets be mechanically worked by forcing them through a restricted orifice. The pellets may undergo the required mechanical working in various other ways wherein particulate material is compacted into a homogeneous mass and that mass may then be formed into a desired article in a closed die process as herein described or in any of the typically high energy forming processes previously mentioned.

In addition, although the foregoing discussion of the invention has been directed to one alloy system, 78 percent zinc-22 percent aluminum, it will be appreciated by those skilled in the art that alloy systems of eutectic or eutectoid composition and those involving allotropic transformations which are conditionable to exhibit superplasticity, may also be used in accordance with this invention. The process herein described is particularly applicable to those alloy systems which may be conditioned to exhibit sufficient strain-rate sensitivity to be superplastic by either thermal conditioning followed by working and recrystallization or by working and recrystallization alone. The 78 percent zinc-22 percent aluminum alloy system as previously discussed and certain alloys of the iron-chromium-nickel system are examples of alloys suitable for use in the present invention which require the thermal conditioning-recrystallization procedure while alloy systems such as 60 percent tin-40 percent lead which cannot be thermally conditioned but can only be conditioned through working and recrystallization are also suitable to the present invention.

It will be seen, then, that a low energy forming process when practiced in accordance with the process of this invention offers significant advantages over conventional forming processes, some of the advantages being lower forming pressures, lower forming temperatures, more efficient and lower material preparation costs, less tool wear and longer tool life, and smaller and less expensive forming apparatus; without sacrificing structural integrity and the superior mechanical properties of a wrought product.

Having described the preferred process of the invention, reference to the specific examples will further serve to illustrate the described process and its advantages.

EXAMPLE I

Samples from a molten solution of a zinc-aluminum alloy consisting of about 78 percent zinc-22 percent aluminum were quenched into pellets having diameters from 0.06 to 0.12 inch. Metallographic examination assured that the pellets had a nonequilibrium, uniform cast structure. The pellets were heated to about 525° F. and then placed in a forming apparatus substantially like that shown in FIG. **4** having an orifice **18** of about one-half inch in diameter by one-fourth inch in length. The orifice was first plugged and pressure was applied to the pellets by means of the ram **20** until an initial homogeneous layer was formed after which pressure of about 34,000 p.s.i. was applied at an extrusion speed of 3½ inches per minute to form the desired article.

Identical tests performed on samples of the same alloy showed that the shortest forming times at the lowest loads were achieved when the temperature of the pellets was about 525° F. as in this example.

The finished article has a room temperature tensile strength of 34,000 p.s.i. and a Charpy impact value of 17—18 foot-pounds.

EXAMPLE II

In order to demonstrate the inverse relation between the rate of deformation and load required for deformation, the procedure described in example I was repeated but at an extrusion speed of 68 inches per minute. The load required for deformation was found to increase to 55,370 p.s.i.

EXAMPLE III

The procedure as outlined in example I was again repeated except that the pellets were formed in an apparatus substantially like that as shown in FIG. **5** having the same orifice dimensions as those recited in example I. The rod and the finished article were formed under a load of 34,000 p.s.i. and at an extrusion speed of 3½ inches per minute. The finished article was then mechanically tested and showed a room temperature tensile strength of 34,000 p.s.i., the same as that of the article formed in example I. However, in this case the article had a Charpy impact value of 28—29 foot-pounds which was about a 60 percent increase in impact strength over that of the article formed in example I. This increase was due to the improved wrought structure or preferred orientation produced by forming the pellets into a rod and then forming the rod into the article.

EXAMPLE IV

Continuing the investigation it was desired to produce articles having a higher room temperature tensile strength than

those previously achieved with the 78 percent zinc-22 percent aluminum alloy. In order to increase the tensile strength of the alloy small amounts of strengthening elements were added. Two compositions were used: 77 percent zinc-22 percent aluminum—1 percent copper and 74 percent zinc-22 percent aluminum—3 percent copper—1 percent magnesium. These alloys showed a decrease in the degree of superplasticity as compared to the 78 percent Zn-22 percent Al alloy forming at an extrusion speed of 2 inches/minute and a load of 34,000 p.s.i. or 36 inches/minute and a load of 55,370 p.s.i.; however, the room temperature tensile strength increased to about 60,000 p.s.i. as compared to 34,000 p.s.i. previously achieved in the 78 percent Zn-22 percent Al alloy. This test demonstrated that a compromise can be made between the strength required and the degree of superplasticity desired in order to achieve increased strength while obtaining the advantages of low energy forming.

Although the invention has been described in terms of specific embodiments, it will be understood that various modifications may be made within the scope of the invention.

I claim:

1. In a method of forming metallic articles, the improved process comprising the steps of:
providing a die having a surface formed complementary to the shape desired to be formed,
providing a molten solution of an alloy conditionable to exhibit enhanced plasticity,
dispersing said molten solution into discrete droplets,
quenching said droplets at a rate effective to produce pellets having a nonequilibrium, uniform cast structure,
severely mechanically working said pellets, whereby said pellets bond together and undergo recrystallization thereby forming a homogeneous mass having a fine grain structure and exhibiting enhanced plasticity, and
forcing said mass into said die by applying a compressive stress thereto, for a period of time inversely related to said applied compressive stress.

2. In a method of forming metallic articles, the improved process comprising the steps of:
providing a die having a surface formed complementary to the shape desired to be formed,
providing metal pellets of an alloy conditionable to exhibit enhanced plasticity made by dispersing a molten solution of said alloy into discrete droplets and quenching said droplets at a rate effective to produce said pellets having a nonequilibrium, uniform cast structure,
severely mechanically working said pellets, whereby said pellets bond together and undergo recrystallization thereby forming a homogeneous mass having a fine grain structure and exhibiting enhanced plasticity, and
forcing said mass into said die by applying a compressive stress thereto, for a period of time inversely related to said applied compressive stress.

3. In a method of forming metallic articles, the improved process comprising the steps of:
providing a forming apparatus comprising a cylinder having pressure means operable therein, a die cavity formed complementary to the shape desired to be formed, and a restricted orifice communicating between said cylinder and said die cavity,
providing metal pellets of an alloy conditionable to exhibit enhanced plasticity made by dispersing a molten solution of said alloy into discrete droplets and quenching said droplets at a rate effective to produce said pellets having a nonequilibrium, uniform cast structure,
forcing said pellets through said orifice by applying a compressive stress thereto, for a period of time inversely related to said applied compressive stress, whereby said pellets undergo severe mechanical working and thereby bond together and undergo recrystallization in said orifice thereby forming a homogeneous mass having a fine grain structure and exhibiting enhanced plasticity, said mass flowing into and filling said cavity under the application of said stress.

4. In a method of forming metallic articles, the improved process comprising the steps of:
providing a first forming apparatus comprising a cylinder having pressure means operable therein, a tubular die and a restricted orifice communicating between said cylinder and said die,
providing a second forming apparatus comprising a cylinder having pressure means operable therein and a die cavity communicating with said cylinder and having a surface formed complementary to the shape desired to be formed,
providing metal pellets of an alloy conditionable to exhibit enhanced plasticity made by dispersing a molten solution of said alloy into discrete droplets and quenching said droplets at a rate effective to produce said pellets having a nonequilibrium, uniform cast structure,
forcing said pellets through said orifice by applying a compressive stress thereto, for a period of time inversely related to said applied compressive stress, whereby said pellets undergo severe mechanical working and thereby bond together and undergo recrystallization in said orifice thereby forming a homogeneous mass having a fine grain structure and exhibiting enhanced plasticity, said mass flowing into said tubular die under the application of said stress thereby forming a rod,
transferring said rod to said cylinder of said second forming apparatus, and
forcing said rod into said die cavity by applying a second compressive stress thereto, for a period of time inversely related to said second compressive stress.

5. The method of claim 4 wherein said die of said first forming apparatus comprises said cylinder of said second forming apparatus and wherein means are provided for moving said die out of communication with said orifice of said first apparatus and into communication with said die cavity of said second apparatus.

6. In a method of forming metallic articles, the improved process comprising the steps of:
providing a die having a surface formed complementary to the shape desired to be formed,
providing metal pellets of an alloy conditionable to exhibit enhanced plasticity, said alloy exhibiting increased plasticity with increasing temperature up to its phase transformation temperature, made by dispersing a molten solution of said alloy into discrete droplets and quenching said droplets at a rate effective to produce said pellets having a nonequilibrium, uniform cast structure,
heating said pellets to an elevated temperature at which said alloy exhibits substantially its greatest plasticity, but not above said phase transformation temperature,
severely mechanically working said pellets, whereby said pellets bond together and undergo recrystallization thereby forming a homogeneous mass having a fine grain structure and exhibiting enhanced plasticity, and
forcing said mass heated to a temperature in the vicinity of said elevated temperature but not above said phase transformation temperature into said die by applying a compressive stress thereto, for a period of time inversely related to said applied compressive stress.

7. In a method of forming metallic articles, the improved process comprising the steps of:
providing a die having a surface formed complementary to the shape desired to be formed,
providing metal pellets of an alloy of a composition of, by weight, approximately 78 percent zinc and 22 percent aluminum, made by dispersing a molten solution of said alloy into discrete droplets and quenching said droplets at a rate effective to produce said pellets having a nonequilibrium, uniform cast structure,
heating said pellets to a temperature of about 525° F.,

severely mechanically working said pellets, whereby said pellets bond together and undergo recrystallization thereby forming a homogeneous mass having a fine grain structure and exhibiting enhanced plasticity, and

forcing said mass heated to a temperature in the vicinity of 525° F. but not above 527° F. into said die by applying a compressive stress thereto, for a period of time inversely related to said applied compressive stress.