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(54) Al-Si-Mg aluminium alloy product and method of manufacturing the same

(57) An aluminum alloy product includes additive elements of 3.0 to 4.2wt% of silicon, 0.4 to 0.6wt% of magnesium, 0.2wt% or less of iron, and 0.5wt% or less in total of zinc, manganese, nickel, tin and chromium. The additive element substantially excludes copper. The aluminum alloy product is formed by forging a casting of which shape is approximated to a shape of a final product.

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Description

FIELD OF THE INVENTION

[0001] This invention generally relates to an aluminum alloy member having qualities of die-castability and forgeability, having excellent mechanical properties of tensile strength, proof strength and elongation and having high corrosion resistance, and a method of manufacturing the same.

BACKGROUND

[0002] There is a casting-forging method of obtaining an aluminum alloy member conventionally widely known, by which aluminum alloy-base molten metal or raw material is cast into a mold so as to obtain a casting of which shape is approximated to a shape of a final product, and the casting is hot-forged by using a forging press so as to obtain the aluminum alloy member. In the following explanation, a casting of which shape is approximated to a shape of a final product is called an approximately shaped casing. This type of casting-forging method is adopted to manufacture a vehicle suspension part, for example. Various types of materials have been evaluated as an aluminum alloy having composition which can apply the casting-forging method, such as JIS-A6061 alloy (aluminum expanded material) of high forgeability, JIS-AC4CH and AC4C (aluminum casting material) of high castability and an intermediate composition between the aluminum expanded material and the aluminum casting material, as non-limiting examples. The casting-forging methods using these aluminum alloys are disclosed in JP2002-302728A (corresponding to US2003/0010412A1), JP Patent No. 2551882 and JP06 (1994)-073482A.

[0003] Disclosed is an aluminum alloy in the above references, which is light in weight and has higher mechanical properties as an aluminum alloy member used for a vehicle underbody (e.g., a chassis line) such as a vehicular upper arm or lower arm. Components of the vehicle underbody are required to have higher mechanical properties and also required to be of high corrosion resistance. However, the aluminum alloy member disclosed in the above references have been sufficiently weighed in improvement of mechanical properties thereof, and yet have not been sufficiently weighed in improvement of corrosion resistance thereof.

[0004] More particularly, according to JP2002-302728A, paragraph 0028 discloses a benefit to enhance strength of an aluminum alloy member by containing copper therein and by obtaining an Al-Cu based precipitate. Meanwhile, there is an only disclosure therein that it is important to contain a rather low content of copper in the aluminum alloy member in order to improve a corrosion resistance.

[0005] According to JP Patent No. 2551882, paragraph 0014 discloses it is preferable that 0.2 - 0.5 weight% copper be contained in an aluminum alloy member in order to improve strength of the aluminum alloy member. Meanwhile, JP Patent No. 2551882 includes few disclosures about improvement of corrosion resistance of the aluminum alloy member and even does not disclose an experiment result related to the corrosion resistance. Further, according to JP2002-302728A and JP Patent No.2551882, the content of silicon is set at a rather low amount, and so the aluminum alloy member may not be able to be cast with sufficient die-castability.

[0006] According to JP06 (1994)-073482A, an aluminum alloy member is disclosed, of which composition is 0.3 wt% or less copper, 2.5 - 4.0 wt% silicon and 0.4 - 0.5 wt% magnesium. The aluminum alloy member with the above-described composition is forged by a compression ratio at more than 50 % inclusive. According to the aforementioned method of forging the aluminum alloy member, sufficiently high mechanical strength of the aluminum alloy member can be achieved even if the copper content contained in the aluminum alloy member is limited to 0.3wt% or less, as far as the compression ratio for hot-forging the aluminum alloy is 50% or more. In this case, the copper content of 0.3wt% or less effectively contributes the corrosion resistance thereof not to be reduced. However, as explained in paragraph 0012 and Fig. 3 of JP06 (1994)-073482A, the optimal content of copper is 0.2 wt%. Namely, these disclosures lead to the aluminum alloy member preferably containing copper therein in order to improve the mechanical properties of the aluminum alloy. Further, JP06 (1994)-073482A discloses just a qualitative explanation about the reduction of the corrosion resistance, which may be caused by containing copper in the aluminum alloy member, and does not disclose explanation of a sufficient study on improvement of the corrosion resistance. This is obvious also from a point of view that JP06 (1994)-073482A does not disclose any experimental results related to the corrosion resistance thereof.

[0007] Further, the aluminum alloy member is required not only to have a higher mechanical strength as the aluminum alloy member used for a vehicle suspension part (e.g., vehicular suspension arm), but also to have excellent mechanical properties of elongation and so on.

[0008] A need exists for providing an aluminum alloy member having qualities of die-castability and forgeability, having excellent mechanical properties such as strength after being forged and elongation and having high corrosion resistance, and for providing a method of manufacturing the same.

SUMMARY OF THE INVENTION

[0009] According to an aspect of the present invention, an aluminum alloy product characterized in that the aluminum alloy product includes additive elements of 3.0 to 4.2wt% of silicon, 0.4 to 0.6wt% of magnesium, 0.2wt% or less of iron, and 0.5wt% or less in total of zinc, manganese, nickel, tin and chromium. The additive element substantially excludes copper. The aluminum alloy product is formed by forging a casting of which shape is approximated to a shape of a final product.

[0010] It is preferable that the aluminum alloy product contains 0.02wt% or less copper as an unavoidable impurity.

[0011] It is further preferable that the aluminum alloy product contains 0.01wt% or less copper as an unavoidable impurity.

[0012] According to another aspect of the present invention, a method of manufacturing an aluminum alloy product characterized in that the method includes the steps of casting an aluminum alloy material to obtain an aluminum alloy casting of which shape is approximated to a shape of a final product, and hot-forging the casting with a compression ratio ranged between 30 and 50%. The aluminum alloy material includes additive elements of 3.0 to 4.2wt% of silicon, 0.4 to 0.6wt% of magnesium, 0.2wt% or less of iron, and 0.5wt% or less in total of zinc, manganese, nickel, tin and chromium, the additive element substantially excludes copper.

[0013] It is preferable that the method of manufacturing an aluminum alloy product further includes the steps of cooling down the aluminum alloy product after a solution heat treatment, and applying an aging treatment to the aluminum alloy product at a temperature ranged between 155 and 165°C for an aging time ranged between 6 and 8 hours.

[0014] It is further preferable that the aluminum alloy product contains 0.01wt% or less copper as an unavoidable impurity.

[0015] It is still further preferable that the aluminum alloy product contains 0.02wt% or less copper as an unavoidable impurity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The foregoing and additional features and characteristics of the present invention will become more apparent from the following detailed description considered with reference to the accompanying drawings, wherein:

[0017] Fig. 1 is view illustrating a mold for casting an aluminum alloy according to an embodiment of the present invention;

[0018] Fig. 2 is a view schematically illustrating an approximately shaped casting by the mold illustrated in Fig. 1;

[0019] Fig. 3 is a cross sectional view illustrating the approximately shaped casting being forged in a forging die;

[0020] Fig. 4 is an explanatory view for explaining a shape of a corrosion resistance specimen;

[0021] Fig. 5 is an explanatory view for explaining the corrosion resistance specimen and an assembling structure of the specimen; and

[0022] Fig. 6 is an explanatory view for explaining a shape of a tensile strength specimen.

DETAILED DESCRIPTION

[0023] An embodiment of the present invention will be described hereinbelow in detail with reference to the accompanying drawings.

[0024] A basis for limiting the composition of the aluminum alloy member according to the embodiment of the present invention is described as follow.

[0025] Silicon (atomic symbol: Si) is an element capable of improving fluidity and shrinkage tendency, reducing occurrences of casting crack and improving castability. An excessive content of silicon in an aluminum alloy could lead to deterioration of plastic strain and lowering of elongation property and mechanical strength. Therefore, the content of silicon is defined at approximately 3.0 to 4.2 wt%. When the content of silicon is less than 3.0 wt%, the aforementioned effects yield by containing silicon in the aluminum alloy member at a preferable amount may not be sufficiently achieved, On the other hand, when the content of silicon exceeds 4.2 wt%, the mechanical strength of the aluminum alloy member may be damaged. As aforementioned, it is preferable that the aluminum alloy member contains approximately 3.0 to 4.2 wt% silicon, more preferably approximately 3.0 to 4.0 wt%.

[0026] Magnesium (atomic symbol: Mg) is an element that can deposit a chemical compound Mg_2Si in the aluminum alloy member when magnesium coexists with silicon. By precipitation hardening of the chemical compound Mg_2Si in the aluminum alloy member, magnesium can contribute to improvement of mechanical properties of tensile strength and proof strength. However, when magnesium is contained excessively in the aluminum alloy member, elongation and impact value of the aluminum alloy member may be reduced. Therefore, the content of magnesium is defined at approximately 0.4 to 0.6wt%.

[0027] As described above, according to the embodiment of the present invention, the corrosion resistance of the aluminum alloy member can be largely improved substantially by not containing copper (atomic symbol: Cu) therein. Conventionally, a perspective has been highly weighed, in which copper is indispensable in order to improve mechanical strength of the aluminum alloy member used for a vehicle suspension part (e.g., vehicular suspension arm), for example. However, the method of manufacturing the aluminum alloy member according to the embodiment of the present invention enables manufacturing the aluminum alloy member without substantially containing copper therein. The manufactured aluminum alloy member has excellent mechanical strength and corrosion resistance. Therefore, it is preferable that the aluminum alloy member does not contain copper therein, if possible. Alternatively, the aluminum alloy member can contain copper therein as an unavoidable impurity. When copper is contained in the aluminum alloy member as the unavoidable impurity, the copper content can be limited approximately 0.02 wt% or less. Further, when copper is more restrictively contained in the aluminum alloy member as the unavoidable impurity, the copper content can be limited to approximately 0.01wt% or less.

[0028] Iron (atomic symbol: Fe) causes porosity and affects die-castability of the aluminum alloy member. Iron further damages plastic deformation of the aluminum alloy member and affects the forgeability thereof. Therefore, it is preferable that the content of iron as the unavoidable impurity be defined as small as possible. When the iron content exceeds approximately 0.2 wt%, the more porosities are liable to be formed at an approximately shaped casting. Therefore, when the approximately shaped casting is forged, forging cracks may be easily generated. Therefore, the iron content is defined to be approximately 0.2 wt% or less.

[0029] An excessive content of zinc (atomic symbol: Zn) may lead to deterioration of the corrosion resistance of the aluminum alloy member. Therefore, it is preferable the zinc content be restrained to the best of its ability in the aluminum alloy member which is aimed to have higher corrosion resistance. An excessive content of manganese (atomic symbol: Mn) may lead to occurrence of sludge. An excessive content of nickel (atomic symbol: Ni) or tin (atomic symbol: Sn) may lead to deterioration of the corrosion resistance of the aluminum alloy. An excessive content of chromium (atomic symbol: Cr) may promote sludge generation. As described above, it is preferable that the content of each element is limited in the aluminum alloy member. The above-described defects can be prevented by defining the total content of all these elements at approximately 0.5 wt% or less. Further, JP2002-361399A discloses a basis for limiting each content of silicon, magnesium and iron and the total content of zinc, manganese, nickel, tin and chromium.

[0030] Next, following explanation will be given for explaining the aluminum alloy member according to the embodiment of the present invention.

[0031] A mold 1, which is used for casting the aluminum alloy member through a casting process, is a metal mold mounted at a casting device pivotally rotating the mold 1. The mold 1 can be effectively adopted for manufacturing a vehicle suspension part (e.g., vehicular suspension arm) that represents a par required to be of high strength and high corrosion resistance. As schematically illustrated in Fig. 1, the mold 1 includes a first cavity 11 of which shape is approximated to a shape of a final product and a second cavity 2 communicating with the first cavity 11. The mold 1 is a horizontal type mold which is horizontally oriented before casting an aluminum alloy base molten metal (material) into the mold 1. The aluminum alloy-base molten metal runs in the first cavity 11 of the mold 1.

[0032] The composition of the aluminum alloy-base molten metal is approximately 3.0 to 4.2 wt% silicon, approximately 0.4 to 0.6 wt% magnesium, approximately 0.2 wt% or less iron, a total content at approximately 0.5 wt% or less of zinc, manganese, nickel, tin and chromium, and a balance of aluminum and unavoidable impurities. Further, according to the embodiment of the present invention, the aluminum alloy-base molten metal substantially does not contain copper as an additive element. More particularly, when the aluminum alloy-base molten metal substantially does not contain copper as the additive element, the content of the unavoidably contained Cu can be limited to approximately 0.02 wt% or less, more preferably approximately 0.01 wt% or less.

[0033] The aluminum alloy-base molten metal for casting is generally approximately 720 to 750°C. The mold temperature of the mold 1 is generally approximately 250 to 350°C. The aluminum alloy-base molten metal is first cast through a gate 12x defined at a side of the second cavity 12. When the first cavity 11 and the second cavity 12 are filled in with the molten metal, the horizontally oriented mold 1 is pivotally rotated so as to become a vertical type, i.e., so as to orient the first cavity 11 upwards. In this case, the molten metal in the first cavity 11 can be solidified at an earlier stage, while the molten metal in the second cavity 12 is delayed from being solidified. Therefore, even when an approximately shaped casting 2 as a casting mold is of complex shaped, the aforementioned directional solidification of the molten metal enables restraining occurrences of shrinkage and porosity as the casting mold.

[0034] Once the entire molten metal is solidified, the mold 1 is pivotally rotated to return to a horizontal orientation. The mold 1 is opened so as to trim the approximately shaped casting 2 molded as illustrated in Fig.2. As schematically illustrated in Fig. 2, the approximately shaped casting 2 includes a main body 2a, a boss 2s adjusted to have a bolt inserting bore and a pair of bosses 2b and 2c adjusted to have bolt inserting bores respectively. A time for solidifying the molten metal depends on a size or shape of the casting, and yet can be generally 30 to 120 seconds, especially 40 to 80 seconds. However, the time for solidifying the molten metal is not limited to the above.

[0035] Next, following explanation will be given for explaining the method of forging the approximately shaped casting 2.

[0036] In the forging process according to the embodiment of the present invention, the approximately shaped casting 2 cooled to a room temperature is put in a melting furnace and is heated to a predetermined temperature such as approximately 430°C as a non-limiting example. The approximately shaped casting 2 is positioned in a forging mold 4 as illustrated in Fig. 3. The approximately shaped casting 2 is subjected in a press die 4 having a pair of press dies and is hot-forged by forging press in a thickness direction thereof, by which a cast-forged product 5 (i.e., aluminum alloy product) can be obtained. The press die 4 includes a metal made upper press die 43 having a parting surface 40 and a metal made bottom press die 41. The press die 4 further includes a forging cavity 46, which is defined by mating the parting surface 40 and the other parting surface 42, and a flash defining space 47 defined to surround an exterior side of the forging cavity 46. The approximately shaped casting 2 is generally forged at a forging temperature of approximately 390 to 430°C. More particularly, the approximately shaped casting 2 is forged at the forging temperature of approximately 390 to 430°C by forging press via die surfaces 46f of the pair of press dies 43 and 41 in the thickness direction thereof. According to the embodiment of the present invention, the forging method of the approximately shaped casting 2 is half-closed forging by which the approximately shaped casting 2 is forged while actively producing flash around a vertically inner portion thereof. The flash runs into the flash defining space 47, thereby obtaining the cast-forged product 5 having a flash portion 20 at an outer peripheral portion thereof.

[0037] Strength of the body 2a, the boss portions 2s, 2b and 2c is enhanced by the forging. The flash portion 20 is defined at an intermediate area in the thickness direction of the cast-forged product 5. The cast-forged product 5 includes forged surfaces 5f defined by being pressed by the die surfaces 46f. A compression ratio for forging a portion in the vicinity of the second cavity 12 of the approximately shaped casting 2 is denoted as αn , while a compression ratio for forging a portion away from the second cavity 12 thereof is denoted as αd ($an > \alpha d$). The compression ratio means a rate of decrease of a thickness of the approximately shaped casting pressed upon the forging process. According to the embodiment of the present invention, the approximately shaped casting 2 is directionally solidified. Therefore, shrinkage and porosity can be prevented from occurring at the approximately shaped casting 2 in the first cavity 11. However, shrinkage and porosity may occur at a portion of the approximately shaped casting 2 in the first cavity 11 and in the vicinity of the second cavity 12. Therefore, by setting the relationship between the compression ratios of the first and second cavities 11 and 12 as described above, shrinkage hole and porosity can be easily cancelled through the forging process. Therefore, the forging process according to the embodiment of the present invention can contribute to improvement in the mechanical strength of the aluminum alloy member.

[0038] According to the embodiment of the present invention, the compression ratio can be designed within a range approximately between 30 and 50 %. It is preferable that a reduction in area be designed approximately 30% or less, more preferably approximately 15% or less. As described above, in the aluminum alloy member which substantially does not contain copper therein, tensile strength and elongation thereof can be enhanced by increasing the compression ratio from 0% to 50%. However, once the compression ratio exceeds 50%, the tensile strength and elongation are reduced. On the other hand, when the compression ratio is less than 30%, sufficient tensile strength, proof strength and elongation cannot be achieved. Taking the aluminum alloy member used for the vehicle suspension arm as an example, it is preferable that elongation thereof is designed at approximately 11% or more. In order to design the elongation of the aluminum alloy member at 11% or more, it is preferable that the compression ratio be approximately 30% or more. When the reduction in area is designed approximately 30% or less, a portion having an area corresponding to the reduction in area becomes the flash portion 20.

[0039] According to the embodiment of the present invention, the casting-forged product 5 exhibits a relatively high degree of orientational regarding metal flow at an intermediate area in the thickness direction of the casting-forged product 5. On the other hand, the casting-forged product 5 does not show a relatively high degree of orientational at the forging surfaces 5f in the vicinity of the die surfaces 46f. Therefore, a chill structure may remain around the die surfaces 46f of the forging cavity 46 during the casting process.

[0040] According to the embodiment of the present invention, following experiments were implemented in order to verify and confirm that the aluminum alloy member has excellent mechanical properties and good corrosion resistance, or in order to verify and confirm that this manufacturing method can manufacture the aluminum alloy member having excellent mechanical properties and good corrosion resistance.

Experiment 1

[0041] Table 1 summarizes five types of prepared row materials (Nos.1 to 5) as aluminum alloy base molten metals, each of which contains an indicated composition and the balance aluminum. Each aluminum alloy base molten metal is used to cast an approximately shaped casting summarized in Table 2 by use of the mold 1 illustrated in Fig. 1. Upon the casting process, each row material which contains the indicated composition coexisting with aluminum was melted at a molten metal temperature of approximately 720°C at a mold temperature of approximately 250 to 350°C, to obtain the approximately shaped casting illustrated in Fig. 2. After heating up the approximately shaped casting at a surface temperature of approximately 430°C, closed die hot-forging was performed by using a forging press to apply the reduction in area of approximately 10% and the compression ratio of approximately 30%, to obtain the aluminum casting forged product. The obtained aluminum casting forged product was applied with thermal treatment. More specifically, after solution heat treatment was done at a temperature of approximately 540°C for six hours, aging treatment was done at a temperature of approximately 155 to 165°C, more preferably at a temperature of approximately 160°C, for six to eight hours, more preferably for eight hours.

[0042] Following corrosion resistance test was implemented to each aluminum casting forged product obtained as described above. The aluminum casting forged product was cut away to form a corrosion resistance specimen 10 of approximately c-caped structure as illustrated in Fig. 4. The dimension of the specimen 10 is indicated in Fig. 4. The specimen 10 is assembled as illustrated in Fig. 5 so as to be applied with load. More specifically, an annular shaped penetrating hole 10a is defined at each collar portion of the approximately c-shaped specimen 10. A bolt 6 is inserted into the penetrating holes 10a and is fixed by a nut 7 as illustrated in Fig. 5.

Table 1

	Si (wt%)	Mg (wt%)	Fe (wt%)	Cu (wt%)
No.1	3.73	0.46	0.15	Not added
No.2	3.8	0.47	0.15	0.26
No.3	3.98	0.37	0.15	0.33
No.4	3.6	0.46	0.15	0.44
No.5	3.98	0.47	0.15	0.64

[0043] A salt spray test was applied to the corrosion resistance specimen 10 assembled as illustrated in Fig. 5 while being applied with a stress ranging from approximately 150 to 200Mpa by the bolt 6. A sectional area of the corrosion resistance specimen 10 was evaluated by a microscope whether intergranular corrosion had occurred at the sectional area thereof. The stress was measured by a deformation gage 8 equipped at the specimen 10.

Table 2

	Total Numbers of Samples (pcs)	Numbers of Corroded Samples (pcs)	Corrosion Ratio (%)
No.1	108	0	0
No.2	108	9	8.3
No.3	108	12	11.1
No.4	108	17	17.7
No.5	108	23	21.3

[0044] As being summarized in Table 2, the specimen 10 (No.1), which does not substantially contain copper therein or contains approximately 0.01wt% or less copper as the unavoidable impurity therein, does not exhibit any intergranular corrosions and can have fairly preferable corrosion resistance. On the other hand, the specimen 10, which contains approximately 0.33wt% or 0.26wt% copper therein, exhibits that the percentage of the specimens, which were corroded, of all specimens (the total number of specimens:108 pieces) reached approximately 10%. This corrosion test result shows that high corrosion resistance can be achieved at the aluminum alloy member substantially not containing copper or containing approximately 0.01wt% copper as the unavoidable impurity therein, while it is difficult to achieve a sufficient corrosion resistance at the aluminum alloy member containing 0.33wt% or 0.26wt% copper. Each content of silicon, magnesium and iron, and a total content of zinc, manganese, nickel, tin and chromium is described in JP2002-361399A. Further, JP2002-361399A discloses a preferable content of each element, which highly contributes to improvement in die-castability and mechanical strength.

Experiment 2

[0045] Plural aluminum alloy members containing the composition of the specimen No. 1, in which copper is not substantially contained as the additive element, were prepared. The plural aluminum alloy members were processed being applied with each compression ratio during the forging process, which was designed independently, as summarized in Table 3. The process apart from the forging process, which is applied to each aluminum alloy member, was substantially the same as Experiment 1. The aluminum casting forged product was cut way to form a tensile strength specimen 15 as illustrated in Fig. 6.

Table 3

	Forging Conditions	Mechanical Properties		
	Compression ratio	Tensile Strength (MPa)	0.2% Proof (MPa)	Elongation (%)
1	20	318.9	258.7	10.5
2	30	317.4	256	12.9
3	40	314.8	254	13.7
4	50	314.3	252.5	14.4
5	60	313	251.3	13.3
6	70	310.5	250.8	12.9

[0046] As summarized in Table 3, when the specimen 15 is forged by the compression ratio of approximately 30% or more, relatively high tensile strength and proof strength can be achieved, while elongation thereof can reach 11% or more. Therefore, this type of aluminum alloy member can be preferably used for a vehicle underbody (e.g., a chassis line). However, once the specimen 15 is forged by the compression ratio of 50% or more, the elongation property of the aluminum alloy member is saturated, thereby reducing the tensile strength and proof strength thereof. Therefore, when the aluminum alloy member, which substantially does not contain copper therein, is applied with the compression ratio during the forging process, it is preferable that the compression ratio be designed between approximately 30 and 50%.

Experiment 3

[0047] Plural aluminum alloy members containing the composition of the specimen No.1 were prepared. Aging treatment was applied to each aluminum alloy member for an aging time that was designed independently, as summarized in Table 4. During the forging process, each aluminum alloy was applied with the reduction in area of approximately 10% and the compression ratio of approximately 40%. During the aging treatment, each aluminum alloy member was exposed to the ambient air at approximately 160°C which is the same temperature as Experiment 1. The other conditions for obtaining the casing-forged product apart from the aging time are the same as Experiment 1. The aluminum alloy member obtained as described above was applied with the tensile strength test in the same manner as Experiment 2. The test result is summarized in Table 4 as follow.

Table 4

	Aging Treatment	Mechanical Properties		
	Aging Time (hr)	Tensile Strength (MPa)	0.2% Proof (MPa)	Elongation (%)
1	2	285.2	204.9	18.7
2	4	300.6	232.7	15
3	6	314.8	254	13.7
4	8	323.5	269.4	13.4
5	24	318.6	274.2	10.2

[0048] As summarized in Table 4, the aluminum alloy member, which had been applied with the aging treatment for the aging time ranging from 6 to 8 hours, exhibited excellent tensile strength and proof strength which is not inferior to an aluminum alloy member containing copper for the purpose of improvement in mechanical strength. Further, the aluminum alloy member applied with the aging treatment for the aging time ranging from 6 to 8 hours exhibited the elongation of 11% or more. On the other hand, when the aging time was less than 6 hours, the sufficient tensile strength and proof strength could not be achieved. When the aging time exceeded 8 hours, the sufficient elongation of 11% or more could not be achieved.

[0049] As described above, according to the embodiment of the present invention, an aluminum alloy product substantially not containing cupper added can be obtained, which has excellent mechanical properties such as mechanical strength and elongation, by hot-forging an aluminum alloy casting of which shape is approximated to a shape of a final product. The aluminum alloy product according to the embodiment of the present invention is characterized in containing silicon and magnesium at each limited content and not containing cupper as the additive element. Therefore, comparing with a conventional aluminum alloy product containing cupper for improvement in mechanical strength thereof, the aluminum alloy product according to the embodiment of the present invention can have improved corrosion resistance and mechanical strength while maintaining die-castability and forgeability at an appropriate level.

[0050] As described above, according to the embodiment of the present invention, the aluminum alloy product, i.e., the cast-forged product 5, can effectively have excellent mechanical properties and high corrosion resistance.

[0051] Further, according to the embodiment of the present invention, the method of manufacturing the aluminum alloy product can effectively contribute to obtaining the aluminum alloy product having sufficiently good mechanical strength even if the aluminum alloy product does not actively contain copper therein. More particularly, the aluminum alloy product can be manufactured having sufficiently improved mechanical properties such as a mechanical strength by defining the compression ratio within a range between 30 and 50% even if copper is not actively added to the aluminum alloy product.

[0052] According to a general concept, the mechanical properties such as tensile strength and elongation are enhanced in response to an increase of the compression ratio. However, after studying some experiments according to the embodiment of the present invention regarding the aluminum alloy product does not contain copper as an additive element, it was confirmed that the improvement in mechanical properties such as tensile strength and elongation be stopped when the compression ratio exceeds 50%. What is worse, it was confirmed that there was a case that those mechanical properties be deteriorated when the compression ratio exceeds 50%. Namely, the forging contributes to reduce shrinkage and pinhole generated in a structure of the aluminum alloy product, thereby improving the mechanical properties in accordance with a higher structure precision. However, once the compression ratio exceeds 50%, a degree of orientation of the composition of the aluminum alloy product becomes too strong, thereby undesirably yielding the deterioration of the mechanical property such as tensile strength. When the approximately shaped casting is applied with the compression ratio at 50%, it means that the thickness of the approximately shaped casting before being forged is reduced 50% after being forged.

[0053] On the other hand, when the compression ratio is less than 30%, the elongation of the aluminum alloy product cannot be maintained at a sufficient level. When the aluminum alloy product is used for a vehicle suspension part for example, it is preferable that the elongation thereof be 11% or more. When the compression ratio is designed to be 30% or more, the elongation of the aluminum alloy product can be maintained at a preferable range at 11% or more.

[0054] Further, the method of manufacturing the aluminum alloy product according to the embodiment of the present invention can effectively contribute to manufacturing the aluminum alloy product having excellent mechanical properties and high corrosion resistance.

[0055] Still further, in order to improve the mechanical strength of the aluminum alloy product, it is preferable that the aluminum alloy product is cooled down after the solution heat treatment, and is applied with the aging treatment. The conditions for the aging treatment are a temperature ranged between 155 and 165°C and an aging time ranged between 6 and 8 hours. When the temperature is less than 155°C, the mechanical property is deteriorated. When the temperature exceeds 165°C, the precipitation is not sufficiently performed and so sufficient elongation is not achieved. When the aging time is less than 6 hours, the precipitation is not sufficiently performed and so enough mechanical strength is not achieved. When the aging time exceeds 8 hours, the improvement in the strength of the aluminum alloy product is saturated, thereby rapidly reducing the elongation.

An aluminum alloy product includes additive elements of 3.0 to 4.2wt% of silicon, 0.4 to 0.6wt% of magnesium, 0.2wt% or less of iron, and 0.5wt% or less in total of zinc, manganese, nickel, tin and chromium. The additive element substantially excludes copper. The aluminum alloy product is formed by forging a casting of which shape is approximated to a shape of a final product.

Claims

1. An aluminum alloy product formed by forging a casting of which shape is approximated to a shape of a final product **characterized in that** the aluminum alloy product comprises additive elements of 3.0 to 4.2wt% of silicon, 0.4 to 0.6wt% of magnesium, 0.2wt% or less of iron, and 0.5wt% or less in total of zinc, manganese, nickel, tin and chromium, wherein the additive element substantially excludes copper.

2. An aluminum alloy product formed by forging a casting of which shape is approximated to a shape of a final product **characterized in that** the aluminum alloy product comprises 3.0 to 4.2wt% of silicon, 0.4 to 0.6wt% of magnesium, 0.2wt% or less of iron, and 0.5wt% or less in total of zinc, manganese, nickel, tin and chromium, wherein a balance of the aluminum alloy product is aluminum.

3. An aluminum alloy product according to claim 1 or 2, wherein the aluminum alloy product contains 0.02wt% or less copper as an unavoidable impurity.

4. An aluminum alloy product according to claim 1 or 2, wherein the aluminum alloy product contains 0.01wt% or less copper as an unavoidable impurity.

5. An aluminum alloy product according to any preceding claim, wherein the aluminum alloy product is manufactured by hot-forging a casting of which shape is approximated to a shape of a final product with a compression ratio ranged between 30 and 50%.

6. An aluminum alloy product according to any preceding claim, wherein the aluminum alloy product is cooled down after a solution heat treatment, and is applied with an aging treatment at a temperature ranged between 155 and 165°C for an aging time ranged between 6 and 8 hours.

7. An aluminum alloy product according to any preceding claim, wherein the aluminum alloy product is used for a vehicle suspension part.

8. A method of manufacturing an aluminum alloy product **characterized in that** the method comprising the steps of:

casting an aluminum alloy material to obtain an aluminum alloy casting of which shape is approximated to a shape of a final product; and
hot-forging the casting with a compression ratio ranged between 30 and 50%, wherein the aluminum alloy material includes additive elements of 3.0 to 4.2wt% of silicon, 0.4 to 0.6wt% of magnesium, 0.2wt% or less of iron, and 0.5wt% or less in total of zinc, manganese, nickel, tin and chromium, the additive element substantially excludes copper.

9. A method of manufacturing an aluminum alloy product according to claim 8 further comprising;

cooling down the aluminum alloy product after a solution heat treatment, and
applying an aging treatment to the aluminum alloy product at a temperature ranged between 155 and 165°C for an aging time ranged between 6 and 8 hours.

10. A method of manufacturing an aluminum alloy product according to claim 8 or 9, wherein the aluminum alloy product contains 0.02wt% or less copper as an unavoidable impurity.

11. A method of manufacturing an aluminum alloy product according to claim 8 or 9, wherein the aluminum alloy product contains 0.01wt% or less copper as an unavoidable impurity.

12. A method of manufacturing an aluminum alloy product according to one of claims 8, 9, 10 and 11, wherein the aluminum alloy product is used for a vehicle suspension part.

FIG. 1

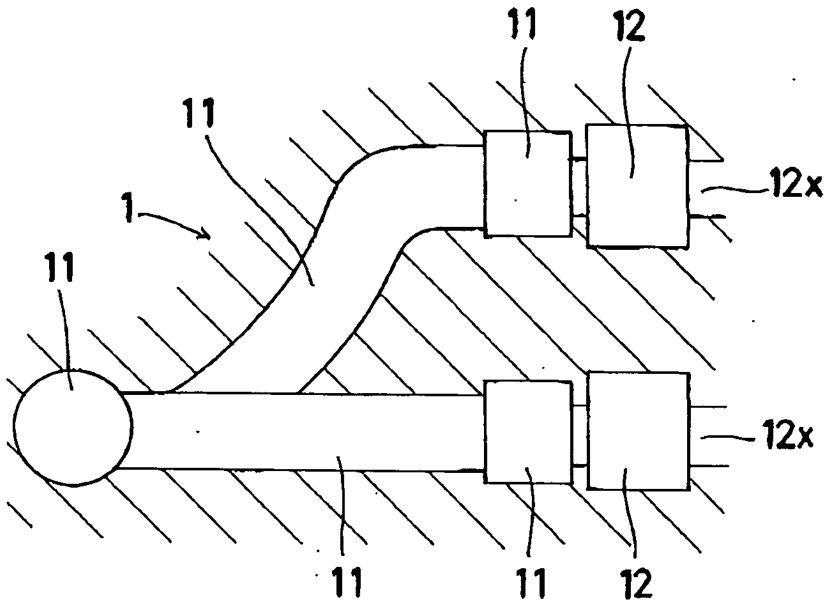


FIG. 2

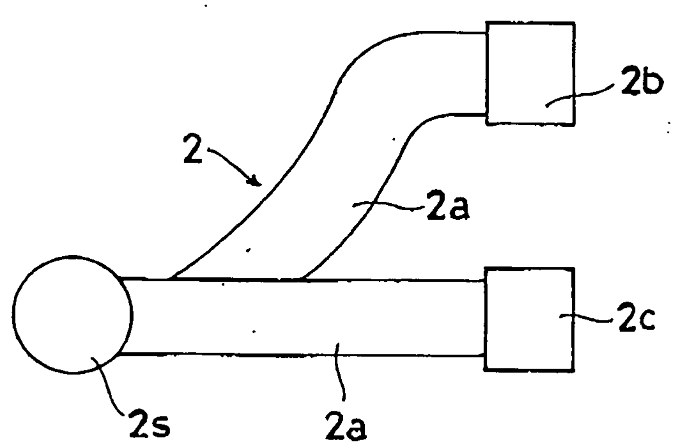
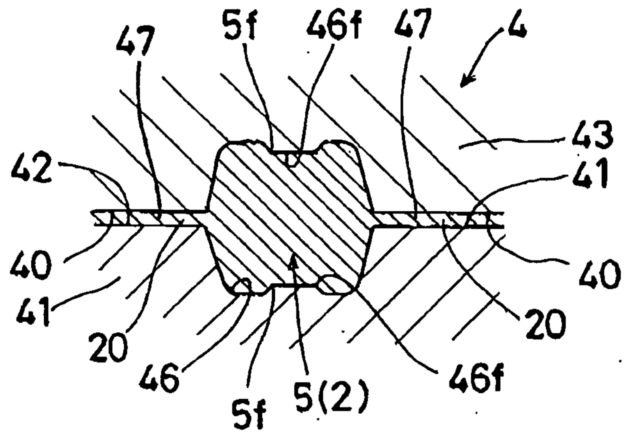


FIG. 3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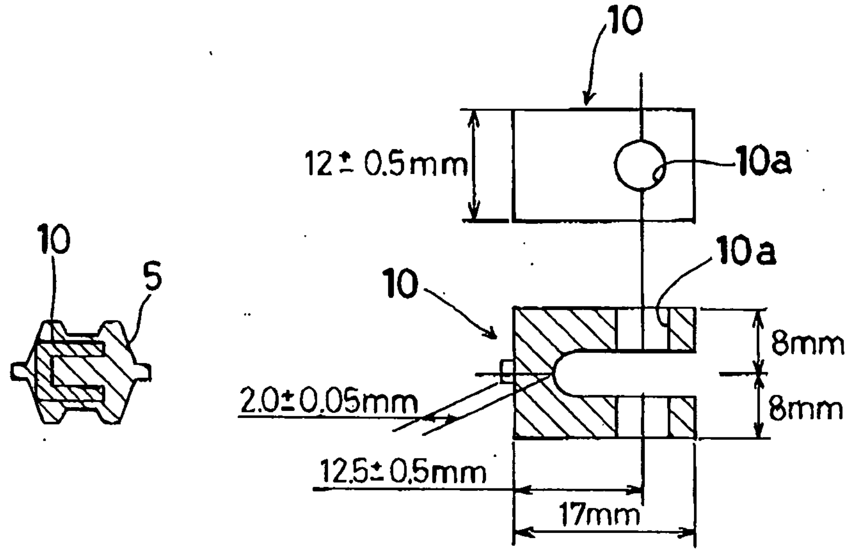
5(2)
46f

FIG. 4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10
5
10a
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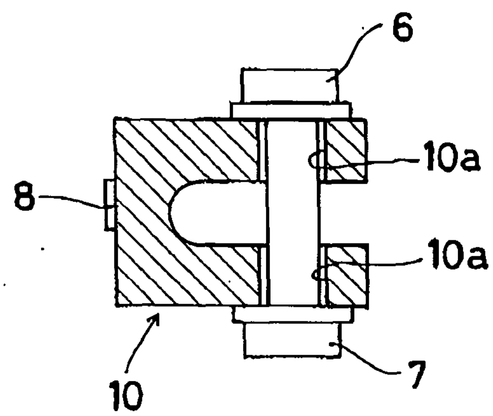
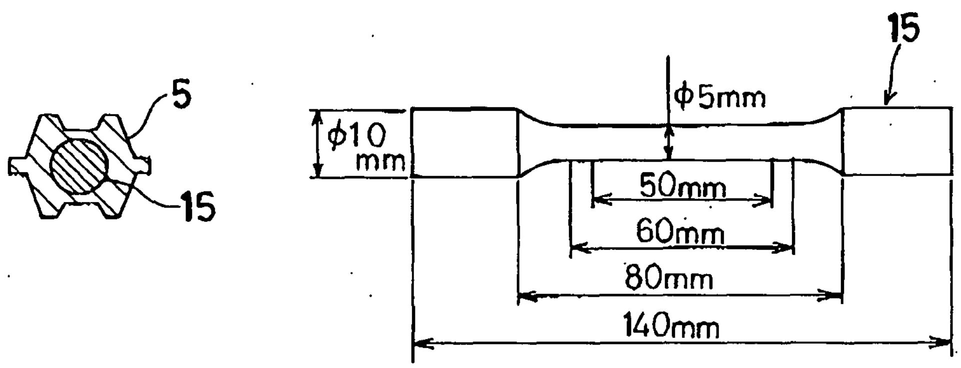
8mm
8mm
2.0±0.05mm
12.5±0.5mm
17mm

F I G. 5



F I G. 6



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EUROPEAN SEARCH REPORT

Application Number
EP 04 02 5523

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	4 January 2005	Patton, G

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3

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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
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