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## METAL-WORKING PROCESS

Eugene E. Fresch, 2544 McCoy Road; Jerome Nakrin,  
2743 Barnaby Drive; and Thomas G. Pillifant, 2639  
Donna Drive, all of Columbus, Ohio 43220

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2 Claims

### ABSTRACT OF THE DISCLOSURE

This disclosure relates generally to a method of manufacturing metal components and parts from a high alloyed (hard) stock comprising heating the stock to a temperature that renders the material ductile but below a temperature that destroys the material hardness, working the material within the temperature range and then cooling the material.

The present invention finds particular utility in the factory worked aluminum components and parts. However, it is understood the principles herein set forth may also be applicable to other types of metal components and parts having a high strength requirement.

The metal working art, generally speaking, includes operations for cutting, bending, pushing or pulling the metal into a desired shape. The cutting operation includes milling, drilling, shearing, and grinding; the forming group of operations includes curling, blurring, necking, and expanding; the pulling operation includes drawing; and the squeezing operation involves a compression stress or tensile strain. The last group is subdivided into sizing, swagging, coining and extrusion.

Metals may be deformed elastically in compression or tension within certain limits, returning to their original shape when the deforming force is removed. The elastic limit of a metal measures the greatest stress per unit of area under which it will behave elastically. When metals are loaded beyond their elastic limit, they retain a permanent set or change of form. As the loading continues, the metal is deformed plastically more and more, until fracture starts. A complete break follows quickly at what is known as the ultimate strength. Ductility and malleability are qualitative terms describing the relative ability of metals to stand plastic deformation without fracturing. The hardness of metals is its resilience or resistance to deformation.

In producing an article by stamping, the metal is worked entirely beyond its elastic limit or the yield point. As the alloy content is increased (to increase hardness), the metal behaves elastically up to a higher and higher stress before it begins to yield. At the same time the amount that the metal elongates, or moves plastically, becomes less and less as the alloy content is increased.

In conventional cold-working, plasticity is reduced to an extent dependent upon the severity of the operation or amount of cold-working and upon the rate at which the cold-working strain hardens the metal. When metals are permanently deformed by cold-working, they are stressed beyond their elastic limits beyond what the bonds between atoms will stand. After severe cold-working, the metals show considerable increase in hardness, and resistance to further working.

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In the conventional prior art systems, it is necessary that this strain hardening be removed since it is necessary to traverse the plastic cycle several times during fabrication of the article. The removal of the strain hardening, to permit further working, is generally accomplished by annealing and recrystallization. To exceed the elastic limit of a metal blank and to shape it plastically, without exceeding its ultimate strength, or to stress the metal to a point without damaging the presses or dies, is the problem of structure and treatment not fully taught by the prior art systems.

In accordance with the general concepts of this invention, an aluminum metal blank of an alloyed content is plastically worked far in excess of what would normally be considered its breaking point. The result is that an article is fabricated from a high alloyed blank in a single operation—that is, without the intermediate processes of annealing.

Accordingly, it is a general object of the present invention to provide a new method and means of working a high strength aluminum product.

Another object of the present invention is to provide a new method and means of working a high strength aluminum product that does not reduce the strength thereof in its formation.

Another object of the present invention is to provide a manufactured product having a definite shape and configuration with a minimum amount of milling, grinding or cutting.

Another object of the present invention is to provide a manufactured aluminum product from a high strength aluminum without the intermediate steps of annealing.

Another object of the present invention is to manufacture aluminum components and parts in a process that is relatively quick and inexpensive.

A unique combination of properties makes aluminum a most versatile engineering and construction material. It is light in weight, yet some of its alloys have strengths greater than that of structural steel. Light weight is perhaps aluminum's best known characteristic. With a specific gravity of about 2.7, the metal weighs only about 0.1 pound per cubic inch, as compared with 0.28 for iron and 0.32 for copper. Thus in applications where the physical volume of metal is the controlling factor aluminum goes about three times as far as either of these two metals.

Commercially pure aluminum has a tensile strength of about 13,000 pounds per square inch. Its usefulness as a structural material in this form thus is somewhat limited. By working the metal, as by cold rolling, its strength can be approximately doubled. Much larger increases in strength can be obtained by alloying aluminum with small percentages of one or more other metals such as manganese, silicon, copper, magnesium or zinc. Like pure aluminum, the alloys are also made stronger by cold working. Some of the alloys are further strengthened and hardened by heat treatments so that today aluminum alloys having tensile strengths approaching 100,000 pounds per square inch are available.

The ease with which aluminum may be fabricated into any form is one of its most important assets. Often it can complete successfully with cheaper materials having a lower degree of workability. The metal can be cast by any method known to foundrymen; it can be rolled to any desired thickness down to foil thinner than paper; aluminum sheet can be stamped; drawn, spun or rolled-formed.

The metal also may be hammered or forged. Aluminum wire, drawn from rolled rod, may be stranded into cable of any desired size and type. There is almost no limit to the different shapes in which the metal may be extruded.

The ease and speed with which aluminum may be machined is one of the important factors contributing to the low cost of finished aluminum parts. The metal may be turned, milled, bored, or machined in other manners at the maximum speeds of which the majority of machines are capable. Another advantage of its flexible machining characteristics is that aluminum rod and bar may readily be employed in the high-speed manufacture of automatic screw-machine parts.

In effect since Jan. 1, 1948, The Aluminum Association Temper Designation System is used for all forms of wrought and cast aluminum and aluminum alloys except ingot. It is based on the sequences of basic treatments used to produce the various tempers. The temper designation follows the alloy designation, the two being separated by a dash.

The basic temper designations and subdivisions are as follows:

- F: as fabricated
- O: annealed, recrystallized (wrought products only)
- H: strain-hardened (wrought products only)
- W: solution heat-treated
- T: thermally treated to produce stable tempers other than —F, —O, or —H: applies to products which are thermally treated, with or without supplementary strain-hardening, to produce stable tempers. The —T is always followed by one or more digits. Numerals 1 through 10 have been assigned to indicate specific sequences of basic treatments

In the present application, primary concern is with the aluminum alloy having a temper designation of T6. This is a solution heat-treated and then artificially treated metal.

In high-purity form aluminum is soft and ductile. Most commercial uses, however, require greater strength than pure aluminum affords. This is achieved in aluminum first by the addition of other elements to produce various alloys, which singly or in combination impart strength to the metal.

A system of four-digit numerical designations for wrought aluminum and wrought aluminum alloys was adopted by the Aluminum Association in 1954 and became effective on October 1 of that year. The first digit of the designation serves to indicate alloy groups. The last two digits identify the aluminum alloy or indicate the aluminum purity. The second digit indicates modifications of the original alloy or impurity limits. Further strengthening is possible by means which classify the alloys roughly into two categories, non-heat-treatable and heat-treatable.

Non-heat-treatable alloys.—The initial strength of alloys in this group depends upon the hardening effect of elements such as manganese, silicon, iron and magnesium, singly or in various combinations. The non-heat-treatable alloys are usually designated in the 1000, 3000, 4000, or 5000 series. Since these alloys are work-hardenable, further strengthening is made possible by various degrees of cold working, denoted by the "H" series of tempers. Alloys containing appreciable amounts of magnesium when supplied in strain-hardened tempers are usually given a final elevated-temperature treatment called stabilizing to insure stability of properties.

Heat-treatable alloys.—The initial strength of alloys in this group is enhanced by the addition of alloying elements such as copper, magnesium, zinc, and silicon. Since these elements singly or in various combinations show increasing solid solubility in aluminum with increasing temperature, it is possible to subject them to thermal treatments which will impart pronounced strengthening. The heat-treatable alloys are usually designated in the 6000 and 7000 series.

7000 Series.—Zinc is the major alloying element in this group, and when coupled with a smaller percentage

of magnesium results in heat-treatable alloys of very high strength. Usually other elements such as copper and chromium are also added in small quantities. Outstanding member of this group is 7075, which is among the highest strength alloys available and is used in air-frame structures and for highly stressed parts. Specifically the chemical composition is as follows:

|           |           |
|-----------|-----------|
| Silicon   | 0.50      |
| Iron      | 0.7       |
| Copper    | 1.2-2.0   |
| Manganese | 0.30      |
| Magnesium | 2.1-2.9   |
| Chromium  | 0.18-0.40 |
| Zinc      | 5.1-6.1   |
| Titanium  | 0.20      |
| Others    | 0.15      |
| Aluminum  | Remainder |

The approximate bend radii for 90-degree bend of 7075 is as follows. Radii for various thicknesses expressed in terms of thickness "t":

|           | Temper —O   | Temper —T6 |
|-----------|-------------|------------|
| 1/4 in.   | 0           | 2t-4t      |
| 3/8 in.   | 0           | 3t-5t      |
| 1/2 in.   | 0-1t        | 4t-6t      |
| 5/8 in.   | 1/2t-1 1/2t | 5t-7t      |
| 3/4 in.   | 1t-2t       | 5t-7t      |
| 7/8 in.   | 1 1/2t-3t   | 6t-10t     |
| 1 in.     | 2 1/2t-4t   | 7t-11t     |
| 1 1/8 in. | 3t-5t       | 7t-12t     |

The mechanical property limits of aluminum 7075 —T6 are as follows:

| Material      | Thickness     | Tensile strength<br>K s.i. (kg./mm. <sup>2</sup> ) |           | Elongation |
|---------------|---------------|----------------------------------------------------|-----------|------------|
|               |               | Ultimate                                           | Yield     |            |
| Sheet         | 0.015-0.039   | 76 (53.4)                                          | 65 (45.7) |            |
|               | 0.040-0.249   | 77 (54.1)                                          | 66 (46.4) |            |
| Extruded rod, | 0.249         | 78 (54.8)                                          | 70 (49.2) |            |
| bar and tube. | 0.250-0.499   | 81 (56.9)                                          | 73 (51.3) |            |
|               | 0.500-1.499   | 81 (56.9)                                          | 72 (50.6) |            |
|               | 1.500-2.999   | 81 (56.9)                                          | 72 (50.6) |            |
|               | 3.000-4.999   | 81 (56.9)                                          | 71 (49.9) |            |
|               | 5.000-9.999   | 78 (54.8)                                          | 70 (49.2) |            |
|               | 10.000-14.999 | 78 (54.8)                                          | 68 (47.8) |            |
| Drawn tube    | 0.035-0.259   | 77 (54.1)                                          | 66 (46.4) | 8          |
|               | 0.260-0.500   | 77 (54.1)                                          | 66 (46.4) | 9          |

Under certain circumstances the hardness condition of the material dictates the manner in which it is worked. For instance, if a hole is desired in a bar and the bar is relatively hard the hole must be drilled. On the other hand, if the bar is relatively soft the whole process can be simplified by the use of a simple punch operation. Similarly, whether the bar may be sheared rather than ground is also dependent on the relative hardness of the material. Therefore, in the manufacture of certain component parts punching and shearing rather than drilling and grinding may represent an appreciable savings in cost.

In the prior methods of working an aluminum alloy such as 7075, it was customary to use material having a T0 condition. That is, the material in the T0 condition is relatively ductile and amenable to working. Once the component part is formed or completed it was annealed to attain the proper degree of hardness.

In this way the prior art processes utilized the most economical working process. The sacrifice, or course, being that the component needed to be annealed for hardness.

Very simply the present invention encompasses a process of metal working the components in a soft condition and yet maintains the most rigid requirement of hardness—without the step of annealing. In order to achieve this unique process two things were learned: first, the amount of heat required to render 7075 —T6 aluminum alloy material ductile; and, secondly, the maximum heat a 7075 —T6 aluminum material could withstand without destroying the material properties. Specifically, with-

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out destroying the hardness of the material. It was further found that if the material is heated within the specific minimum and maximum range the material is ductile. In this way the material is worked in a manner similar to the T0 hardness material. Of significant importance, however, is that the material when cooled to normal room temperatures would again have the T6 hardness condition.

To utilize this discovery the industrial manufacture of aluminum component parts comprised use of 7075 —T6 hardness aluminum material. The aluminum material was preheated to a temperature within minimum and maximum range. Next the material was heated while being worked to maintain the temperature of the material within the range. Finally, the worked component was permitted to return to room temperature.

More particularly in one specific process for the manufacture of a component, a bar stock was used having the above specified 7075 —T6 hardness condition. The stock was passed through an oven wherein it was heated to a temperature sufficient to render it ductile. The bar stock was then fed to a working die. The die being continuously heated to maintain the bar stock above the working temperature. Specifically, what was achieved in this process was an over-simplification of operations. Prior to the present invention with use of hard stock the stock had to be cut, holes drilled therein and the square corners rounded off. In other words three major operations. Alternatively, if a T0 condition stock were used the finished needed to be heat treated to attain the proper degree of hardness. With the present invention a single stamping operation cuts the bar with rounded corners and the holes punched. The worked component then falls into a bin where it is permitted to cool and without a loss of its original hardness or tensile strength.

Other aluminum alloy materials having the 7075 —T6 condition were also processed with the method of the present invention. This included sheet material that was formed into a folded condition. Also worked was a flanged extruded stock requiring several holes in the flanges.

In the specific operation described above it was found that the minimum temperature to render the 7075 —T6 aluminum material ductile is in the order of 300° F. It was also found that the maximum temperature this material could withstand without destroying its properties is in the order of 375° F. It must be appreciated, how-

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ever, that the hardness of any material is relative and therefore other temperatures for other materials or composition of materials would be applicable. Further, once the process of learning that a relative hard material could be worked by heating to a ductile state, the exact temperature range could be found empirically.

Also in the specific operation described, it was found that the working means, i.e., the die, need not be heated completely. That is, if for instance only the ends of the bar stock were to be sheared off, the die only needed to be heated towards its outer limits. In those areas where the material was not worked the die could remain at a normal temperature.

Although a certain and specific process is described, modifications and departures may be made thereto without departing from the true spirit and scope of the invention.

What is claimed is:

1. A metal working process utilizing work dies for an aluminum alloy having properties specified as 7075 and a tensile strength of T6 comprising: preheating the aluminum material to a minimum temperature in the order of 300° F. and a maximum temperature in the order of 375° F. to render the same ductile, heating said work dies for maintaining said aluminum material within the prescribed temperature range, working said aluminum material including punching and cutting, and permitting said aluminum material to cool to room temperature and whereby said high strength of said aluminum material is retained.

2. A metal working process as set forth in claim 1 wherein said heating of said work dies is confined to the specific areas of said work dies which contact and form said aluminum material.

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RICHARD J. HERBST, Primary Examiner

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