



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
12.10.2022 Bulletin 2022/41

(51) International Patent Classification (IPC):
C22C 23/02 ^(2006.01) **C22F 1/06** ^(2006.01)
B64C 1/00 ^(2006.01)

(21) Application number: **21209865.1**

(52) Cooperative Patent Classification (CPC):
C22C 23/02; C22F 1/06

(22) Date of filing: **23.11.2021**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(30) Priority: **09.04.2021 JP 2021066471**

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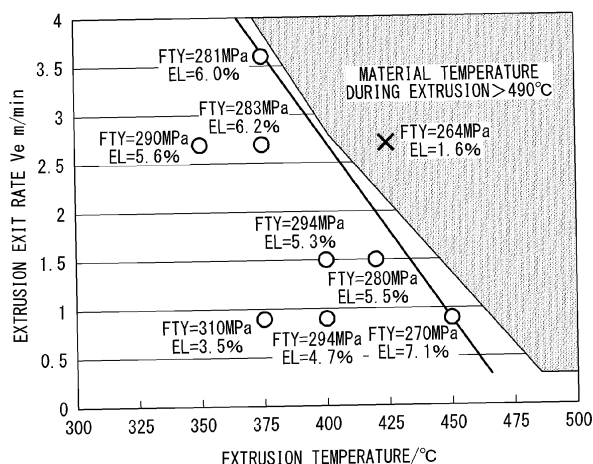
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(54) **MANUFACTURING METHOD OF AIRCRAFT MEMBER**

(57) The present disclosure intends to provide a manufacturing method that enables stable acquisition of a magnesium alloy member having both good strength and ductility regardless of a billet size. A manufacturing method of an aircraft member according to the present disclosure is a manufacturing method of an aircraft member to perform extrusion processing by using an Mg-Al-Ca based alloy containing (Mg, Al)₂Ca compound,

and the manufacturing method includes: selecting a billet of an Mg-Al-Ca based alloy containing Al: greater than or equal to 6 atom% and less than or equal to 8 atom% and Ca: greater than or equal to 3 atom% and less than or equal to 4 atom% with respect to the whole amount; and extruding the billet under a condition where a temperature of the billet is maintained to be lower than a melting temperature of the (Mg, Al)₂Ca.

FIG. 1



Description

BACKGROUND OF THE INVENTION

5 1. FIELD OF THE INVENTION

[0001] The present disclosure relates to a manufacturing method of an aircraft member, in particular, a manufacturing method of a secondary structure member of an aircraft.

10 2. DESCRIPTION OF RELATED ART

[0002] Due to a recent demand for improvement of fuel efficiency, there is a growing need in civil aircrafts to reduce the weight of an airframe. While an aluminum alloy is used for main structure members (fuselage outer plates or the like) of conventional civil aircrafts, increase of strength of an aluminum alloy member has reached its limit, which requires a raw material having much higher specific strength.

[0003] In such a situation, composite materials have been applied to the airframe main structure in recent years. However, this requires high manufacturing cost, long manufacturing lead time, high assembly cost, or the like.

[0004] To solve these problems, research of a magnesium alloy is in progress. The magnesium alloy needs substantially the same manufacturing cost as an aluminum alloy and has specific strength greater than or equal to the aluminum alloy (see Japanese Patent Laid-Open No. 2008-536013, Japanese Patent Laid-Open No. 2010-209452).

[0005] A magnesium alloy is an active metal and thus requires anti-corrosion treatment. In Japanese Patent Laid-Open No. 2008-536013, a non-chromate conversion coating is formed on the surface of the magnesium alloy to improve corrosion resistance. On the other hand, Japanese Patent Laid-Open No. 2010-209452 discloses a magnesium alloy member having high corrosion resistance that does not require anti-corrosion treatment by defining the number and the size of fine precipitates containing both Mg and Al that are present in a surface layer region.

[0006] Japanese Patent Application Laid-Open No. 2008-536013 and Japanese Patent Application Laid-Open No. 2010-209452 are examples of the related art.

[0007] In addition to corrosion resistance, a material applied to an aircraft member is required to balance strength (tensile strength) and ductility (elongation). Magnesium alloys have lower strength than aluminum alloys. Thus, it is required to improve the strength, but the strength of magnesium alloy is in a trade-off relationship with ductility, and it is difficult to balance the strength and the ductility.

[0008] Further, to apply a magnesium alloy to an aircraft member, it is required to improve incombustibility to increase an ignition temperature.

[0009] As disclosed in Japanese Patent Laid-Open No. 2010-209452, a magnesium alloy member is manufactured by using a billet casted by using an ingot made of a magnesium alloy.

[0010] Use of a somewhat large billet is desirable for manufacturing of a large-sized aircraft member. However, the larger diameter of the billet is more likely to cause an uneven quality as a whole billet. Such unevenness in quality may become a factor that affects strength and ductility of the magnesium alloy member.

[0011] The crystal grain diameter and the microstructure of a magnesium alloy are varied depending on processing conditions, and then the strength and the ductility of magnesium alloy are varied.

BRIEF SUMMARY OF THE INVENTION

[0012] Fig. 5 illustrates a metallographic structure photograph of an Mg-Al-Ca-Si based alloy as an example. As illustrated in Fig. 5, α -Mg (Al, Ca being dissolved into a solid solution), an Mg-Si-Ca compound, an $(\text{Mg}, \text{Al})_2\text{Ca}$ compound (C36), and the like are included in the metallographic structure. Fig. 6 illustrates a metallographic structure photograph of an Mg-Si-Ca compound. Fig. 7 illustrates a metallographic structure photograph of an $(\text{Mg}, \text{Al})_2\text{Ca}$ compound.

[0013] According to studies by the present inventors, it has been found that, when an intermetallic compound such as an Mg-Si-Ca compound and an $(\text{Mg}, \text{Al})_2\text{Ca}$ compound is coarsened, the ductility tends to decrease. When the billet is larger, an $(\text{Mg}, \text{Al})_2\text{Ca}$ compound is more likely to be coarsened.

[0014] In a small billet, addition of Si to a magnesium alloy may improve the ductility. However, according to studies by the present inventors, it has been found that ductility decreases in a somewhat large billet.

[0015] The present disclosure has been made in view of the above problems and intends to provide a manufacturing method that enables stable acquisition of a magnesium alloy member having both good strength and ductility regardless of a billet size.

[0016] To solve the above problems, the manufacturing method of an aircraft member of the present disclosure employs the following measures.

[0017] The present disclosure provides a manufacturing method of an aircraft member to perform extrusion processing

by using an Mg-Al-Ca based alloy containing (Mg, Al)₂Ca compound, and the manufacturing method of an aircraft member includes: selecting a billet of an Mg-Al-Ca based alloy containing Al: greater than or equal to 6 atom% and less than or equal to 8 atom% and Ca: greater than or equal to 3 atom% and less than or equal to 4 atom% with respect to the whole amount; and extruding the billet under a condition where a temperature of the billet is maintained to be lower

than a melting temperature of the (Mg, Al)₂Ca.
[0018] According to the manufacturing method of the present disclosure, a billet whose Al content and Ca content are within the above range is used, and extrusion processing conditions are optimized, so that an aircraft member having both good strength and ductility can be obtained more stably than in the conventional methods. Further, according to the manufacturing method of the present disclosure, an aircraft member that meets required incombustibility can be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

Fig. 1 is a diagram illustrating a relationship of extrusion conditions, tensile strength (FTY), and ductility (elongation/EL).

Fig. 2 is a diagram illustrating a range of preferable extrusion processing conditions.

Fig. 3 is a diagram illustrating a relationship of contents of Al and Ca, extrusion conditions, tensile strength (FTY), and ductility (elongation/EL).

Fig. 4 is a diagram illustrating a result of a corrosion test.

Fig. 5 is a metallographic structure photograph of an Mg-Al-Ca-Si based alloy as one example.

Fig. 6 is a metallographic structure photograph of an Mg-Si-Ca compound.

Fig. 7 is a metallographic structure photograph of an (Mg, Al)₂Ca compound.

DETAILED DESCRIPTION OF THE INVENTION

[0020] A manufacturing method according to the present disclosure is suitable for manufacturing a secondary structure member for an aircraft. The secondary structure member is a member installed in a primary structure member such as a stringer. The secondary structure member is a clip, a bracket, a metal fitting used for fastening pipes, a seat frame, or the like. The secondary structure member is not loaded as heavily as the primary structure member.

[0021] One embodiment of a manufacturing method of an aircraft member according to the present disclosure will be described below with reference to the drawings.

[0022] In the present embodiment, an aircraft member is extruded by using an Mg-Al-Ca based alloy billet including an (Mg, Al)₂Ca compound (hereinafter, (Mg, Al)₂Ca). The extrusion processing is performed under a condition where the billet temperature is maintained to be lower than a melting temperature of the (Mg, Al)₂Ca compound. In the extruded aircraft member (extruded material), (Mg, Al)₂Ca is dispersed in a metallographic structure.

[0023] The above Mg-Al-Ca based alloy (billet) is a casting manufactured by melt casting. The cooling rate during billet casting is lower than or equal to 1000 K/sec, preferably, lower than or equal to 100 K/sec.

[0024] The diameter of the billet is greater than or equal to 29 mm and less than or equal to 180 mm. The diameter of the billet may be greater than or equal to 69 mm.

[0025] For the billet, an Mg-Al-Ca based alloy containing Al of greater than or equal to 6 atom% and less than or equal to 8 atom% and Ca of greater than or equal to 3 atom% and less than or equal to 4 atom% with respect to the whole amount is selected.

[0026] The Mg-Al-Ca based alloy (billet) may contain Mn of greater than 0 atom% and less than or equal to 0.3 atom%, preferably, greater than or equal to 0.01 and less than or equal to 0.05.

[0027] The remaining part of the Mg-Al-Ca based alloy (billet) is made of Mg. This not only means that the whole remaining part is made of Mg but also indicates that the remaining part may include impurities or other elements to the extent that does not affect the alloy characteristics.

[0028] The Mg-Al-Ca based alloy (billet) does not contain Si. This not only means that the Si content is 0 atom% but also indicates that Si may be unavoidably contained (for example, less than or equal to 0.1 atom%).

[0029] The above Mg-Al-Ca based alloy (billet) contains an (Mg, Al)₂Ca compound. In the Mg-Al-Ca based alloy, (Mg, Al)₂Ca may be contained by preferably greater than or equal to 10 volume% and less than or equal to 35 volume%, more preferably, greater than or equal to 10 volume% and less than or equal to 30 volume%.

[0030] The melting temperature of (Mg, Al)₂Ca is 490 degrees Celsius. The melting temperature is derived from a phase diagram.

[0031] The billet temperature during extrusion processing may be maintained to be lower than the melting temperature by setting an extrusion temperature and an extrusion exit rate. The "extrusion exit rate" is a rate at which a material is

extruded from an extrusion mold (die) during extrusion molding.

[0032] A extrusion ratio may be higher than or equal to 10 and lower than or equal to 80.

[0033] The cross section of the extruded material may be an L-shape, a T-shape, or a Z-shape, for example.

[0034] The billet of the Mg-Al-Ca based alloy may be heat-treated at a temperature higher than or equal to 400 degrees Celsius and lower than or equal to 500 degrees Celsius for a period longer than or equal to one hour and shorter than or equal to six hours before extrusion processing. The processing temperature is preferably higher than or equal to 450 degrees Celsius and lower than or equal to 500 degrees Celsius. More desirably, the processing time is made shorter, which is about one hour.

[Extrusion Temperature and Extrusion Exit Rate]

[0035] Billets were extruded under predetermined conditions, and the tensile strength (FTY) and the ductility (elongation/EL) of the obtained extruded material were measured.

[0036] An Mg-Al-Ca based alloy ($\Phi 69$ mm) containing Al: 8 atom%, Ca: 4 atom%, and Mn: 0.015 atom% was used for the billet. The extrusion ratio was 15.

[0037] Fig. 1 and Table 1 illustrate measurement results. In Fig. 1, the horizontal axis (x-axis) represents an extrusion temperature (degrees Celsius), the vertical axis (y-axis) represents an extrusion exit rate V_e (m/min), and a solid line is a straight line ($y = -0.036x + 17.1$) that connects a circle (O) plot (x: 375 degrees Celsius, y: 3.6 m/min) to a circle plot (x: 450 degrees Celsius, y: 0.9 m/min). In the graph of the x-y coordinate system of Fig. 1, a colored portion on the right side of the above-described straight line in the sheet is a region of conditions where the material temperature during extrusion (billet temperature) exceeds 490 degrees Celsius.

Table 1

Extrusion material No.	Extrusion condition		Tensile strength (MPa)	Ductility (%)
	Extrusion temperature (°C)	Extrusion exit rate (m/min)		
1	350	2.7	290	5.6
2	375	3.6	281	6.0
3	400	2.7	283	6.2
4		0.9	310	3.5
5		1.5	294	5.3
6		0.9	294	4.7
7	420	1.5	280	5.5
8	425	2.7	264	1.6
9	450	0.9	270	7.1

[0038] According to Fig. 1 and Table 1, the extruded material (a cross (X) plot /extruded material No. 8) extruded under a condition where the billet temperature exceeds 490 degrees Celsius (the billet being melted) had tensile strength of 264 MPa and ductility of 1.6%. On the other hand, all the extruded materials (circle plots /extruded materials No. 1 to 7, 9) extruded under a condition of a billet temperature at which no melting occurs (the temperature being maintained to be lower than the billet melting temperature) had tensile strength greater than or equal to 270 MPa and ductility greater than or equal to 3%.

[0039] It was suggested from the above results that an extruded material having both good tensile strength and ductility can be obtained when extrusion processing is performed under conditions (an extrusion temperature and an extrusion exit rate) where the billet is not melted.

[0040] Fig. 2 illustrates a range of preferable extrusion processing conditions suggested from the result of Fig. 1. In Fig. 2, the horizontal axis (x-axis) represents an extrusion temperature (degrees Celsius), the vertical axis (y-axis) represents an extrusion exit rate V_e (m/min), a solid line is a straight line ($y = -0.036x + 17.1$) connecting a circle plot (x: 375 degrees Celsius, y: 3.6 m/min) to a circle plot (x: 450 degrees Celsius, y: 0.9 m/min), a long dashed double-short dashed line represents a preferable range, and a shaded portion between the solid line and the long dashed double-short dashed line is a region that represents a more preferable range. In the graph of the x-y coordinate system of Fig. 2, a colored portion on the right side of the above-described straight line in the sheet is a region of conditions where the

material temperature during extrusion (billet temperature) exceeds 490 degrees Celsius.

[0041] With respect to a straight line connecting a first plot (x: 375 degrees Celsius, y: 3.6 m/min) to a second plot (x: 450 degrees Celsius, y: 0.9 m/min) in a graph of the x-y coordinate system where the x-axis represents the extrusion temperature (degrees Celsius) and the y-axis represents the extrusion exit rate (m/min), it is preferable to select an extrusion temperature and an extrusion exit rate from values on the straight line or a range in which x and y are smaller than values on the straight line.

[0042] It is practical that the extrusion temperature is higher than or equal to 350 degrees Celsius, and the extrusion exit rate is higher than or equal to 0.3 m/min. When the extrusion temperature is lower than 350 degrees Celsius, the fluidity of the billet is deteriorated, which makes extrusion difficult. When the extrusion exit rate is lower than 0.3 m/min, it becomes difficult to perform rate control of the extrusion apparatus.

[0043] Given the restriction in the performance of the extrusion apparatus, it is preferable to select an extrusion temperature and an extrusion exit rate from a range (including values on the straight line) surrounded by three straight lines of Equation (1) to Equation (3).

$$\text{Equation (1): } y = -0.036x + 17.1$$

$$\text{Equation (2): } x = 350$$

$$\text{Equation (3): } y = 0.3$$

[0044] According to Fig. 2, it was confirmed that, as long as the extrusion exit rate is within a range that is higher than or equal to 0.9 m/min and lower than or equal to 3.6 m/min, an extruded material having both good tensile strength and ductility can be more reliably obtained. Accordingly, it is more desirable to select the extrusion temperature and the extrusion exit rate from a range (including values on the straight line) surrounded by four straight lines of Equation (1) to Equation (4).

$$\text{Equation (1): } y = -0.036x + 17.1$$

$$\text{Equation (2): } x = 350$$

$$\text{Equation (3'): } y = 0.9$$

$$\text{Equation (4): } y = 3.6$$

[0045] As a reference, Fig. 3 and Table 2 illustrate results obtained by measuring the tensile strength (FTY) and the ductility (elongation/EL) of extruded materials obtained by performing extrusion processing by using billets whose Al and Ca contents are larger than values of the range defined in the present embodiment.

[0046] An Mg-Al-Ca based alloy ($\Phi 69\text{mm}$) containing Al: 10 atom%, Ca: 5 atom%, and Mn: 0.05 atom% was used for the billet. The extrusion ratio was 15.

Table 2

Extrusion material No.	Extrusion condition		Tensile strength (MPa)	Ductility (%)
	Extrusion temperature (°C)	Extrusion exit rate (m/min)		
10	400	2.7	299	1.9
11		1.4	309	2.3

[0047] It was confirmed that, in an extruded material obtained by using billets whose Al and Ca are out of the range

of the embodiment described above, there is a case where the ductility is significantly reduced even when the extrusion processing condition is within the range disclosed above.

[0048] It was suggested from the above results that it is required to select a billet of an Mg-Al-Ca based alloy containing Al: greater than or equal to 6 atom% and less than or equal to 8 atom% and Ca: greater than or equal to 3 atom% and less than or equal to 4 atom% with respect to the whole amount.

[Ignition Temperature]

[0049] Extruded materials No. 12 to 23 were heated by using a heater, and the temperatures at the time of ignition were measured. The extrusion ratio during extrusion processing was 15. The measurement results are illustrated in Table 3.

Table 3

Extruded material No.	Billet (φ69mm) Composition	Extrusion condition		Ignition temperature (°C)	
		Extrusion temperature (°C)	Extrusion exit rate (m/min)	Measurement result	Average
12	Mg-8Al-4Ca-0.015Mn	375	3.6	1033	1038
13				1062	
14				1020	
15	Mg-8Al-4Ca-0.015Mn	450	0.9	1036	1039
16				1049	
17				1032	
18	Mg-6Al-3Ca	400	0.9	1080	1077
19				1075	
20				1077	
21	Mg-6Al-3Ca-0.05Mn	400	0.9	1017	1061
22				1082	
23				1085	
Reference : Elektron 43				845	869
				865	
				898	

[0050] All the ignition temperatures of the extruded materials No. 12 to 23 were higher than or equal to 1000 degrees Celsius. On the other hand, the ignition temperature of a commercially available magnesium alloy (Elektron 43) was lower than 900 degrees Celsius. From these results, it is suggested that an extruded material (an aircraft member) having greater incombustibility than conventional materials can be manufactured by the method according to the embodiment described above.

[Corrosive Property]

[0051] Billets were extruded under predetermined conditions, and a corrosion test was performed on the obtained extruded materials (test plates, $n = 3$) in accordance with a method compliant with ATSM B117. More specifically, a rectangular-shaped test plate was leaned internally on a chamber and was continuously sprayed with salt water (5% NaCl) for 96 hours, a weight change of the test plate before and after being sprayed was measured, and a reduction in thickness (a corrosion rate with time) was calculated.

[0052] As a billet (ϕ 69 mm), Mg-10Al-5Ca, Mg-10Al-5Ca-0.015Mn, Mg-8Al-4Ca-0.015Mn, Elektron 43 (commercially available magnesium alloy), and 7075-T6 (commercially available aluminum alloy) were used. The extrusion ratio was 15.

[0053] Fig. 4 illustrates results of the corrosion test. In Fig. 4, the vertical axis represents a corrosion rate (mm/year), and a bar of each test piece represents an average value.

[0054] The corrosion rate (average) of Mg-10Al-5Ca was 0.75 mm/year. On the other hand, the corrosion rate (average)

of Mg-10Al-5Ca-0.015Mn was 0.125 mm/year. Accordingly, it was confirmed that the presence of Mn affects the corrosion rate. Similarly, the corrosion rate (average) of Mg-8Al-4Ca-0.015Mn containing Mn was also low such as 0.175 mm/year.

[0055] The corrosion rate (average) of Elektron 43 was 0.425 mm/year. It was confirmed that the Mg-Al-Ca based alloy containing Mn has a lower corrosion rate than Elektron 43.

[0056] The corrosion rate (average) of 7075-T6 was 0.15 mm/year. It was confirmed that the Mg-Al-Ca based alloy containing Mn has the same corrosion rate as 7075-T6.

[Supplementary Notes]

[0057] A refrigerant, a design method of the same, and a freezing machine filled with the refrigerant described in the above embodiment are understood as follows, for example.

[0058] The present disclosure relates to a manufacturing method of an aircraft member to perform extrusion processing by using an Mg-Al-Ca based alloy containing (Mg, Al)₂Ca. In the present disclosure, a billet of an Mg-Al-Ca based alloy containing Al: greater than or equal to 6 atom% and less than or equal to 8 atom% and Ca: greater than or equal to 3 atom% and less than or equal to 4 atom% with respect to the whole amount is selected, and the billet is extruded under a condition where the temperature of the billet is maintained to be lower than a melting temperature of the (Mg, Al)₂Ca. The melting temperature of (Mg, Al)₂Ca is 490 degrees Celsius.

[0059] The Mg-Al-Ca based alloy described above has less specific gravity than an aluminum alloy used in a conventional aircraft field. Therefore, the weight can be reduced by 10% or more as compared to an aluminum alloy member by processing such an Mg-Al-Ca based alloy into an aircraft member.

[0060] According to intensive studies by the present inventors, it has been found that elongation (ductility) is reduced due to start of melting of (Mg, Al)₂Ca in performing extrusion processing by using an Mg-Al-Ca based alloy containing (Mg, Al)₂Ca.

[0061] In the disclosure described above, when the extrusion processing is performed under a condition where (Mg, Al)₂Ca is not melted, a reduction in the ductility due to melting of (Mg, Al)₂Ca can be prevented.

[0062] (Mg, Al)₂Ca that is a C36 type compound is a hard compound. When (Mg, Al)₂Ca is dispersed in a metallographic structure, high strength and relatively large ductility can be obtained. The degree of dispersion of (Mg, Al)₂Ca may be greater than or equal to 1 piece/ μm^2 . It is preferable that (Mg, Al)₂Ca be fine (for example, less than or equal to 2 μm).

[0063] Addition of Ca can improve the incombustibility and the mechanical property of the extruded material (aircraft member). If the Ca content is excessively high, this makes it difficult to obtain a solidified state of the magnesium alloy, and extrusion processing becomes difficult. If the Ca content is excessively low, it is not possible to obtain sufficient incombustibility.

[0064] Addition of Al can improve the mechanical property and the corrosion resistance of the extruded material. If the Al content is excessively high, it is not possible to obtain sufficient strength. If the Al content is excessively low, it is not possible to obtain sufficient ductility.

[0065] Increased contents of Al and Ca contained in an Mg-Al-Ca based alloy may become a factor of coarsening (Mg, Al)₂Ca in a metallographic structure. If the (Mg, Al)₂Ca is coarsened, the ductility of the extruded material is likely to be reduced. With the contents of Al and Ca being within the range described above, this may result in an extruded material having desired ductility.

[0066] In one aspect of the disclosure described above, the condition is set by an extrusion temperature and an extrusion exit rate, and with respect to a straight line connecting a first plot (x: 375 degrees Celsius, y: 3.6 m/min) to a second plot (x: 450 degrees Celsius, y: 0.9 m/min) in a graph of the x-y coordinate system where the x-axis represents the extrusion temperature (degrees Celsius) and the y-axis represents the extrusion exit rate (m/min), the extrusion temperature and the extrusion exit rate may be selected from values on the straight line or a range in which x and y are smaller than values on the straight line.

[0067] In one aspect of the disclosure described above, the straight line is expressed by Equation (1): $y = -0.036x + 17.1$.

[0068] According to intensive studies by the present inventors, when the extrusion temperature and the extrusion exit rate are selected from the range described above, the temperature of the billet can be maintained to be lower than the melting temperature of the (Mg, Al)₂Ca during extrusion processing. Coordinates of the first plot and the second plot are obtained by actual measurement, which are highly reliable. Therefore, an extruded material having both good tensile strength and ductility can be more stably manufactured than in the conventional materials.

[0069] In one aspect of the disclosure described above, it is desirable that the extrusion temperature in the condition be higher than or equal to 350 degrees Celsius. If the extrusion temperature is excessively low, the fluidity of the billet is reduced, which makes the extrusion difficult.

[0070] Given the performance of the extrusion apparatus, in one aspect of the disclosure described above, it is desirable that the extrusion exit rate in the condition be higher than or equal to 0.3 m/min.

[0071] In one aspect of the disclosure described above, the extrusion temperature and the extrusion exit rate may be selected from a range surrounded by three straight lines of Equation (1), Equation (2): $x = 350$, and Equation (3): $y = 0.3$.

[0072] In one aspect of the disclosure described above, the extrusion temperature and the extrusion exit rate may be selected from a range surrounded by four straight lines of Equation (1), Equation (2): $x = 350$, Equation (3'): $y = 0.9$, and Equation (4): $y = 3.6$.

[0073] According to intensive studies by the present inventors, it is possible to more reliably obtain an extruded material having both good tensile strength and ductility by performing extrusion processing with values of x and y that are smaller than values on the straight line of (1): $y = -0.036x + 17.1$, at an extrusion temperature that is higher than or equal to 350 degrees Celsius, and at an extrusion exit rate that is higher than or equal to 0.9 m/min and lower than or equal to 3.6 m/min.

[0074] In one aspect of the disclosure described above, the Mg-Al-Ca based alloy may contain Mn of greater than 0 atom% and less than or equal to 0.3 atom%.

[0075] Mn has an effect of improving the corrosion resistance even with a small amount. On the other hand, the ductility of the extruded material is reduced in accordance with an increase in the addition amount. To balance good corrosion resistance and ductility, it is desirable to suppress the addition amount of Mn.

Claims

1. A manufacturing method of an aircraft member to perform extrusion processing by using an Mg-Al-Ca based alloy containing (Mg, Al)₂Ca compound, the manufacturing method comprising:

selecting a billet of an Mg-Al-Ca based alloy containing Al: greater than or equal to 6 atom% and less than or equal to 8 atom% and Ca: greater than or equal to 3 atom% and less than or equal to 4 atom% with respect to the whole amount; and

extruding the billet under a condition where a temperature of the billet is maintained to be lower than a melting temperature of the (Mg, Al)₂Ca.

2. The manufacturing method of an aircraft member according to claim 1,

wherein the condition is set by an extrusion temperature and an extrusion exit rate, and wherein with respect to a straight line connecting a first plot (x : 375 degrees Celsius, y : 3.6 m/min) to a second plot (x : 450 degrees Celsius, y : 0.9 m/min) in a graph of an x - y coordinate system where an x -axis represents the extrusion temperature (degrees Celsius) and a y -axis represents the extrusion exit rate (m/min), the extrusion temperature and the extrusion exit rate are selected from values on the straight line or a range in which x and y are smaller than values on the straight line.

3. The manufacturing method of an aircraft member according to claim 2, wherein the extrusion temperature in the condition is higher than or equal to 350 degrees Celsius.

4. The manufacturing method of an aircraft member according to claim 2 or claim 3, wherein the extrusion exit rate in the condition is higher than or equal to 0.3 m/min.

5. The manufacturing method of an aircraft member according to claim 2, wherein the straight line is expressed by Equation (1): $y = -0.036x + 17.1$.

6. The manufacturing method of an aircraft member according to claim 5, wherein the extrusion temperature and the extrusion exit rate are selected from a range surrounded by three straight lines of the Equation (1), Equation (2): $x = 350$, and Equation (3): $y = 0.3$.

7. The manufacturing method of an aircraft member according to claim 6, wherein the extrusion temperature and the extrusion exit rate are selected from a range surrounded by four straight lines of the Equation (1), Equation (2): $x = 350$, Equation (3'): $y = 0.9$, and Equation (4): $y = 3.6$.

8. The manufacturing method of an aircraft member according to any one of claims 1 to 7, wherein the Mg-Al-Ca based alloy contains Mn of greater than 0 atom% and less than or equal to 0.3 atom%.

FIG. 1

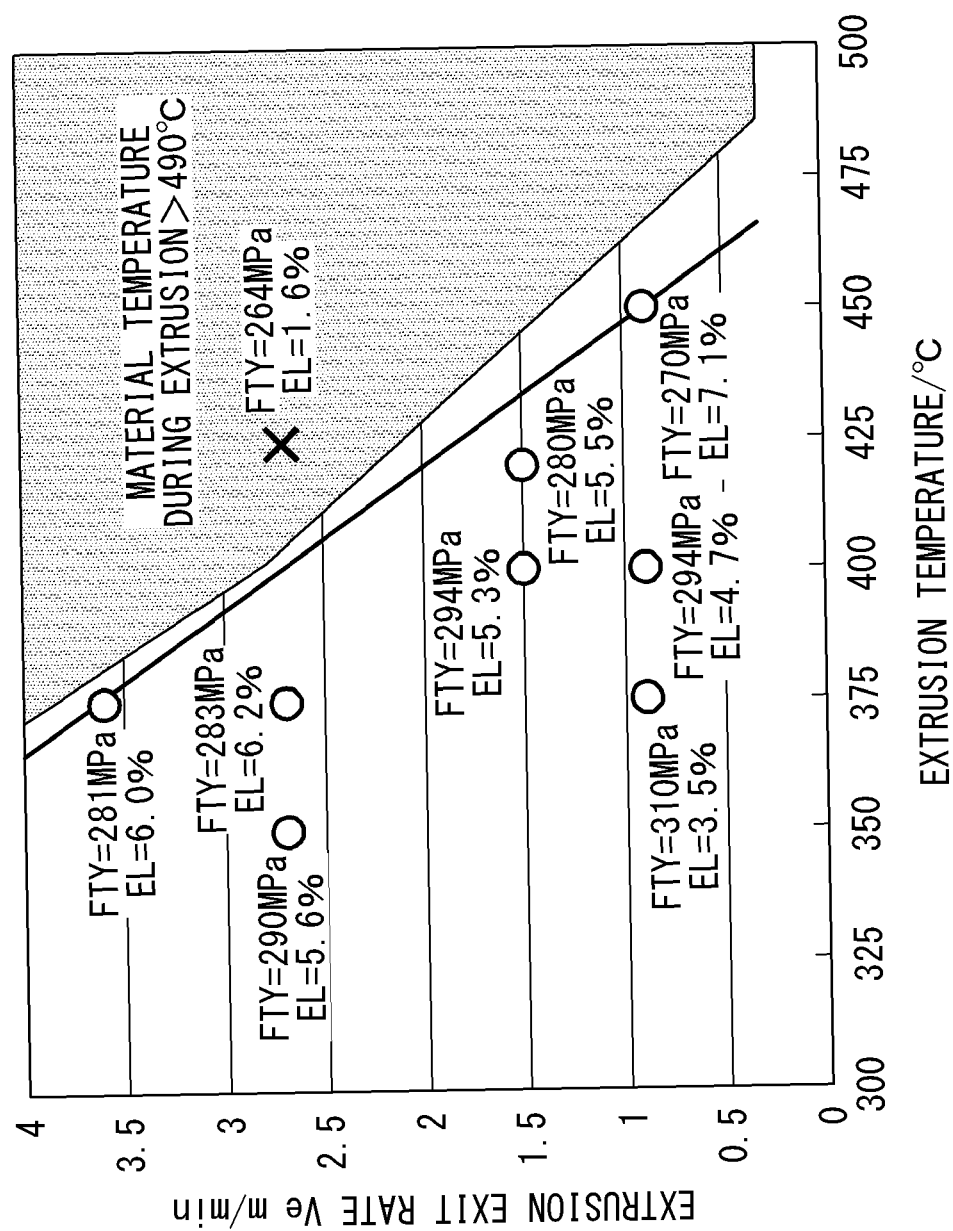


FIG. 2

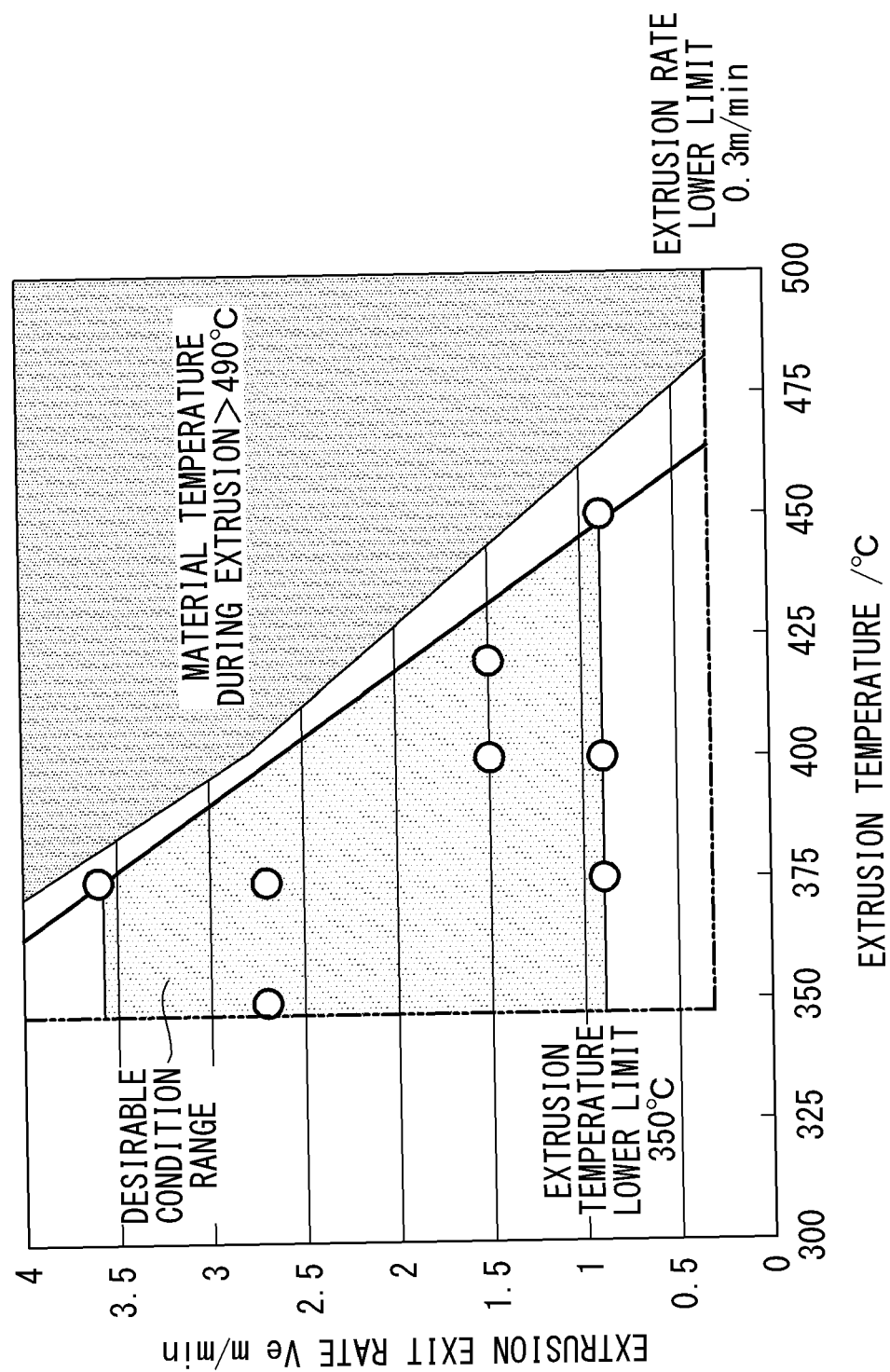


FIG. 3

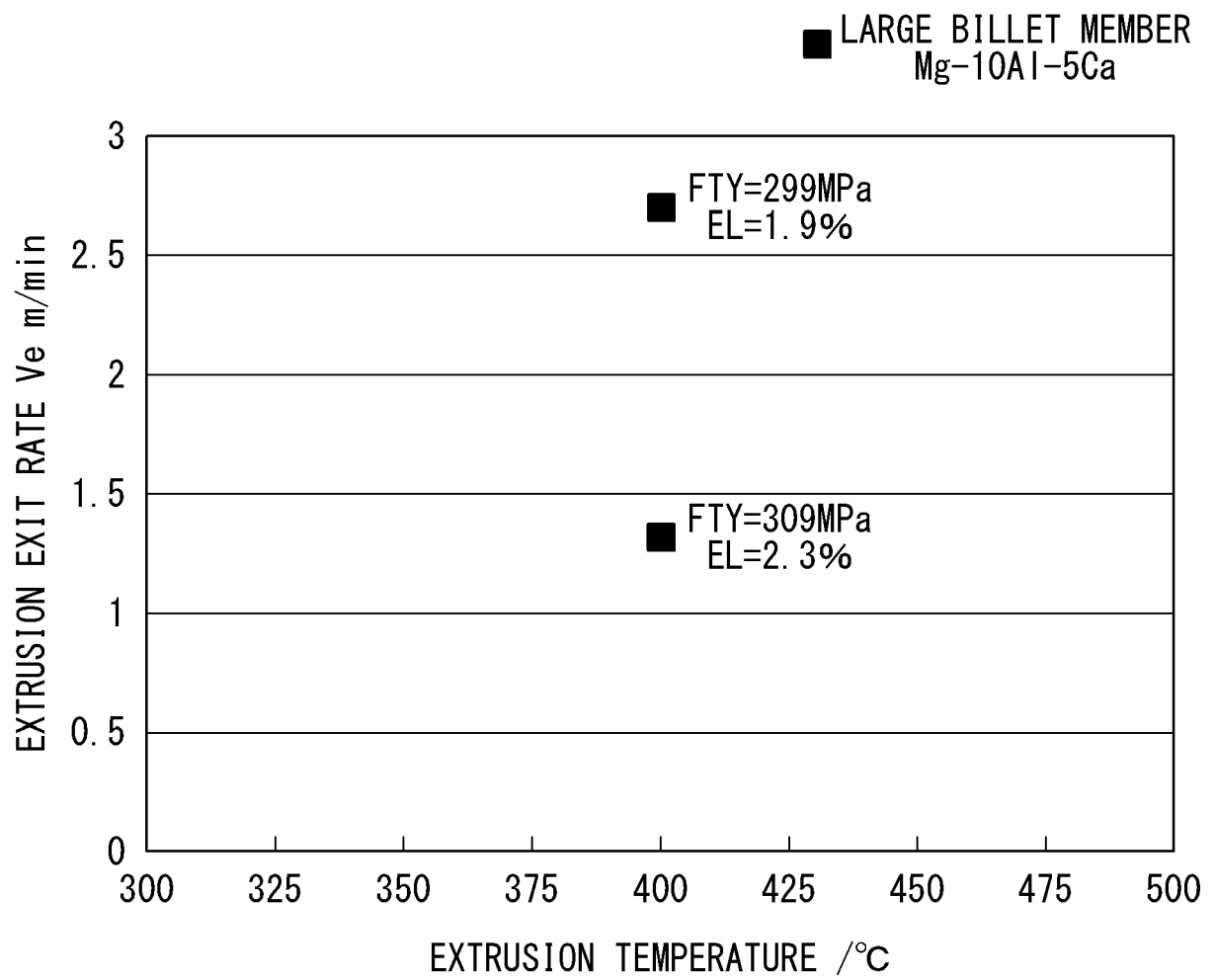


FIG. 4

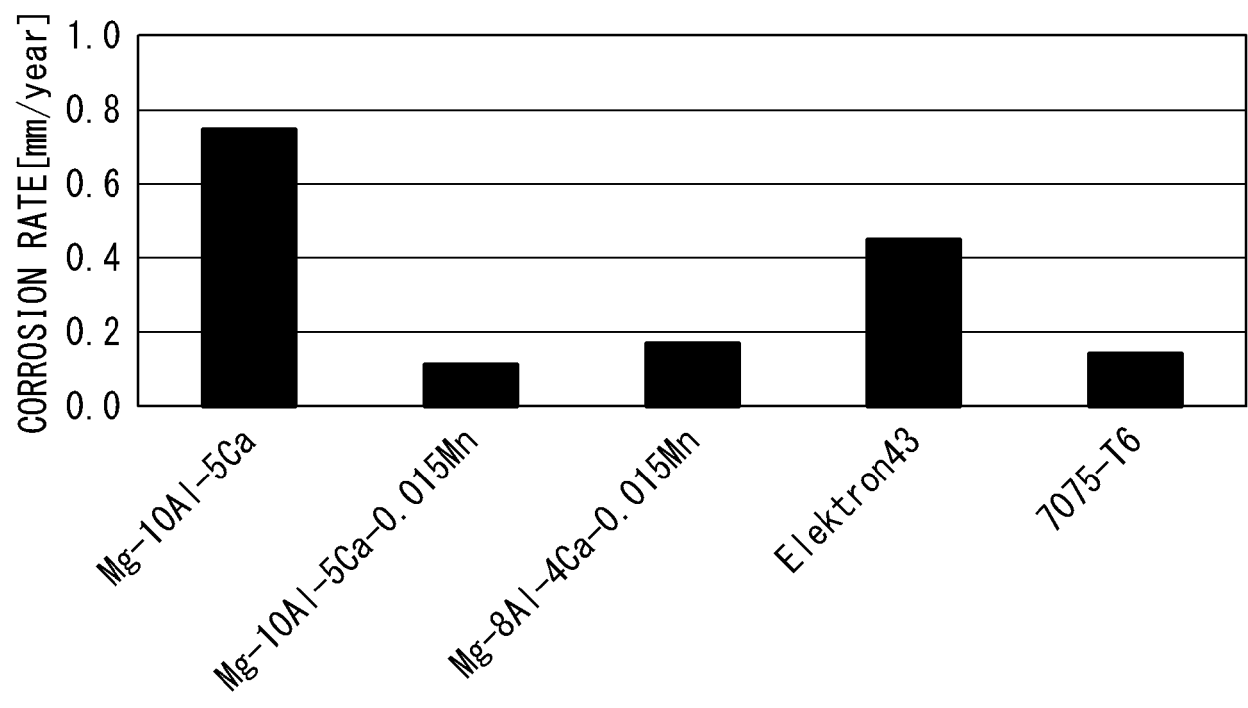
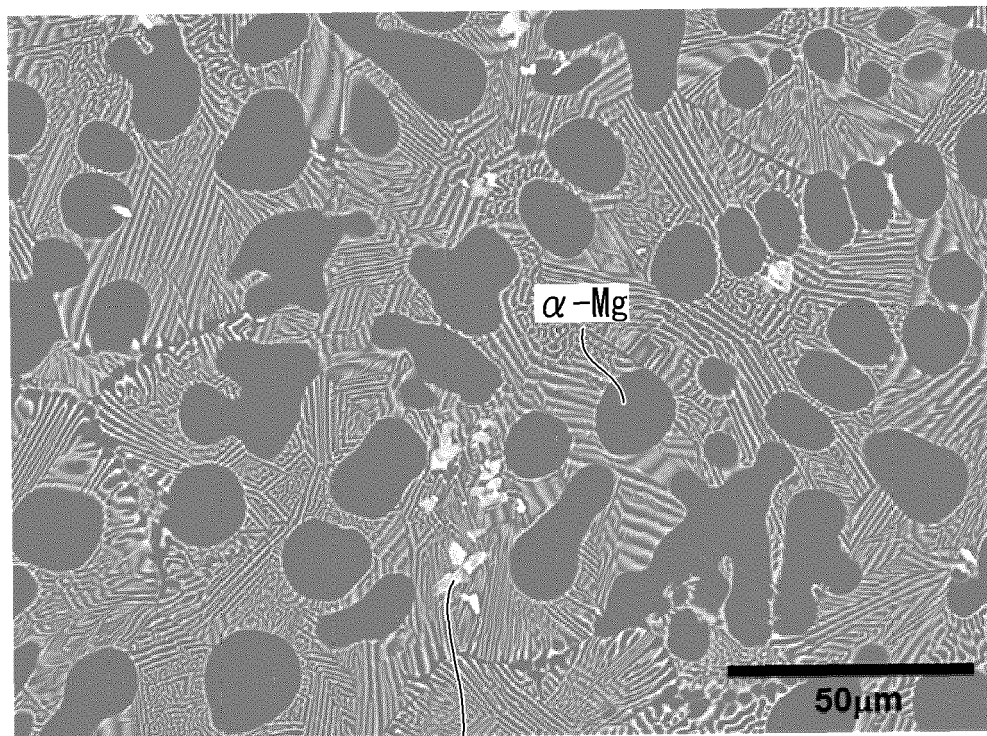


FIG. 5



Mg-Si-Ca COMPOUND

FIG. 6

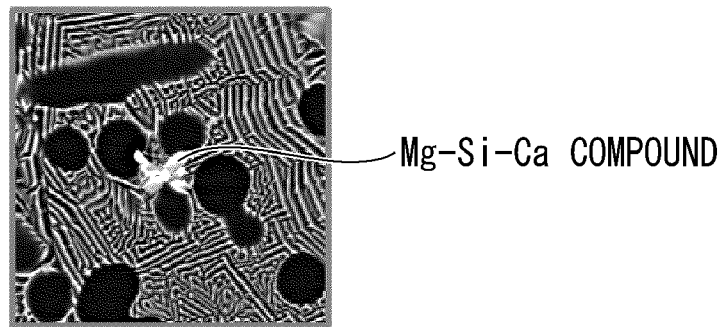
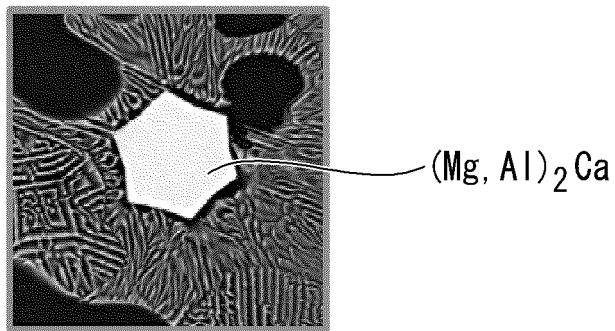


FIG. 7





EUROPEAN SEARCH REPORT

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Place of search Munich		Date of completion of the search 26 April 2022	Examiner Brown, Andrew
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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