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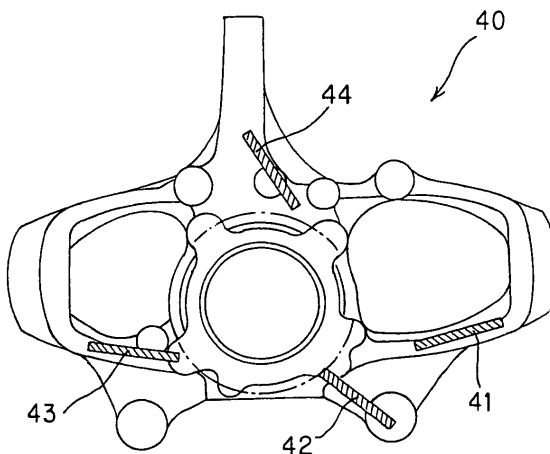
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(54) **ALUMINUM ALLOY FOR CASTING-FORGING, ALUMINUM CAST/FORGED ARTICLE, AND
METHOD FOR MANUFACTURE THEREOF**

(57) There is disclosed a cast-forged product of an aluminum alloy consisting essentially of: 0.6 to 1.8 wt% of silicon; 0.6 to 1.8 wt% of magnesium; 0.8 wt% or less of copper; 0.2 to 1.0 wt% of manganese; 0.25 wt% or less of chromium; 0.0 to 0.15 wt% of titanium; and una-

voidably contained impurities. When the product is used as various parts for automobiles formed of aluminum, such as suspension parts, frames, and parts for engines, the product is more superior in mechanical properties such as a tensile strength, proof stress, and elongation, and can be manufactured with a low cost.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a cast aluminum alloy for forging and an aluminum cast-forged product that is used for a vehicular part or the like and is less costly, and a method of manufacturing an aluminum cast-forged product. More particularly, it relates to a cast aluminum alloy for forging that is used to manufacture vehicular suspension parts which are required to be light in weight to improve fuel consumption of an automobile and can use useless forging materials such as flash generated in a forging process, an aluminum cast-forged product that has high mechanical properties and contains particular amounts of silicon, magnesium, copper, and manganese, and a method of manufacturing an aluminum cast-forged product.

Background Art

[0002] It is said that global warming, which is one of global environmental problems, is greatly affected by carbon dioxide produced by all human activities, and a reduction in carbon dioxide discharged from factories and electric power plants and a reduction in fuel consumption of automobiles are strongly required all over the world. At the third conference of the United Nations Framework Convention on Climate Change, so-called Global Warming Prevention Conference COP3, held in Kyoto in 1997, Japan promised that the emission of gas causing greenhouse effect which mainly contains carbon dioxide will be decreased by 6% on average of values in 2008 through 2012 as compared with 1990. Based on this promise, regarding the fuel consumption rate of automobiles, the target reference value of fuel consumption rate under vehicle weight classification was determined with the target fiscal year being fiscal 2010 for gasoline engine and fiscal year 2005 for diesel engine. Also, in the taxation system, measures were taken to treat low-pollution cars favorably. Hereafter, auto manufacturers will strongly be pressed to promote technology development to improve fuel consumption and to develop an automobile having improved fuel consumption, with further progress of understanding towards environmental problems by automobile purchasers and users. Such development will be needed to win competition among the auto manufactures.

[0003] The measures for improving the fuel consumption of the automobile include the use of new power sources such as a fuel cell, natural gas, and electricity, or the hybrid use thereof, the technical improvement in a motor system such as a lean fuel engine and a direct injection engine, and the decrease of running resistance due to improvement in loss of a power transmission system and improvement in vehicle body contours. Among these measures, a measure that is most effective and capable of being taken together with any other technology is the reduction in weight of the automobile. If the automobile itself is made light in the weight, the load on the power source is lessened, and the amount of power to be consumed can be saved irrespective of power sources. As one measure for the reduction in weight of the automobile, the reduction in weight of the suspension parts of the automobile is an object having a higher priority, because this reduction contributes to the improvement in drivability and riding quality of the automobile. In recent years, frame parts or some parts of the engine have also been regarded as the objects of the reduction in weight, and attempts have been made to use light metal materials therefor.

[0004] Incidentally, when the lightening in the weight of automobile is intended, the up in the cost remains as a theme to be solved. The weight lightening technology is broadly divided into a structure design technology and a material technology. In comparison with the drastic improvement in vehicle body structure and construction elements, the change of material used is an easily employable measure for lightening the weight. However, such a material for lightening the weight is generally expensive. Examples of the material for lightening the weight include resin materials such as FRP, thinned iron sheets using high tensile strength steel sheets, aluminum alloys, magnesium alloys, titanium alloys, ceramics, metallic compound materials, and the like. Among these materials, aluminum alloys have fewest drawbacks such as corrosion resistance and the like, and are lowest in cost in the materials for lightening the weight although being higher in cost than iron, and can easily be applied as alternatives without requiring any large change in the basic design of the automobile.

[0005] The aluminum alloys, having a density about one-third that of iron, have already been used for many easy-to-manufacture castings such as engine cylinder heads and engine cylinder blocks. These castings are manufactured by highspeed injection molding, a so-called high pressure die casting method, and thus can be manufactured at a relatively low cost with high production efficiency. However, castings having large thickness and high strength cannot be produced. There is a problem that the application of cast parts to suspensions as a part light in weight since a failure of such a part due to insufficient strength directly leads to the safety problem.

[0006] Referring to the suspension parts which have advanced in studies of the weight reduction technology as examples, the present status of the technology will be described. Materials used for the suspension parts such as a steering knuckle and a suspension arm are required to have high corrosion resistance, sufficient properties such as strength and elongation, and few defects, and an A6061 alloy forged product, an AC4CH alloy squeeze cast product

(low-speed injection molded product), and the like that meet the requirements have already been used. However, these materials still have an unsolved problem of high cost, so that the application thereof is extremely limited at present.

[0007] Reasons why so-called aluminum products formed only by forging, such as the conventional A6061 alloy forged product are high in cost lie in that the number of manufacturing processes is large and that the raw material for forging itself is expensive and that wastes such as flash are caused during the manufacturing process and that useless materials such as the flash cannot be recycled as the raw material for forging. Also, for a squeeze casting, because of a large number of processes and a low injection speed, the productivity is low and the cost reduction cannot be attained.

[0008] Thus, in particular, in order to reduce the weight of the vehicular part, an aluminum product having superior corrosion resistance, strength, and elongation, no defects, and a low cost has been demanded. To meet this demand, various improved aluminum alloys have heretofore been proposed as a material for manufacturing an aluminum product.

[0009] According to JP-A-5-59477, an aluminum alloy for forging in which the coarseness of crystal grains is restrained by controlling a composition, whereby high mechanical properties are attained has been proposed. It is stated that a tensile strength of 40 kgf/mm² has been attained because of the improvement in strength of matrix, and the restraint in not coarsening crystal grains by adjusting the composition so as to contain 1.0 to 1.5 wt% of silicon, 0.8 to 1.5 wt% of magnesium, 0.4 to 0.9 wt% of copper, 0.2 to 0.6 wt% of manganese, 0.3 to 0.9 wt% of chromium, and the like.

[0010] Although the strength is increased, there arises a new problem that a low cost cannot be attained, and the corrosion resistance is deteriorated because a larger amount of copper is contained than the conventional raw material for forging (A6061 alloy), and also the fluidity decreases so that the castability is poor because much magnesium is contained.

[0011] Also, an aluminum alloy material for forging having superior castability and high strength has been proposed in JP-A-7-258784. According to this document, the formation of crack during casting, which has been formed in the case where the conventional A6061 alloy is used as the raw material, does not occur, in the case of aluminum alloy forged product obtained by casting continuously a molten metal of an aluminum alloy material in which the composition is adjusted so as to contain 0.8 to 2.0 wt% of silicon, 0.5 to 1.5 wt% of magnesium, 0.5 to 1.0 wt% of copper, 0.4 to 1.5 wt% of manganese, 0.1 to 0.3 wt% of chromium, and the like with controlling a cooling rate in a solidification process, thereafter soaking the resultant, subsequently hot-forging aluminum alloy, thereafter subjecting to a solution heat treatment, and further an aging treatment, when the aluminum alloy forged product is cast into a shape close to a final product.

[0012] In this proposal, although castability is improved, the low cost cannot be attained yet as compared with the conventional raw material for forging (A6061 alloy), also the corrosion resistance is deteriorated because much copper is contained, and there remains anxiety when this material is used for the suspension part. Also, there arises a problem that the fluidity decreases because much magnesium is contained, and the above-described rigorous control is needed in the casting process, and the manufacturing cost rather increases.

[0013] Furthermore, according to JP-A-8-3675, an aluminum alloy for forging having superior mechanical properties and involving the low cost has been proposed. It is stated that the formation of the hot crack does not occur at the time of casting, and that the strength after the forging can be improved by forging, with an upsetting ratio of 10 to 50%, an aluminum alloy whose components have been adjusted so as to contain 0.6 to 3.0 wt% of silicon, 0.2 to 2.0 wt% of magnesium, 0.3 to 1.0 wt% of copper, 0.1 to 0.5 wt% of manganese, 0.1 to 0.5 wt% of chromium, and the like, and also 1.5 wt% or more of Mg₂Si.

[0014] In this proposal, although a shape close to that of the final product can be formed at the time of the casting, and the manufacturing cost can be reduced because the forging can be performed by omitting an extrusion process, there arises a problem in that the strength decreases because an excessive amount of manganese is contained. Manganese is an element capable of restraining the growth of aluminum crystal grains, keeping the grain structure to be refined, and improving the strength. If the content thereof is high, however, intermetallic compounds are liable to be formed, and the strength is rather decreased.

[0015] In JP-A-2002-302728, the present inventors also have proposed a thick-wall aluminum processed product which is an aluminum cast-forged product having high tensile strength, proof stress, and elongation and having improved mechanical properties as compared with the conventional cast-forged product, and having superior corrosion resistance and high quality without any defects and involving the low cost, and a method of manufacturing the product. In this proposal, there is proposed, as a cast aluminum alloy for forging which is the raw material for the forging, an aluminum alloy, characterized in that the alloy contains 0.2 to 2.0 wt% of silicon, 0.35 to 1.2 wt% of magnesium, 0.1 to 0.4 wt% of copper, and 0.01 to 0.08 wt% of manganese.

[0016] When the above-described material is used, a desired effect can be attained. However, in respect of the mechanical strength, it cannot be said that the material can sufficiently satisfy needs of the market, depending on use conditions. It is the present situation that there still exists a demand for a material more superior in the mechanical strength.

[0017] There has been a demand for a low-cost aluminum product which is more superior in mechanical properties such as the tensile strength, proof stress, and elongation and which can be applied as various components for automobiles such as the suspension components, frames, and engine parts and which involves the low cost, but it is the present situation that an appropriate aluminum product has not been proposed yet.

Disclosure of Invention

[0018] The present invention has been developed in view of the above-described conventional problems, and an object thereof is to solve the problems with the conventional art and, more particularly, to provide an aluminum cast-forged product capable of satisfying needs of the market as an aluminum thick-wall processed product and having high tensile strength, proof stress, and elongation; and a method of manufacturing an aluminum cast-forged product. That is, the object is to provide an aluminum alloy material which can be cast/processed like high-concentration products such as AC4CH containing 3 wt% or more of silicon and which can be processed in a final shape of a desired component like AC4CH without requiring low-speed casting, an aluminum cast-forged product cast/forged by the material, and a method of manufacturing an aluminum cast-forged product. Another object of the present invention is to provide various lightweight parts for vehicles brought about by the above-described aluminum cast-forged product and the method of manufacturing the product, and accordingly to save fuel consumption of automobiles and to reduce the amount of emitted carbon dioxide and to contribute to environmental measures such as the prevention of global warming.

[0019] As a result of various studies on raw materials and manufacturing method for the thick-wall aluminum product to solve the above problems, the present inventors have found that an aluminum cast-forged product having a sufficient strength capable of meeting needs of market can be obtained by making predetermined amounts of silicon, magnesium, copper, manganese, and chromium, and optionally titanium contain therein, with improving fluidity and castability. Thus, the present invention has been completed.

[0020] That is, according to the present invention, there is provided a cast aluminum alloy for forging which is usable for a material for forging, consisting essentially of: 0.6 to 1.8 wt% of silicon; 0.6 to 1.8 wt% of magnesium; 0.8 wt% or less of copper; 0.2 to 1.0 wt% of manganese; 0.25 wt% or less of chromium; 0.0 to 0.15 wt% of titanium; and unavoidable impurities. It is possible to use the present cast aluminum alloy for forging in manufacturing various parts for vehicles including suspension parts having mechanical properties capable of satisfying needs of the market such as a tensile strength of 320 MPa or more, a proof stress of 280 MPa or more, and an elongation of 10% or more.

[0021] To use the material in manufacturing a desired final product, assuming that a shape of the final product is 100%, the aluminum alloy is used to cast a preformed product having a forging ratio of 18 to 60%, and subsequently the preformed product may be cast and formed in the shape of the final product. Accordingly, it is possible to manufacture the parts for vehicles with a lower cost and higher productivity as compared with low-speed casting using AC4CH.

[0022] Moreover, according to the present invention, there is also provided an aluminum cast-forged product which is manufactured by forging a preformed product cast from the above-described aluminum alloy consisting essentially of 0.6 to 1.8 wt% of silicon, 0.6 to 1.8 wt% of magnesium, 0.8 wt% or less of copper, 0.2 to 1.0 wt% of manganese, 0.25 wt% or less of chromium, 0.0 to 0.15 wt% of titanium, and unavoidable impurities, the aluminum cast-forged product consisting essentially of: 0.6 to 1.8 wt% of silicon; 0.6 to 1.8 wt% of magnesium; 0.8 wt% or less of copper; 0.2 to 1.0 wt% of manganese; 0.25 wt% or less of chromium; 0.0 to 0.15 wt% of titanium; and unavoidable impurities. Therefore, the manufactured aluminum cast-forged product has sufficient mechanical properties such that the product is usable as the suspension parts for the vehicles, the frames for the vehicles, and the parts for the engines.

[0023] Furthermore, according to the present invention, there is provided a method of manufacturing an aluminum cast-forged product consisting essentially of 0.6 to 1.8 wt% of silicon, 0.6 to 1.8 wt% of magnesium, 0.8 wt% or less of copper, 0.2 to 1.0 wt% of manganese, 0.25 wt% or less of chromium, 0.0 to 0.15 wt% of titanium, and unavoidable impurities, the method including: a melting step of melting a material for forging which is an aluminum alloy consisting essentially of 0.6 to 1.8 wt% of silicon, 0.6 to 1.8 wt% of magnesium, 0.8 wt% or less of copper, 0.2 to 1.0 wt% of manganese, 0.25 wt% or less of chromium, 0.0 to 0.15 wt% of titanium, and unavoidable impurities at about 680 to 780°C to obtain a molten metal; a casting step of casting the obtained molten metal at a mold temperature of about 60 to 150°C to obtain a raw material for forging; a rough forging step of heating the raw material for forging to a surface temperature at about 380°C to a melting point or less and forging the raw material to obtain a roughly forged material; a finish forging step of heating the roughly forged material to a surface temperature at about 380°C to the melting point or less and forging the roughly forged material to obtain a finish forged material; and a clipping flash step of removing flash from the finish forged material to obtain a final product.

[0024] For the material for forging, while the respective components are adjusted so as to obtain the composition of the aluminum alloy according to the present invention, the flash generated at the time of the forging may be reused as the raw material. It is to be noted that assuming that the shape of the final product is 100%, a shape forging ratio of the raw material for forging, that is, the preformed material is preferably 18 to 60%. Therefore, it is possible to preferably

manufacture the suspension parts for the vehicles, the frames for the vehicles, and the parts for engine by the method of manufacturing an aluminum cast-forged product according to the present invention.

Brief Description of Drawings

[0025]

FIG. 1 is a side view showing one example of an aluminum cast-forged product in accordance with the present invention;

FIGS. 2(a), (b), and (c) are views showing one example of a method of manufacturing an aluminum cast-forged product of the present invention, FIG. 2(a) is a schematic explanatory view showing a difference in shape of a preformed material for each forging ratio at the time of casting, FIG. 2(b) is an enlarged side view showing one example of a cast body in which an internal defect is generated at the time of the casting, and FIG. 2(c) is an enlarged side view showing one example of a cast body in which no internal defect is generated at the time of the casting; and

FIGS. 3(a) and (b) are sectional views of the preformed material showing the forging ratio.

[0026] The numerical references used in the drawings denote respectively a part, an apparatus, a portion or the like as specified below:

[0027] 21, 22...columnar test piece, 40...steering knuckle, 41, 42, 43, 44...position from which test piece was taken, and 50... internal defect.

Best Mode for Carrying Out the Invention

[0028] Hereunder, embodiments of a cast aluminum alloy for forging, an aluminum cast-forged product, and a method of manufacturing an aluminum cast-forged product in accordance with the present invention will be described in detail. The present invention is not construed by being limited to these embodiments, and various changes, modifications, and improvements can be made based on the knowledge of those skilled in the art as far as such changes, modifications, or improvements are within the scope of the invention.

[0029] In the present invention, an aluminum alloy consisting essentially of 0.6 to 1.8 wt% of silicon, 0.6 to 1.8 wt% of magnesium, 0.8 wt% or less of copper, 0.2 to 1.0 wt% of manganese, 0.25 wt% or less of chromium, 0.0 to 0.15 wt% of titanium, and unavoidable impurities is used to first cast a preformed material, and next the preformed material is forged to manufacture a cast-forged product having a desired shape. When the aluminum alloy constituted of the above-described composition is used, it is possible to prepare an aluminum cast-forged product of the present invention, having mechanical properties meeting marketing needs. It is possible to preferably use the product in parts for vehicles in rugged environments, especially suspension parts for automobiles, frames for vehicles, and parts for engines.

[0030] The cast aluminum alloy for forging and the aluminum cast-forged product of the present invention will hereinafter concretely be described.

[0031] The cast aluminum alloy for forging of the present invention is an aluminum alloy consisting essentially of 0.6 to 1.8 wt% of silicon, 0.6 to 1.8 wt% of magnesium, 0.8 wt% or less of copper, 0.2 to 1.0 wt% of manganese, 0.25 wt% or less of chromium, 0.0 to 0.15 wt% of titanium, and unavoidable impurities.

[0032] Silicon serves to enhance fluidity and to improve a casting shrinkage when contained in the aluminum alloy. Also, this element precipitates Mg_2Si when coexisting with magnesium, and contributes to the improvement in mechanical properties such as elongation, tensile strength, and proof stress. When the content of silicon is less than 0.6 wt%, a sufficient mechanical property is not secured. On the other hand, when the content of silicon exceeds 1.8 wt%, the elongation decreases, it is not possible to manufacture the product in accordance with marketing needs, and therefore this is not preferable. It is to be noted that the content of silicon is preferably 0.8 to 1.3 wt%, further preferably 0.8 to 1.1 wt%.

[0033] Magnesium precipitates Mg_2Si in a matrix, when coexisting with silicon, and improves the mechanical properties such as the elongation, tensile strength, and proof stress when contained in the aluminum alloy. Since the present invention provides an aluminum cast-forged product substituted for the conventional forged product although being low in cost, the strength higher than that of the conventional product is indispensable, and magnesium needs to be contained. However, even if much magnesium is contained, there is no increase in strength. With too much content, since magnesium is an element liable to be oxidized, oxidation of molten metal is accelerated, the fluidity decreases, and the casting defect is liable to be generated. Also, the corrosion resistance is deteriorated, so that the product cannot withstand harsh service environments. Therefore, a rather low content is preferable.

[0034] It is preferable that 0.6 to 1.8 wt% of magnesium be contained in the cast aluminum alloy for forging. If the content of magnesium is less than 0.6 wt%, the amount of precipitation of Mg_2Si is undesirably insufficient, and the

strength is insufficient. If the content is more than 1.8 wt%, in addition to the insufficient strength, quenching sensitivity decreases, and thus the forging defect is liable to be generated. As a result, the quality of the forged material decreases, and the mechanical property also unfavorably decreases. The content is preferably 0.6 to 1.2 wt%, further preferably 0.7 to 1.1 wt%.

[0035] Copper is an element that can improve the strength, when contained in the aluminum alloy. For a copper-containing forged material, an Al-Cu or Al-Cu-Mg based precipitate yielded by a so-called aging treatment, in which the forged material is left to stand at ordinary temperature after cooled and crystals are precipitated for a long period of time, can be obtained. Accordingly, a strength improving function by Mg_2Si precipitated as described above is promoted to enhance the strength. In the present invention, since the strength higher than that of the conventional forged material is indispensable, it is preferable that copper be contained. However, in consideration of an application to products in which corrosion resistance is regarded as most important, such as an automobile suspension part, if too much copper, liable to be oxidized, is contained, the forged material is easily corroded, and it is therefore preferable that the content of copper be controlled to be as low as possible.

[0036] It is preferable that 0.8 wt% or less of copper be contained in the cast aluminum alloy for forging. If the content of copper is more than 0.8 wt%, the corrosion resistance is deteriorated, the alloy is liable to rust, and the strength cannot unfavorably be maintained over a long period. The content is preferably 0.005 wt% or more, less than 0.3 wt%, further preferably more than 0.1 wt%, and less than 0.2 wt%.

[0037] Manganese is an element that restrains the recrystallization of the aluminum alloy and the growth of crystal grains, when contained in the aluminum alloy. As a result, the grain structure in the aluminum alloy is kept to be refined, and the strength is maintained. In the present invention, since it is necessary to maintain the mechanical properties such as the elongation, tensile strength, and proof stress over the long period, a minute amount of manganese needs to be contained. However, if too much manganese is contained, workability decreases at the time of the forging, also intermetallic compounds are formed, and a decrease in the mechanical properties, especially the elongation, is found.

[0038] It is preferable that 0.2 to 1.0 wt% of manganese be contained in the cast aluminum alloy for forging. If the content of manganese is less than 0.2 wt%, a desired strength cannot sometimes be obtained. If the content is more than 1.0 wt%, formability undesirably decreases, and defects are liable to be generated. The content is more preferably more than 0.5 wt%, and 0.7 wt% or less.

[0039] Chromium forms dispersed particles, and it has an effect of inhibiting a grain boundary from moving after recrystallization, when contained in the aluminum alloy. Therefore, refined crystal grains and sub-crystal grains can be obtained. It is preferable that 0.25 wt% or less of chromium be contained in the cast aluminum alloy for forging. Even when the content of chromium exceeds 0.25 wt%, the desired effect cannot sometimes unfavorably be attained. The content is more preferably 0.04 to 0.25 wt%.

[0040] Titanium refines the crystal grains of a casting, and enhances workability at the time of the forging, when contained in the aluminum alloy. It is preferable that 0.0 to 0.15 wt% of titanium be contained in the cast aluminum alloy for forging. It is to be noted that even when titanium is not contained, a considerably large trouble is not caused.

[0041] The metals contained in minute amounts in the cast aluminum alloy for forging and the aluminum cast-forged product in accordance with the present invention are as described above, and the balance is unavoidably contained impurities and aluminum. It is preferable that the unavoidably contained impurities be contained by an amount as small as possible. The content is less than 0.1 wt%, preferably 0.05 wt% or less.

[0042] It is to be noted that in a casting/forging method according to the present invention, flash generated in the forging process and accounting for about 30% of the generally used raw material can be recovered and reused as the raw material of the aluminum alloy according to the present invention. Therefore, in the present invention, the cost of raw materials can be reduced.

[0043] Next, the method of manufacturing an aluminum cast-forged product of the present invention will be described.

[0044] As described above, it is preferable that the flash generated at the time of the forging be used as the raw material. This raw material is adjusted so as to allow the resulting composition to form the intended aluminum alloy consisting essentially of 0.6 to 1.8 wt% of silicon, 0.6 to 1.8 wt% of magnesium, 0.8 wt% or less of copper, 0.2 to 1.0 wt% of manganese, 0.25 wt% or less of chromium, 0.0 to 0.15 wt% of titanium, and unavoidably contained impurities by measures such as preparing of metals that are insufficient using pure metals, and mixing with another aluminum alloy. At this time, it is preferable that the unavoidable impurities be not contained in the aluminum alloy by 0.1 wt% or more in total.

[0045] These raw materials are charged in a melting furnace and is heated to a temperature at about 680 to 780°C to be melted, and next is charged into a holding furnace where a degassing treatment and deoxidizing treatment are done to obtain a molten metal. In this case, the temperature of a mold is preferably adjusted at about 60 to 150°C. Also, the mold preferably has a shape such that a forging ratio is about 18 to 60%, assuming that the shape of the final forged product is 100%, because the strength is enhanced by the subsequent forging and the forging process can further be simplified. That is, when the forging ratio is set to about 18 to 60%, the strength improving effect due to the forging and the cost reduction due to a simplified forging process are balanced.

[0046] Herein, the forging ratio means a value representing the degree of forming. For example, as shown in FIG. 3(a), when a material A with an initial thickness D1 is formed by a load F and the thickness is changed to D2 after forming as shown in FIG. 3(b), a forging ratio R is represented by the following equation.

$$R[\%] = (D1 - D2)/D1 \times 100 \quad (D1 > D2)$$

However, when the thickness D2 after the forming is larger than the initial thickness, the forging ratio is represented by the following equation.

$$R[\%] = (D2 - D1)/D1 \times 100 \quad (D2 > D1)$$

[0047] That is, in the present invention, the fact that the so-called preformed material having a shape such that the forging ratio is about 18 to 60% assuming that the shape of the final forged product is 100% is obtained by the casting means that the preformed material having a shape such that the forging ratio determined using the thickness of each portion of the raw material for forging and the thickness of each corresponding portion in the final product obtained by forging the raw material for forging is about 18 to 60% in each portion is obtained by the casting.

[0048] Next, the cast material obtained/molded using a casting apparatus, that is, the raw material for forging is heated to a surface temperature at about 380°C to a melting point or less and is stamped by a forging press to obtain a roughly forged material. The roughly forged material is cooled, thereafter heated again to the surface temperature at about 380°C to the melting point or less, and is finished/stamped by the forging press to obtain a finish forged material. The finish forged material is subjected to clipping flash and heat treatment such as T6 treatment to obtain a forged product. For example, to manufacture a steering knuckle which is one of the suspension parts for the automobiles, the load of the forging press is about 2600 to 2800 tons for rough forging and about 3200 to 3800 tons for finish forging. By this manufacturing process, the aluminum cast-forged product in accordance with the present invention can be obtained.

[0049] In the present invention, the flash generated by the forge-pressing and clipping flash in the manufacturing process of the present invention is collected by a flash removing machine, and can be reused as the raw material for the aluminum cast-forged product of the present invention. Therefore, all of the raw materials for forging are recycled, and are not disposed of as wastes or are not used as an inexpensive raw material for forging.

[0050] In the method of manufacturing an aluminum cast-forged product of the present invention, after the raw material is melted to obtain the molten metal, the mold for the casting is brought closer to the shape of the product as compared with the conventional raw material for forging so that the forging ratio is about 18 to 60% assuming that the shape of the final forged product is 100% while achieving the strength improving effect by the forging, by which the pressing is facilitated. Therefore, unlike the conventional forging process, steps of extruding, cutting, heating, rough forging, finish forging, and clipping flash are not observed, thus the manufacturing process can be simplified, and the manufacturing cost can be reduced.

(Examples)

[0051] Examples of the present invention will hereinafter be described, but the present invention is not limited to these examples.

(Examples 1 and 2)

[0052] FIG. 1 is a diagram showing one example of the aluminum cast-forged product of the present invention. A steering knuckle 40 which is the part for the automobile is shown. A small amount of copper was added to scraps of A6082 alloy to prepare a raw material forming the aluminum alloy consisting essentially of 0.6 to 1.8 wt% of silicon, 0.6 to 1.8 wt% of magnesium, 0.8 wt% or less of copper, 0.2 to 1.0 wt% of manganese, 0.25 wt% or less of chromium, 0.0 to 0.15 wt% of titanium, and unavoidably contained impurities. Using this raw material, the steering knuckle 40 having a shape shown in FIG. 1 was manufactured in accordance with the following steps.

[0053] After the raw material was melted at a molten metal temperature of 728°C to obtain the molten metal, the raw material for forging having a shape with a forging ratio of 30% assuming that the shape of the final steering knuckle 40 was 100% was cast at a mold temperature of 100°C. Next, die forging was performed using a forging press at a rough forging temperature of 395°C (surface temperature) by applying a rough forging load of 2770 tons to obtain a roughly forged material. Then, the roughly forged material was subjected to the die forging again using the forging press at a finish forging temperature of 460°C (surface temperature) by applying a finish forging load of 3260 tons.

Finally, the finish forged material was trimmed. After a solution heat treatment which was a T4 treatment by heating the finish forged material at 530°C for three hours, the finish forged material was cooled. Then, an aging treatment was done as T6 treatment by heating the finish forged material at 180°C for six hours. Thus, the steering knuckle 40 was obtained as a product. In Example 2, operations similar to those of Example 1 were repeated to obtain the steering knuckle 40, except that the molten metal temperature was set to 720°C and the mold temperature was set to 125°C. Temperature conditions and load conditions are given in Tables 1 and 2, respectively.

[Table 1]

	Molten metal temperature (°C)	Mold temperature (°C)
Example 1	728	100
Example 2	720	125

[Table 2]

	Rough forging		Finish forging	
	Load (ton)	Surface temperature (°C)	Load (ton)	Surface temperature (°C)
Example 1	2770	395	3260	460
Example 2	2730	400	3780	445

[0054] The test pieces were cut out from thus obtained steering knuckle 40, and tensile strength, proof stress, and elongation were measured as mechanical properties. The results are shown in Table 3.

[Table 3]

	Tensile strength (MPa)	Proof stress (MPa)	Elongation [%]
Example 1	358	323	14.7
Example 2	378.6	335.8	14.3
Required value from market	320	280	10

[0055] The results of Examples 1 and 2 reveal that the mechanical properties of the aluminum cast-forged product in accordance with the present invention were capable of clearing the standards as needs of market in all of the tensile strength, proof stress, and elongation.

Industrial Applicability

[0056] As described above, in accordance with the present invention, there is provided an aluminum cast-forged product further satisfying needs of market in mechanical properties such as a tensile strength, proof stress, and elongation with a simpler manufacturing process with good productivity and at low cost. Moreover, by this aluminum cast-forged product, various lightweight and inexpensive vehicular parts such as suspension parts for vehicles, frames for the vehicles, and parts for engines are provided. Through lightening of weights of the vehicles, fuel consumption of automobiles is saved. As a result, emitted carbon dioxide is reduced, and an effect of contribution to prevention of global warming is also attained.

Claims

1. An aluminum alloy consisting essentially of: 0.6 to 1.8 wt% of silicon; 0.6 to 1.8 wt% of magnesium; 0.8 wt% or less of copper; 0.2 to 1.0 wt% of manganese; 0.25 wt% or less of chromium; 0.0 to 0.15 wt% of titanium; and unavoidably contained impurities.
2. A use of an aluminum alloy in manufacturing an aluminum cast-forged product, wherein a preformed material is made from the aluminum alloy recited in claim 1, and the preformed material is forged to manufacture an aluminum cast-forged product.

3. The use in manufacturing an aluminum cast-forged product according to claim 2, wherein the preformed material has a shape indicating a forging ratio of 18 to 60%, assuming that the shape of a final product is 100%.

4. The use in manufacturing an aluminum cast-forged product according to claim 2 or claim 3, wherein the aluminum cast-forged product is a suspension part for a vehicle, a frame for the vehicle, or a part for an engine.

5. A method of manufacturing an aluminum cast-forged product consisting essentially of 0.6 to 1.8 wt% of silicon, 0.6 to 1.8 wt% of magnesium, 0.8 wt% or less of copper, 0.2 to 1.0 wt% of manganese, 0.25 wt% or less of chromium, 0.0 to 0.15 wt% of titanium, and unavoidable impurities, the method including:

a melting step of melting an aluminum alloy consisting essentially of 0.6 to 1.8 wt% of silicon, 0.6 to 1.8 wt% of magnesium, 0.8 wt% or less of copper, 0.2 to 1.0 wt% of manganese, 0.25 wt% or less of chromium, 0.0 to 0.15 wt% of titanium, and the unavoidable impurities at about 680 to 780°C to obtain a molten metal;

a casting step of casting the obtained molten metal at a mold temperature of about 60 to 150°C to obtain a preformed material which is a raw material for forging;

a rough forging step of heating the raw material for forging to a surface temperature at about 380°C to a melting point or less and forging the raw material to obtain a roughly forged material;

a finish forging step of heating the roughly forged material to a surface temperature at about 380°C to the melting point or less and forging the roughly forged material to obtain a finish forged material; and

a clipping flash step of removing flash from the finish forged material to obtain a final product.

6. The method according to claim 5, wherein the aluminum alloy includes the flash generated at the time of the forging as a portion of a raw material.

7. The method according to claim 6, wherein a forging ratio of the shape of a preformed material is in a range of 18 to 60%, assuming that the shape of a final product is 100%.

8. A suspension part for a vehicle, a frame for the vehicle, or a part for an engine prepared by the method of manufacturing an aluminum cast-forged product according to any one of claims 5 to 7.

9. The suspension part for the vehicle, the frame for the vehicle, or the part for the engine according to claim 8, having mechanical properties such as a tensile strength of 320 MPa or more, a proof stress of 280 MPa or more, and an elongation of 10% or more.

FIG. 1

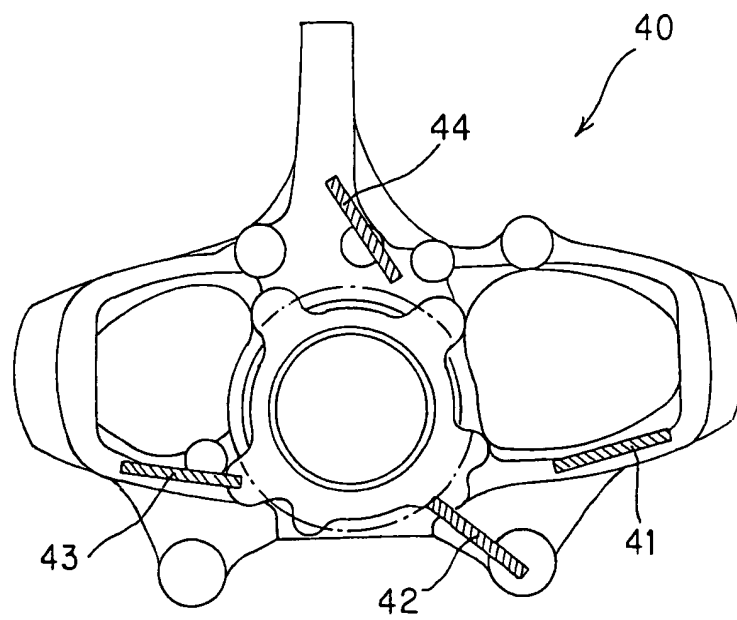


FIG. 2(a)

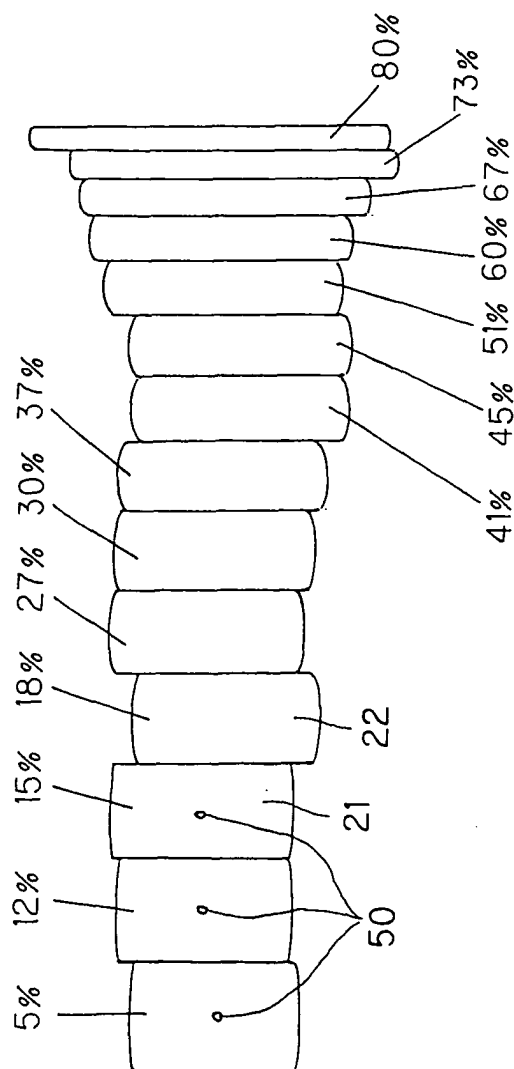


FIG. 2(b)

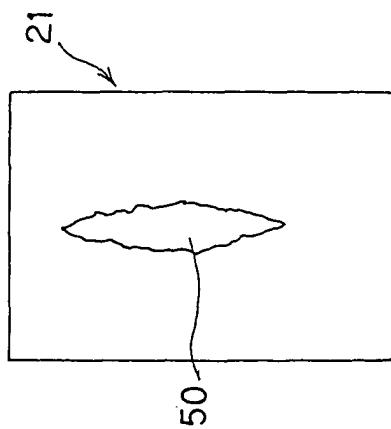


FIG. 2(c)

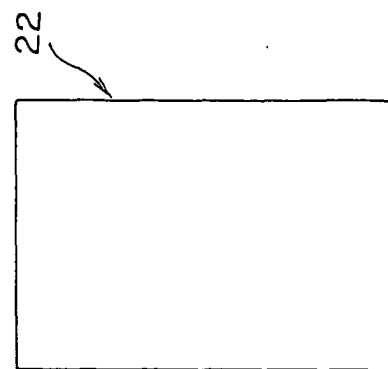
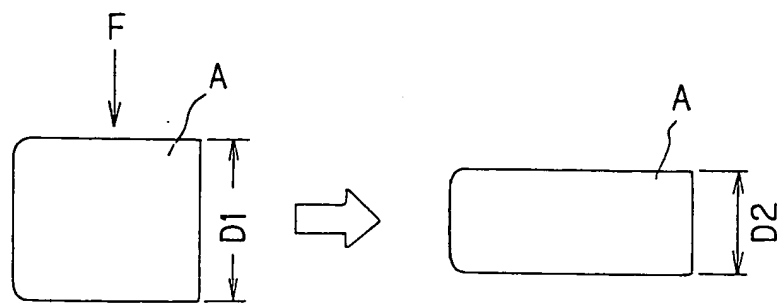


FIG. 3(a)

FIG. 3(b)



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP03/12514

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl.⁷ C22C21/06, B21J5/00, B21K1/26, B22D21/04, C22F1/05

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl.⁷ C22C21/00-21/18, B21J5/00, B21K1/00-1/76, B22D21/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-2003
Kokai Jitsuyo Shinan Koho	1971-2003	Jitsuyo Shinan Toroku Koho	1996-2003

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	JP 2002-348630 A (Nissan Motor Co., Ltd.), 04 December, 2002 (04.12.02), Full text (Family: none)	1-9
P,A	JP 2002-302728 A (Hoei Industries Co., Ltd.), 18 October, 2002 (18.10.02), Claims & WO 02/083963 A1 & US 2003/0010412 A1	1-9
X	JP 9-78210 A (Mitsubishi Materials Corp.), 25 March, 1997 (25.03.97), Full text (Family: none)	1-9

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
19 December, 2003 (19.12.03)Date of mailing of the international search report
20 January, 2004 (20.01.04)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP03/12514

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 8-3675 A (Nippon Light Metal Co., Ltd.), 09 January, 1996 (09.01.96), Full text (Family: none)	1-9
X	JP 7-258784 A (Kobe Steel, Ltd.), 09 October, 1995 (09.10.95), Claims (Family: none)	1
X	JP 1-225756 A (Nippon Light Metal Co., Ltd.), 08 September, 1989 (08.09.89), Claims (Family: none)	1
X	JP 63-230844 A (Showa Aluminum Corp.), 27 September, 1988 (27.09.88), Claims (Family: none)	1
X	US 4082578 A (ALUMINUM CO. OF AMERICA), 04 April, 1978 (04.04.78), Claims & JP 53-19117 A	1

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