July 24, 1956 R. F. MOORE 2,755,545

METAL WORKING

Filed July 10, 1952 2 Sheets-Sheet 1

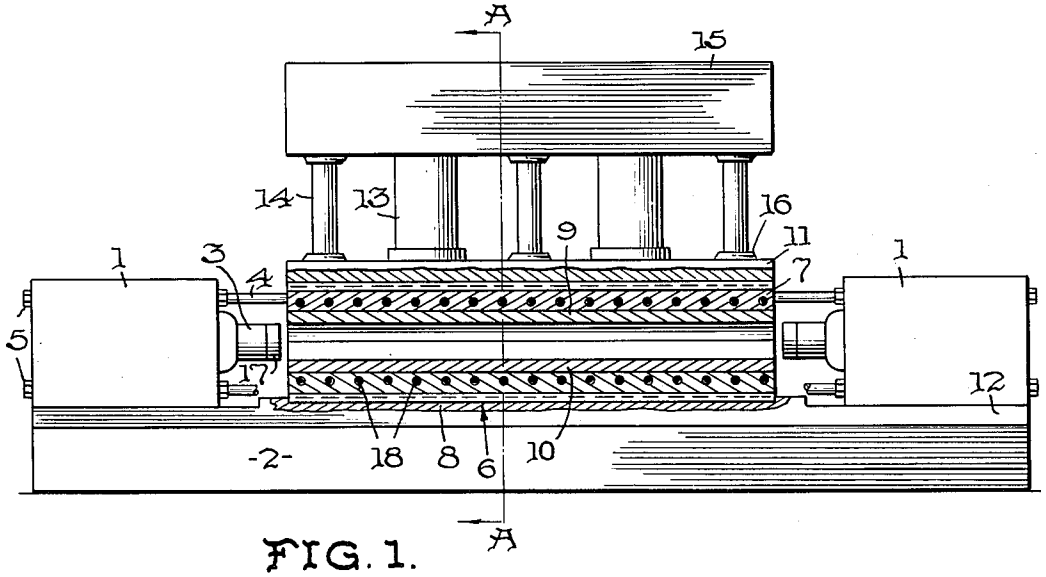


FIG. 1.

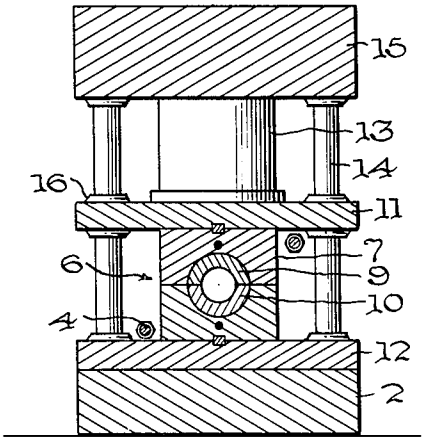


FIG. 2.

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METAL WORKING

Filed July 10, 1952 2 Sheets-Sheet 2

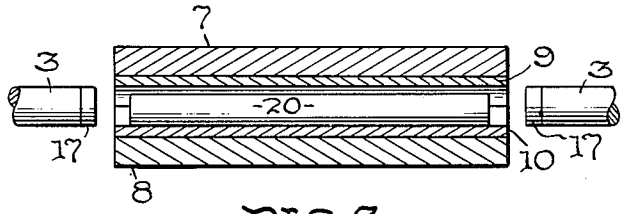


FIG. 3.

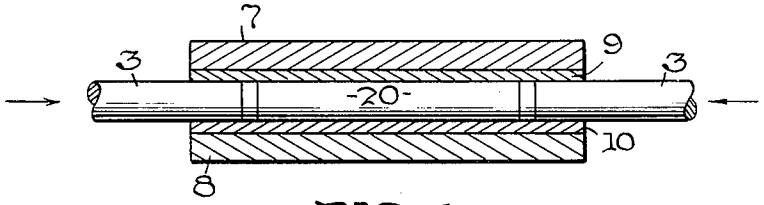


FIG. 4.

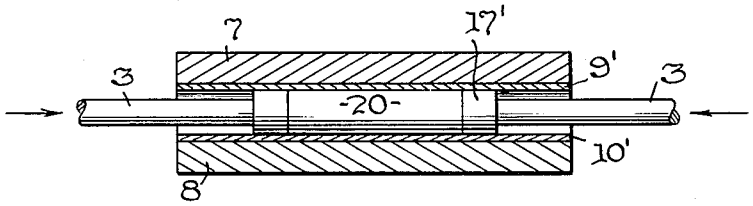


FIG. 5.

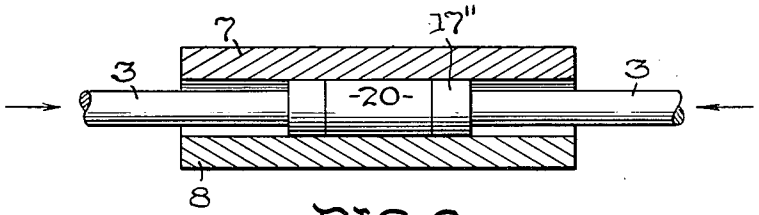


FIG. 6.

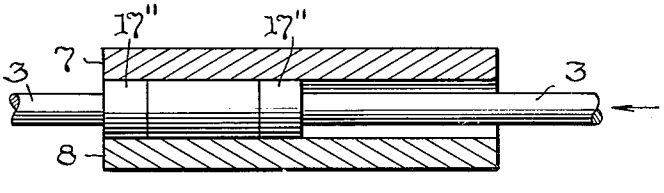


FIG. 7.

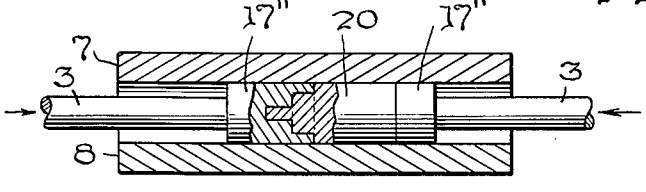


FIG. 8.

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2,755,545

METAL WORKING

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Application July 10, 1952, Serial No. 298,136

3 Claims. (Cl. 29—553)

This invention relates to the working of metal. More particularly the invention relates to the production of sound metal bodies of large cross-sectional area and possessing physical properties of a high order such as are required for use in forging operations and the like.

In the metal industry, large quantities of metal annually go into the manufacture of tools, structural members for aircraft and other metal articles requiring high physical properties. It is highly advantageous, if these articles which sometimes are of massive size, can be made from a single piece of stock since this does away with the necessity of making the article in sections, which later have to be joined by welding, riveting, etc. Such a procedure is not only time consuming and costly, but also the mechanical or welded joints necessary in securing the sections together are often subject to structural defects. A specific example of this is in the aircraft industry where it has been proposed to simplify the construction of aircraft by producing some of the large aluminum structural elements such as bulkheads from a single forging.

When such articles can be forged in a single piece, they are much stronger than those made in sections. One of the reasons for this is due to the fact that in the forging operation the proper grain flow can be worked into the metal. However, before such pieces can be produced for later forging operations, sound metal stock of exceptionally large cross-section are a prerequisite and must first be produced. It is one of the advantages of this invention that the method proposed herein can be utilized for producing such stock material.

Various processes have been proposed for producing suitable aluminum ingots having the requisite size and physical properties, but they have not been found completely satisfactory. Attempts have been made to cast billets, ingots, or the like of relatively massive size. In such a process, the billets, ingots, or the like are conventionally either cast in a stationary mold or by what is commonly called direct chill or continuous casting which is the preferred process from a production standpoint. Where large size ingots, for example of aluminum and its alloys, on the order of sixteen inches in diameter or over are cast by either of the aforementioned processes, close control of the casting conditions must be maintained, otherwise there is found to be a tendency toward porosity and unsoundness in the ingot, which will not be suitable for later rolling and other working operations. Such ingots having the defect of porosity are generally not considered suitable as future stock material for forging where high physical properties are required. When producing large size ingots by continuous casting, it has also been found in the case of certain metals, that the ingots are subject to internal cracks and other serious defects rendering them unsuitable for further working operations, unless close control of the casting conditions is maintained.

As an alternative, therefore, to any method of continuously casting a sound ingot of large cross-section, which involves close control of temperature and other

casting factors, it has been found that if a small sound ingot or as-cast blank is taken in the as-cast condition and then compressed and upset under tremendous pressure between a plurality of pressure applying surfaces, the metal in the ingot will be so worked during the application of pressure thereto that a massive structurally sound blank having a homogeneous grain structure can be easily produced. The size of the blanks which are contemplated may be on the order of 32" in diameter or larger. It is obvious that when such blanks are produced, the way is then open for forging massive articles from a single blank. These forgings are highly desirous, particularly to the aircraft industry. In this industry, it is now possible, by utilizing the method of the instant invention, to obtain suitable forging stock of the proper size so that structural members for aircraft capable of resisting the tremendous loads and pressures encountered by jet planes flying at high speeds can be made from a single piece of metal. As stated before, when these structural elements are forged from a single piece of metal the best possible grain flow is worked into the metal and the elements will have exceptional strength and rigidity.

It is to be noted that the present day development of massive presses capable of exerting tremendous amounts of pressure, for example on the order of 15,000 tons or more, also make possible the practicing of the method for producing structurally sound blanks hereinafter described.

One of the primary benefits derived from the use of the method of the instant invention for producing structurally sound forging blanks resides in the fact that it allows the use of present day small size ingots cast by conventional methods. That it, it complements the present day known casting practices, which themselves are not capable of making structurally sound ingots of massive sizes, for example on the order of 32" in diameter and larger. Furthermore, the stock or blanks produced by this invention are not limited as in a casting procedure to a particular shape or configuration. Instead, by using suitable dies, the blank can be upset to take the rough configuration of the finished forged product even while the properties of the material undergo a change as a result of the upsetting operation.

Although in the preferred embodiment of the invention, it is contemplated that the method proposed will be used for producing structurally sound forging blanks of large cross-section from otherwise small ingots in the as-cast state, it is to be noted that the method can also be utilized for changing the character of the physical properties of wrought or partially wrought material of any size by the simple process of upsetting the same, so that a blank of a much larger size can be produced. Such practice would be advantageous for example in the manufacture of various parts used in the construction of aircraft wings and body assemblies. For example, if a wing section on an airplane required the use of a forging piece of large cross-section and only a small wrought or partially wrought blank was available, it would be possible by the use of the upsetting method herein described to enlarge the blank to the size required for the final forging.

It is therefore a primary purpose and object of this invention to provide a novel method for producing massive sound blanks from as-cast small ingots.

Another object is to provide a novel method for imparting increased physical properties to metal stock of large size.

A specific object is to provide a novel method for transforming a body of relatively small cross-section in the as-cast or fully or slightly worked state, into a large blank having uniform physical properties suitable for future

forging into massive articles requiring high physical properties.

Another object is to provide a novel method for transforming a conventional as-cast ingot into a wrought blank characterized by having uniform physical properties and having an exceptionally large cross-sectional area.

A more specific object is to provide a method for transforming aluminum and aluminum alloy ingots in the as-cast condition into sound blanks possessing a large cross-sectional area, said blanks being characterized by having high physical properties throughout the cross-section of said bodies.

Another object is to provide a novel machine for increasing the cross-sectional area and physical properties of an ingot by an upsetting operation and while working it at exceptionally high pressures.

Another object is to both produce and place a massive blank in the shape of a roughened out forging piece.

It has been found that an as-cast ingot or metal blank of large size which normally possesses predetermined physical properties in the as-cast condition can be transformed into a massive sound blank possessing satisfactory physical properties for future forging operations and of a large cross-sectional area by heating the ingot and subjecting it to axial pressure within an enclosed die chamber having a transverse cross-sectional area greater than that of the ingot, but in a predetermined critical ratio thereto. This upsetting procedure can be repeated any number of times depending on the results desired, to enlarge the as-cast ingot or blank to any desired cross-sectional area having physical properties required for a specific forging operation.

The invention will now be more fully described in conjunction with the accompanying drawings which illustrate certain advantageous embodiments of the invention herein:

Figure 1 is a front elevational view partly in section with parts removed for the sake of clarity illustrating one form of machine capable of performing the method of the invention and including opposed hydraulically operated pressure cylinders and a forging die cylinder therebetween.

Figure 2 is a sectional view when taken along line A—A of Figure 1 and showing the sectional forging die cylinder with impression die inserts.

Figures 3, 4, 5, and 6 are front elevational views partly in section with parts removed illustrating the use of die chamber inserts and pressure piston modifications in working an elongated ingot by the method of the invention.

Figure 7 is an alternative apparatus which may be used in carrying out the instant invention.

Figure 8 illustrates a modified apparatus wherein the pressure applying surfaces are given contours approximating that of the final product.

Referring to the drawings, Figures 1 and 2 illustrate one form of apparatus which may be used in performing the method of the invention. Mounted on a suitable bolster plate or bed **2** are two opposed cylinders **1**, **1**. Slidably mounted within each opposed cylinder **1** and projecting therefrom is a hydraulically operated pressure piston **3**. Any one of several conventional hydraulic systems can be used for controlling the movement of the pressure pistons **3**, **3** within the cylinders **1**, **1**. The opposed cylinders are tied together by means of suitable tie rods **4** the ends of which pass through longitudinal openings in the cylinder housings and which are securely anchored thereto by means of nuts **5**.

Located intermediate the opposed cylinders **1**, **1** and pressure pistons **3**, **3** and in alignment therewith is a forging die assembly **6**. The die assembly generally comprises a lower die section **8** and an upper die section **7**. As shown in Figures 1 and 2, the opposed surfaces of the sections **7** and **8** are provided with longitudinally extending die cavities that are semi-circular in cross-section such that when the opposed surfaces of the die sections are caused to abut, the two die cavities define a longitudinal die chamber having a circular cross-section or any cross-sectional shape depending on the results desired. As illustrated, the upper and lower die sections are provided with impression die inserts **9** and **10**, respectively, the purpose of which will be set forth hereinafter. The upper and lower die sections **7** and **8** as well as impression die inserts **9** and **10** are made of suitable die material such as chrome steel.

Lower die section **8** is suitably mounted on a stationary lower die shoe **12** which is secured to bolster plate or bed **2**. Upper die section **7** is suitably mounted to upper die shoe **11** which in turn is connected to reciprocating hydraulic cylinders **13**, **13** of a press capable of exerting sufficient pressure to keep the dies closed during the upsetting operation. Slidably mounted along the longitudinal edge portions of the upper die shoe **11** are a plurality of guide posts **14**, the bases of which are fixed to the lower die shoe **12** and the upper extremities of which are fixed to stationary top plate **15**. Suitable bushings **16** are also provided in the vertical openings in upper die shoe **11** through which the guide posts pass. As the hydraulic cylinders **13**, **13** are caused to move upward or downward thereby causing upper die section **7** to move upward and away from lower die section **8** or to move downward into contact with lower die section **8**, the upper die shoe **11** will slide on guide posts **14** which will prevent any misalignment of the two die sections when they are brought together or moved apart.

The operation of the machine as shown in Figures 1 and 2 will now be described as applied to the method of producing sound blanks of large cross-section with particular reference to Figures 3–6, which illustrate one embodiment of the instant invention. With the die sections **7** and **8** in the open position, an elongated body of metal such as a cylindrical blank or as-cast ingot **20** which has been suitably heated is disposed in the longitudinal die cavity of lower die section **8**. As shown in Figures 1–3, lower die section **8** as well as upper die section **7** are provided with suitable impression die inserts **10** and **9**, respectively, the purpose of which will hereinafter be more fully explained. After blank **20** has been positioned in the die cavity of lower die section **8**, hydraulic cylinder **13** is actuated to cause upper die shoe **11** and attached upper die section **7** to move downward until the opposing faces of die sections **7** and **8** abut as shown in Figure 3, thereby defining a circumferentially enclosed die chamber having a diameter which is greater than, but bears a critical relationship to the diameter of the blank **20**. During the time when the blank **20** is being positioned within the cylindrical die defined by die sections **7** and **8**, the opposed pressure pistons **3**, **3** are in a retracted position as shown in Figures 1 and 3. The shape of pressure pistons **3**, **3** is such that they have a very close sliding fit with the inner walls of die inserts **9** and **10**.

Immediately after the upper and lower die sections **7** and **8** are caused to close, hydraulic cylinders **1**, **1** are actuated to cause pressure pistons **3**, **3** to rapidly enter the open ends of the die cavity and abut the opposite ends of blank **20** with sufficient pressure to upset the blank such that it increases in diameter to the diameter of the die space defined by impression die inserts **9** and **10** as shown in Figure 4. In certain instances, it is desirable to have the die in a heated condition to facilitate working the blank, and for this purpose suitable heating elements **18** may be located in upper and lower die sections **7** and **8** in close approximation to the die inserts. Although in the preferred embodiment of the apparatus pressure pistons **3**, **3** are indicated as both being in movement during the upsetting operation, it is contemplated within the scope of the invention that one of such members may be held stationary during the actual upsetting operation as shown in Figure 7.

It has been found that there is a critical relation in any upsetting operation between the cross-sectional width

of the stock (in cylindrical stock this would be the diameter of the stock) and the cross-sectional width of the die chamber within which the stock will be upset such that the desired even grain structure and physical properties will be produced in the upset body of metal throughout the entire cross-section thereof. More specifically, it has been determined that in the axial upsetting of elongated cylindrical stock within an elongated cylindrical die chamber that the diameter of the die chamber should not exceed about 1.5 times the diameter of the elongated stock to be upset. Where the die diameter exceeds this critical ratio, the metal will lap over due to excessive bending or buckling of the stock. This lapping over of the metal gives rise to defective zones in the upset metal body caused by improper flow of metal in these lapped portions. Generally it is found that under normal practice a ratio not exceeding 1.5 will result in greatly enhanced physical properties in the upset stock with no defective zones caused by lapping. It is therefore to be understood with reference to Figure 3 that the diameter of the die chamber defined by impression die inserts **9** and **10** is not to exceed 1.5 times the original diameter of blank **20**.

Although the application of the invention as described above specifically refers to the transformation of stock wherein the cross-sectional configuration remains the same, i. e. circular, it is to be understood that the instant invention can readily be applied to stock having various configurations such as square, elliptical, etc. Moreover, during the upsetting operation the stock may be caused to take a different configuration as by transforming stock from round to square or from elliptical to hexagonal. In any event, however, the same critical relation between the cross-sectional width of the stock and of the die chamber maintains, that is, the cross-sectional width of the die chamber should not exceed 1.5 times the cross-sectional width of the stock or blank to be upset therein.

Since in certain instances the cross-sectional area and physical properties of the as-cast ingot, fully worked or partially worked stock resulting from one upsetting operation are not sufficient for the purpose intended, the previously upset stock may be subjected to further upsetting operations as shown in Figures 5 and 6. In Figure 5 is illustrated a second upsetting operation wherein the wrought blank **20** resulting from the operation shown in Figure 4 is increased in diameter over that of the wrought stock.

To enable the use of the same upper and lower die sections **7** and **8** in progressive upsetting operations, modified impression die inserts **9'** and **10'** are used in place of the original die inserts **9** and **10** and thereby defining a die chamber which bears the 1.5 diameter ratio of the stock to be upset as in the first upsetting operation shown in Figure 4. To facilitate the use of the same pressure pistons **3**, **3** in a plurality of upsetting operations, the ends of the pistons may be provided with adaptors **17**, **17** which are in each instance of such shape as to fit closely within the open ended die. These piston adaptors may be suitably attached to pistons **3**, **3** as by providing the inner end of each adaptor with a threaded recess and providing the outer end of each piston with a complementary threaded projection. It is contemplated, within the scope of the invention, that the adaptor need not be securely affixed to the presure pistons **3**, **3** but may take the form of a simple punch or pressure plug adapted to be inserted within the ends of the open ended forging or upsetting die and against the ends of the metal stock to be upset.

Figure 6 shows the third and last step in the particular embodiment of the invention. In this last upsetting operation modified impression die inserts **9'** and **10'** are removed leaving the die cavities in the inner face of opposed die sections **7** and **8** to define the size of the open ended upsetting die chamber. Pressure piston adaptors **17'**, **17'** are replaced by modified adaptors **17''**, **17''** which possess a close sliding fit with the walls of the die chamber defined by upper and lower die sections **7** and **8**.

In an advantageous embodiment of the invention, it is contemplated that the same die apparatus as shown in Figures 1–6 can be employed not only to produce sound blanks of large cross-section but also to impart to the upset stock a shape which is roughly that desired in the finish forged product. This can be accomplished, as indicated in Figure 8, by providing the pressure applying surfaces of adaptors **17''** with the desired contour which corresponds roughly to that of the finish forged product. Although Figure 8 illustrates only one of said pressure applying surfaces as possessing a contour wherein portions of the surface are in different planes and at angles to each other, both of these surfaces may be contoured as the configuration of the final forged product dictates. By using such a procedure of upsetting, the total number of final forging operations and the forging scrap loss can be held to a minimum.

It is also contemplated, within the scope of the invention, that a suitable lubricant such as graphite and a soluble oil may be used to coat the forging or upsetting die sections where there is found a tendency toward sticking of the upset stock within the die chamber and also it may be beneficial in reducing die wear. In certain cases it also may be desirable to provide the dies with several fine, spaced holes which would act to allow release of any entrapped air between the stock and the die surface as the stock is being upset outwardly. This will alleviate any tendency for the upset stock to have unfilled areas or cavities on the exterior surface thereof.

As a specific example of the invention, an elongated piece of stock 29 inches in length and 1.18 inches in diameter was cut from a conventional 12 inch square 75S as-cast aluminum alloy ingot containing approximately 1.5% copper, 2.5% magnesium, 5.5% zinc, 0.25% chromium, 0.2% manganese, 0.4% silicon, 0.4% iron, 0.1% titanium, balance aluminum. The stock was heated to approximately 850° F. and placed in a first die chamber of circular cross-section having a diameter of about 1.5 inches. The die was heated to 300° F. prior to inserting the heated stock therein. The stock was then subjected to axial pressure on the order of 30,000 to 60,000 pounds per square inch to upset it outwardly into contact with the circular die chamber wall. The resulting stock had a diameter of about 1.5 inches and a length of about 18 inches. This stock was then reheated to 850° F., inserted in a second die chamber having a diameter of 2 inches and rapidly upset therein to about 2 inches in diameter and about 10 inches in length. The stock was reheated to 850° F. and placed in the third and last die chamber having a diameter of about 2.6 inches and upset therein, the resulting product being a worked body of 75S aluminum alloy having a diameter of approximately 2.6 inches and a length of about 5.9 inches. After being subjected to a conventional solution heat treatment, this stock exhibited throughout its entire cross-sectional area an average tensile strength of 76,300 pounds per square inch and an average yield strength of 72,500 pounds per square inch. Furthermore, the stock was free of cracks and porosity and as an incident thereto possessed a partially wrought structure throughout which for certain forging operations would be satisfactory.

Although the specific example set forth above involved a three step process and utilized a blank temperature on the order of 850° F., it is to be understood that in any given instance the number of upsetting operations used and the extent of heating will depend upon the size and type of blank or stock desired as well as on the size of the original stock material. Only a nominal amount of trial and error experimention is needed in any given case to determine the most satisfactory operating conditions.

The temperature to which the blank is heated prior to upsetting will generally fall within the range of from about 800°–950° F. for aluminum alloys.

It is thus evident that by the use of the instant invention as-cast ingots or blanks can be readily transformed into sound bodies having very satisfactory properties throughout their entire cross-sectional area and being of sufficient size in cross-sectional area to be suitable as future stock material for massive forgings and the like. Of particular significance is the application of the method to the production of large size stock material from metal which cannot be satisfactorily cast in such sizes as, for example, the 75S aluminum alloy previously discussed or other high strength aluminum alloy, particularly of the solution heat treatable type. Great difficulty is experienced in attempting to cast such ingots in sizes of 16 to 20 inches in diameter or over because of the close control which must be exercised over the casting operation. One of the conventional methods of casting such ingots is by direct chill continuous casting. As an example, when 75S aluminum alloy ingots of the aforementioned sizes are cast in this manner, the ingots are subject to cold shuts, internal cracks and porosity unless close control of the casting operations is maintained, and as such, are not usable as stock material where high strength is required as in forged structural shapes and the like. Furthermore, where it is attempted to knead or work such ingots by conventional practices such as forging or rolling the tremendous pressures necessary often cause breaks or openings to occur in the core or central portions of the ingots due to the high tensile stress developed therein when the outer portions of the ingot are under tension and compression.

By means of the instant invention, however, it is possible to transform 75S aluminum alloy ingots of conventional sizes which can be satisfactorily cast such as from 10 to 16 inches in diameter into sound wrought bodies or blanks of relatively massive cross-section on the order of 30 to 40 inches or over in diameter. For example, it is possible to transform a 75S aluminum alloy ingot in the as-cast state and being approximately 15 inches in diameter and about 32 feet in length into a sound wrought body approximately 36 inches in diameter and about 5.5 feet in length and which is eminently suited as stock material for massive structural members and the like. In transforming the 15 inch diameter ingot into a 36 inch diameter body, the necessary upsetting operations should always be within the critical 1.5 die-stock diameter ratio.

Generally, it is desirable practice to design the die cavities in the upper and lower die sections to accommodate the largest worked stock which might be desired and then provide suitable die impression inserts for all smaller sizes of wrought stock. It is to be noted that although the specific embodiment of the invention hereinbefore described utilized an aluminum alloy cylindrical ingot in the as-cast condition, the method of the invention is eminently suited for increasing the cross-sectional area and physical properties of stock material of other metals and alloys, as for example, copper, brass, magnesium and other nonferrous metals as well as ferrous metals, either in the as-cast, rolled, extruded, or other worked condition. Moreover, the stock material may possess a circular, elliptical, square, or other polygonal cross-sectional shape as long as the cross-sectional width of the open-ended upsetting die chamber does not exceed 1.5 times the cross-sectional width of the stock material to be worked. By cross-sectional width, with respect to stock having a polygonal cross-sectional configuration, is meant the greatest distance on a line passing through the center and intersecting opposite points on the periphery thereof. It is also contemplated, within the scope of the invention, that the original cross-sectional configuration of the stock may be altered in the final product as by going from round to square shape as long as the aforesaid die-stock cross-sectional width ratio is not exceeded.

Accordingly, it will be apparent to those skilled in the art that various modifications may be made in the instant invention without departing from the spirit and scope thereof and accordingly, the invention is not to be taken as limited except by the appended claims wherein.

What is claimed is:

1. A method of preparing elongated forging stock of relatively massive cross-section from an elongated as-cast blank of aluminum or aluminum alloy, comprising the steps of heating said blank to a temperature of from about 800° to 950° F., confining the heated blank in an elongated chamber having a larger cross-section than that of said blank, subjecting the blank to axial pressure sufficient to upset the entire blank outwardly into close conformity with said chamber and to increase the cross-sectional width of the blank by a factor of about 1.3, and thereafter repeating such cycle of operations of heating and upsetting at least one more time to further increase the cross-section of the blank, whereby said as-cast blank is transformed into sound, worked metal stock having a cross-sectional size substantially greater than that of the original as-cast blank and possessing a substantial increase in physical properties and wherein said properties are substantially uniform throughout the cross-sectional area of the stock.

2. A method of preparing elongated forging stock of relatively massive cross-section from an elongated as-cast blank of aluminum or aluminum alloy, comprising the steps of heating the metal blank to a temperature of from about 800° to 950° F., confining the heated blank in an elongated chamber having a cross-sectional area larger than that of said blank, subjecting the blank to axial pressure sufficient to upset the entire blank outwardly into close conformity with said chamber and to increase the cross-sectional width of the blank by a factor of from about 1.3 to 1.5, and thereafter repeating such cycle of operations of heating and upsetting at least one more time to further increase the cross-section of the blank, whereby said as-cast blank is transformed into sound, worked metal stock having a cross-sectional size substantially greater than that of the original as-cast blank and possessing a substantial increase in physical properties and wherein said properties are substantially uniform throughout the cross-sectional area of the stock.

3. A method of preparing elongated forging stock according to claim 2 wherein simultaneously with said upsetting operations the general configuration of the ultimate article to be forged from the stock is imparted thereto.

References Cited in the file of this patent

UNITED STATES PATENTS

125,376	Brown	Apr. 9, 1872
1,134,348	Preks	Apr. 6, 1915
1,563,124	Wald	Nov. 24, 1925
1,613,595	Abel	Jan. 14, 1927
1,690,419	McCain	Nov. 6, 1928
2,080,641	Templin	May 18, 1937
2,253,003	Whipple	Aug. 19, 1941
2,490,954	Flick	Dec. 13, 1949
2,581,774	Stone et al.	Jan. 8, 1952
2,621,344	Friedman	Dec. 16, 1952