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(71) Applicant: **YOSHIDA KOGYO K.K.**
No. 1 Kanda Izumi-cho Chiyoda-ku
Tokyo(JP)

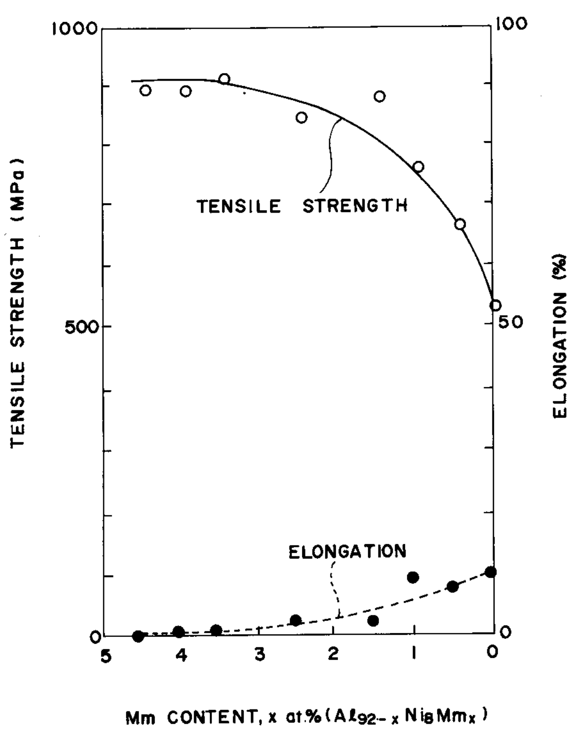
(72) Inventor: **Taketani, Katsuyuki**
4024, Mikkaichi
Kurobe-shi, Toyama(JP)
Inventor: **Nagahama, Hidenobu**
4018, Mikkaichi
Kurobe-shi, Toyama(JP)

(74) Representative: **Patentanwälte Leinweber & Zimmermann**
Rosental 7/II Aufg.
W-8000 München 2(DE)

(54) **Compacted and consolidated aluminium-based alloy material and production process thereof.**

(57) A compacted and consolidated aluminum-based alloy material is obtained by compacting and consolidating a quench-solidified material whose composition is represented by the general formula: $Al_aNi_bX_c$ wherein X is one or more elements selected from La and Ce or an Mm (mischmetal) and a, b and c are, in atom percent, $87.5 \leqq a \leqq 92.5$, $5 \leqq b \leqq 10$, and $0.5 \leqq c \leqq 2.5$. According to its production process, powder or flakes obtained by quench solidification are compacted, followed by compression, forming and consolidation by conventional plastic working. The consolidated material has elongation sufficient to withstand secondary working even when the secondary working is applied. Moreover, the material can retain excellent properties of its raw material as they are. The consolidated material having such advantages can be provided by the simple process.

FIG. 1



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BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a compacted and consolidated aluminum-based alloy material having not only high strength but also elongation sufficient to withstand practically-employed working, and also to a process for the production of the material.

2. Description of the Prior Art

Aluminum-based alloys having high strength and high heat resistance have been produced to date by liquid quenching or the like. In particular, the aluminum alloys disclosed in Japanese Patent Application Laid-Open (Kokai) No. 1 - 275732 and obtained by liquid quenching are amorphous or microcrystalline and are excellent alloys having high strength, high heat resistance and high corrosion resistance.

The aluminum-based alloys referred to above exhibit high strength, high heat resistance and high corrosion resistance and are excellent alloys. When they are each obtained in the form of powder or flakes by liquid quenching and the powder or flakes are then processed or worked as a raw material in one way or another to obtain a final product, in other words, the powder or flakes are converted into a final product by primary processing or working, they are excellent in processability or workability. However, to form the powder or flakes as a raw material into a consolidated material and then to work the consolidated material, namely, to subject the consolidated material to secondary working, there is still room for improvements in their workability and also in the retention of their excellent properties after the working.

SUMMARY OF THE INVENTION

An object of the present invention is, therefore, to provide a compacted and consolidated aluminum-based alloy material having a particular composition that permits easy working upon subjecting the material to secondary working (extrusion, machining or the like) and allows to retain excellent properties of the material even after the working.

The present invention provides a compacted and consolidated aluminum-based alloy material, which is characterized in that said material has been obtained by compacting and consolidating a quench-solidified material in the form of powder or flakes whose composition is represented by the general formula: $Al_aNi_bX_c$ wherein X is one or more elements selected from La and Ce or an Mm (mischmetal) and a, b and c satisfy the following equations by atom percent: $87.5 \leqq a \leqq 92.5$, $5 \leqq b \leqq 10$, and $0.5 \leqq c \leqq 2.5$. More preferably, a, b and c satisfy the following equations by atom percent: $89 \leqq a \leqq 91$, $7 \leqq b \leqq 10$, and $1 \leqq c \leqq 2$. Also more preferably, in the above consolidated material, the matrix is formed of aluminum or a supersaturated aluminum solid solution, whose average crystal grain size is 40 - 400 nm, grains made of a stable or metastable phase of various intermetallic compounds formed of the matrix element and the other alloying elements and/or of various intermetallic compounds formed of the other alloying elements are distributed evenly in the matrix, and the intermetallic compounds have an average grain size of 10 - 200 nm.

The present invention also provides a process characterized in that a material represented by the general formula is molten, then quenched and solidified into powder or flakes and, thereafter, the powder or flakes are compacted and then compressed, formed and consolidated by conventional plastic working. In this case, the powder or flakes as the raw material are required to be amorphous or microcrystalline such that the average crystal grain size of the matrix is 400 nm or less and the average grain size of intermetallic compounds is 200 nm or less or to be in a mixed phase thereof. When the raw material is amorphous, it can be converted into such a microcrystalline phase or mixed phase as defined above by heating it to 200 °C to 300 °C upon compaction.

The term "conventional plastic working" as used herein should be interpreted in a broad sense and should embrace pressure forming techniques and powder metallurgical techniques.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph showing variations in tensile strength and elongation among the consolidated materials in the example.

FIG. 2 is also a graph depicting variations in tensile strength and elongation at 200 °C among the consolidated materials in the example.

FIG. 3 is also a graph showing variations in tensile strength and elongation at 300 °C among the consolidated materials in the example.

FIG. 4 is a graph illustrating relationships between the content of Mm and the grain sizes of Al matrix and La_3Al_{11}.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The proportions a, b and c are limited by atom percent to the ranges of 87.5 - 92.5%, 5 - 10% and 0.5 - 2.5%, respectively, in the above general formula, because the alloys within the above ranges have higher strength than conventional (commercial) high-strength aluminum alloys over the temperature range of from room temperature to 200 ° C and are also equipped with ductility sufficient to withstand practically-employed working. The restriction of a, b and c to the more preferred ranges of 89 - 91%, 7 - 10% and 1 - 2%, respectively, leads to still greater ductility at room temperature while retaining the same advantageous effects as the ranges described above. This greater ductility permits hot or warm working at 400 ° C or lower, to say nothing of easy cold working. In the consolidated alloy material according to this invention, Ni is an element having relatively small ability to diffuse into the Al matrix. As it is contained together with element X, various stable or metastable, fine intermetallic compounds are formed and distributed as fine grains in the Al matrix. Ni is therefore effective not only in strengthening the matrix but also in inhibiting extraordinary coarsening of crystal grains. In other words, Ni improves the hardness and strength of the alloy to significant extent, stabilizes the microcrystalline phase at elevated temperatures, to say nothing of room temperature, and imparts heat resistance.

On the other hand, element X stands for one or more elements selected from La and Ce or Mm. It is an element having small ability to diffuse in the Al matrix. As it is contained together with element Ni, it forms stable intermetallic compounds, thereby contributing to the stabilization of the microcrystalline structure. Further, its combination with the above element can impart ductility required to apply conventional working. Incidentally, Mm is the common name for metal consisting of La and Ce as principal elements and, in addition, containing rare earth (lanthanoid) elements other than La and Ce described above and inevitable impurities (Si, Fe, Mg, Al, etc.). Mm can substitute for La and/or Ce at the ratio of approximately 1 to 1 (by atom percent) and is economical, whereby Mm has a substantial advantage in economy.

In the consolidated aluminum-based alloy material according to the present invention, the average crystalline grain size of the matrix is preferably in the range of 40 - 400 nm for the following reasons. Average crystalline grain sizes smaller than 40 nm are too small to provide sufficient ductility despite high strength. To obtain ductility required for conventional working, an average crystalline grain size of at least 40 nm is therefore desirable. If the average crystalline grain size exceeds 400 nm, on the other hand, the strength drops abruptly, thereby making it impossible to obtain a consolidated material having high strength. To obtain a consolidated material having high strength, an average crystalline grain size not greater than 400 nm is hence needed. Further, the average grain size of the intermetallic compounds is preferably in the range of 10 - 200 nm because intermetallic compounds with an average grain size outside the above range cannot serve as strengthening elements for the Al matrix. If the intermetallic compounds have an average grain size smaller than 10 nm, they do not contribute to the strengthening of the Al matrix and, if distributed in an amount greater than that needed, there is the potential problem of embrittlement. Average grain sizes exceeding 200 nm, on the other hand, result in unduly large grains distributed in the Al matrix so that the Al matrix cannot retain its strength and the intermetallic compounds cannot serve as strengthening elements. The restriction to the above ranges, therefore, provides great improvements in Young's modulus, high-temperature strength and fatigue strength.

In the consolidated aluminum-based alloy material according to the present invention, its average crystal grain size of the matrix and the average grain size of its intermetallic compounds can be controlled by choosing suitable conditions for its production. The average crystal grain size of the matrix and the average grain size of the intermetallic compounds should be controlled small where an importance is placed on the strength. In contrast, they should be controlled large where the ductility is considered important. In this manner, it is possible to obtain consolidated aluminum-based alloy materials which are suited for various purposes, respectively.

Further, the control of the average crystal grain size of the matrix to the range of 100 - 400 nm makes it possible to impart properties so that the resulting material can be used as an excellent superplastic working material.

The present invention will hereinafter be described specifically on the basis of the following examples.

Example

Aluminum-based alloy powder having a desired composition ($Al_{92-x}Ni_8Mm_x$) was produced by a gas atomizing apparatus. The aluminum-based alloy powder so produced was filled in a metal capsule and, while being degassed, was formed into an extrusion billet by vacuum hot-pressing. The billet was extruded at 200 - 550 ° C through an extruder. Mechanical properties (tensile strength and elongation) of the extruded material (consolidated material) obtained under the above production conditions are shown in FIG. 1.

As is depicted in FIG. 1, it is understood that the tensile strength of the consolidated material at room temperature abruptly dropped at Mm contents not greater than 1 at.%. In contrast, it is envisaged that the elongation sharply increased at Mm contents not greater than 2 at.%. It is also seen that the minimum elongation (2%) required for general working can be obtained at the Mm content of 2.5 at.%. Upon working a high-strength extruded material by cold working (i.e., by working it at a temperature close to room temperature), it is understood that the working is feasible at an Mm content of 1 - 2.5 at.%, preferably 1 - 2 at.%. For the sake of comparison, the tensile strength of a conventional, consolidated high-strength aluminum-based alloy material (an extruded material of duralumin) was also measured at room temperature. As a result, the tensile strength was found to be about 650 MPa. It is also understood from this value that the above consolidated material of the present invention is excellent in strength at the Mm content of 0.5 at.%.

The Young's moduli of consolidated materials obtained under the above production conditions were also investigated. The Young's moduli of the consolidated materials according to the present invention were as high as 8900 - 9300 kgf/mm^2 as opposed to about 7000 kg/mm^2 of the conventional high-strength Al alloy (duralumin). The consolidated materials according to the present invention therefore exhibit the advantages that their deflection and deformation are smaller under the same load.

With respect to extruded materials (consolidated materials) obtained under the above production conditions, their mechanical properties (tensile strength and elongation) were investigated at 200 °C after they were held at 200 °C for 100 hours. The results are diagrammatically shown in FIG. 2.

As is indicated in FIG. 2, it is understood that the tensile strength in the environment at 200 °C abruptly dropped at Mm contents not greater than 0.5 at.%. In contrast, the elongation remained at a large value over the entire range of Mm content. It is seen that the elongation increased at Mm contents not greater than 2.5 at.% and sharply jumped up at Mm contents not greater than 1.5 at.%. For the sake of comparison, the tensile strength of a conventional high-strength aluminum-based alloy material (an extruded material of duralumin) was also measured in an environment at 200 °C. As a result, its tensile strength was found to be above 200 MPa. From this value, it is understood that the consolidated materials according to the present invention are excellent in strength in an environment at 200 °C.

With respect to extruded materials (consolidated materials) obtained under the above production conditions, their mechanical properties (tensile strength and elongation) were also investigated at 300 °C after they were held at 300 °C for 100 hours. The results are diagrammatically illustrated in FIG. 3.

As is shown in FIG. 3, it is seen that the tensile strength in the environment at 300 °C gradually dropped as the content of Mm became smaller. In contrast, the elongation has a larger value than that measured in the environment at 200 °C over the entire range of Mm content. The elongation abruptly jumps up at Mm contents not greater than 2.5 at.%. Elongation as much as 30% or greater is indicated at an Mm content not greater than 2 at.%.

It is understood from FIG. 2 and FIG. 3 that, when a high-strength extruded material is worked by warm or hot working (at a temperature from room temperature to about 400 °C), more effective working is feasible at an Mm content in the range of 0.5 - 2.5 at.%. When the tensile strength and elongation are taken into consideration, the elongation abruptly jumps up in the Mm content range of 1 - 2 at.% although the strength does not drop a lot in the range. This Mm content range is therefore most suited for the working in the above temperature range.

Although the above experiment was conducted by setting the content of Ni at 8 at.%, similar results were also obtained in an Ni content range of from 5 at.% to 10 at.%. When the Ni content was 9 at.%, relatively good results were obtained in tensile strength and elongation even at an Mm content as small as about 1 at.%. When the Ni content was 7 at.%, good results were obtained at Mm contents not smaller than 2 at.%

As to the consolidated aluminum-based alloy materials of this invention shown in FIG. 1, their average crystal grain sizes of the matrix and the average grain sizes of their intermetallic compound were measured. The results are diagrammatically shown in FIG. 4. The measurement was conducted by TEM observation.

As shown in FIG. 4, the average crystal grain size of the Al matrix was found to range from 100 nm to 125 nm while the average grain size of the intermetallic compound (La_3Al_{11}) was found to range from 20 nm to 30 nm. It is now understood that the above good results at room temperature were obtained when the average crystal grain size of the matrix and the average grain size of the intermetallic compound fell within the above ranges, respectively. Needless to say, these sizes vary depending on the composition and also depending on whether the extruded material is held at 200 °C or 300 °C. In the latter temperature, especially, grains grow so that the average crystal grain size of the matrix and the average grain size of the intermetallic compound become greater.

Consolidated aluminum-based alloy material according to the present invention are excellent in elongation (toughness) so that they can withstand secondary working when the secondary working is applied. The secondary working can therefore be performed with ease while retaining the excellent properties of their raw material as they are. In addition, such consolidated materials can be obtained by a simple process, that is, by simply compacting powder or flakes, which have been obtained by quench solidification, and then subjecting the thus-compacted powder or flakes to plastic working.

Claims

1. A compacted and consolidated aluminum-based alloy material, characterized in that said material has been obtained by compacting and consolidating a quench-solidified material whose composition is represented by the general formula: $Al_aNi_bX_c$ wherein X is one or more elements selected from La and Ce or an Mm (mischmetal) and a, b and c satisfy the following equations by atom percent: $87.5 \leqq a \leqq 92.5$, $5 \leqq b \leqq 10$, and $0.5 \leqq c \leqq 2.5$.

2. A compacted and consolidated aluminum-based alloy material according to claim 1, wherein a, b and c satisfy the following equations by atom percent: $89 \leqq a \leqq 91$, $7 \leqq b \leqq 10$, and $1 \leqq c \leqq 2$.

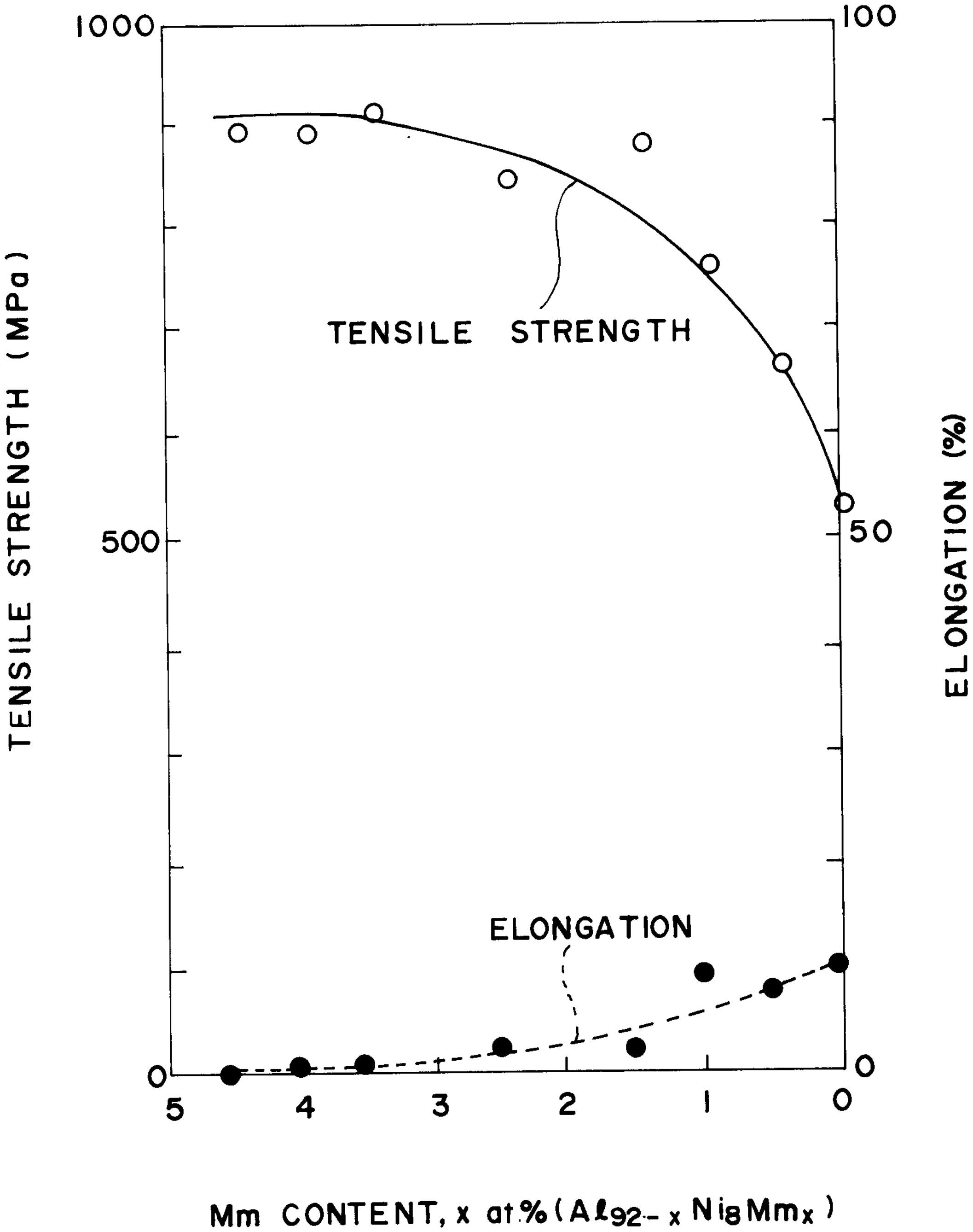
3. A compacted and consolidated aluminum-based alloy material according to claim 1, wherein said compacted and consolidated aluminum-based alloy material is formed of a matrix of aluminum or supersaturated aluminum solid solution, whose average crystal grain size is 40 - 400 nm, and grains made of a stable or metastable phase of various intermetallic compounds formed of the matrix element and the other alloying elements and/or of various intermetallic compounds formed of the other alloying elements and distributed evenly in the matrix; and the intermetallic compounds have an average grain size of 10 - 200 nm.

4. A compacted and consolidated aluminum-based alloy material according to claim 2, wherein said compacted and consolidated aluminum-based alloy material is formed of a matrix of aluminum or supersaturated aluminum solid solution, whose average crystal grain size is 40 - 400 nm, and grains made of a stable or metastable phase of various intermetallic compounds formed of the matrix element and the other alloying elements and/or of various intermetallic compounds formed of the other alloying elements and distributed evenly in the matrix; and the intermetallic compounds have an average grain size of 10 - 200 nm.

5. A process for the production of a compacted and consolidated aluminum-based alloy material, characterized in that said process comprises melting a material whose composition is represented by the general formula: $Al_aNi_bX_c$ wherein X is one or more elements selected from La and Ce or an Mm (mischmetal) and a, b and c satisfy the following equations by atom percent: $87.5 \leqq a \leqq 92.5$, $5 \leqq b \leqq 10$, and $0.5 \leqq c \leqq 2.5$; quenching and solidifying the resultant molten material into powder or flakes; compacting the powder or flakes; and then compressing, forming and consolidating the thus-compacted powder or flakes by conventional plastic working.

6. A process according to claim 5 for the production of a compacted and consolidated aluminum-based alloy material, wherein said consolidated material is formed of a matrix of aluminum or a supersaturated aluminum solid solution, whose average crystal grain size is 40 - 400 nm, and grains made of a stable or metastable phase of various intermetallic compound formed of the matrix element and the other alloying elements and/or of various intermetallic compounds formed of the other alloying elements and distributed evenly in the matrix; and the intermetallic compounds have an average grain size of 10 - 200 nm.

FIG. 1


1000
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TENSILE STRENGTH (MPa)
ELONGATION (%)
TENSILE STRENGTH
ELONGATION
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3
2
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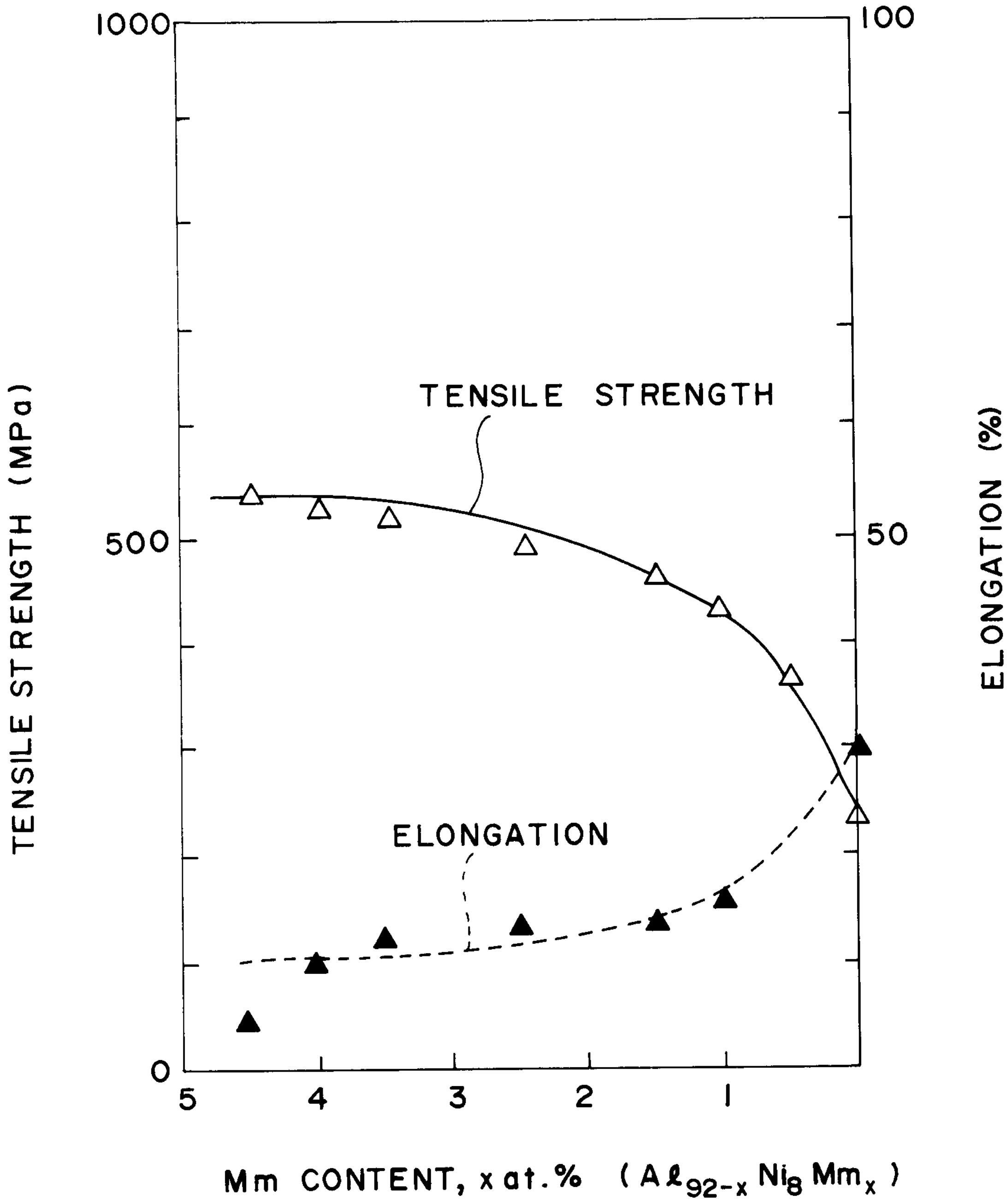
0
Mm CONTENT, x at% ($Al_{92-x}Ni_8Mm_x$)

FIG. 2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TENSILE STRENGTH (MPa)
ELONGATION (%)
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ELONGATION
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2
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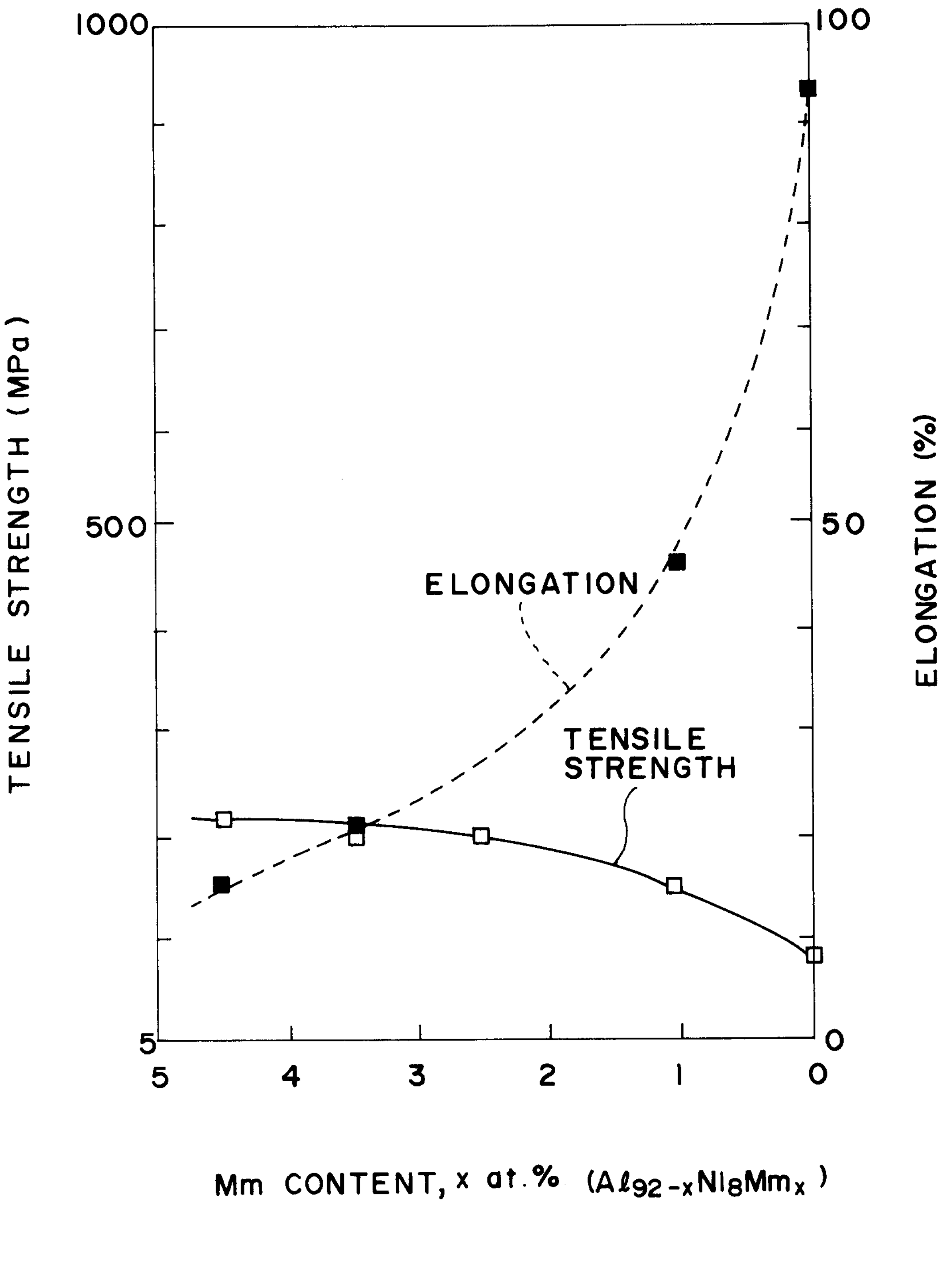
Mm CONTENT, x at.% ($A\ell_{92-x}Ni_8Mm_x$)

FIG. 3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ELONGATION (%)
ELONGATION
TENSILE STRENGTH
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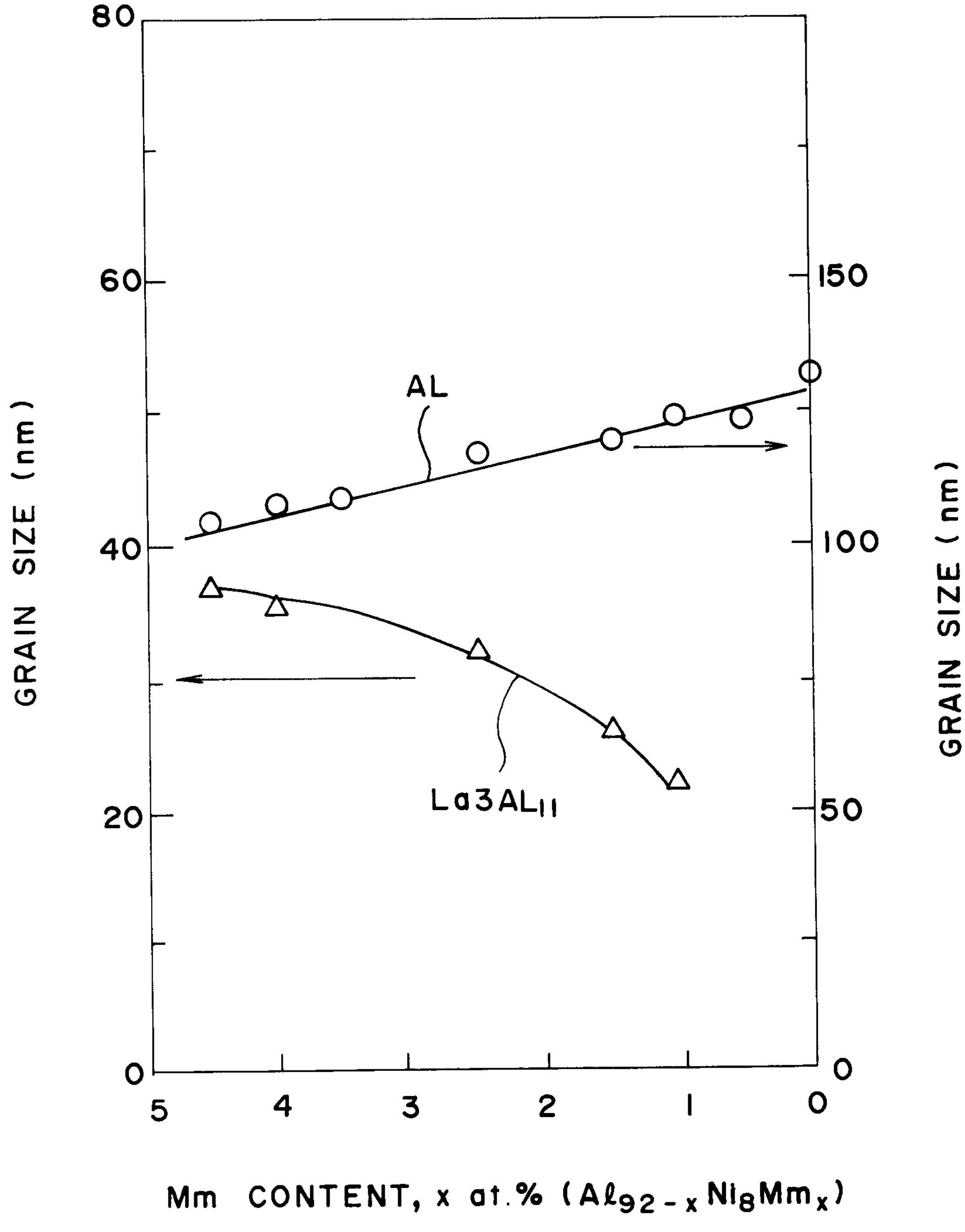
FIG. 4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GRAIN SIZE (nm)
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3
2
1
0
Mm CONTENT, x at.% (Aℓ92-x Ni8Mmx)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 11 1993

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	GB-A-2 015 035 (BICC) * the whole document * ---	1,5,6	B22F3/00
Y,D	EP-A-0 339 676 (YOSHIDA KOGYO K.K.) * the whole document * ---	1,5,6	
A	EP-A-0 265 307 (AUTOMOBILES PEUGEOT + AUTOMOBILES CITROEN) * the whole document * ---	1-6	
A	GB-A-2 167 442 (HONDA GIKEN KOGYO K.K.) * the whole document * ---	1-6	
A	PATENT ABSTRACTS OF JAPAN vol. 12, no. 40 (C-474)(2887) 5 February 1988 & JP-A-62 188 738 (HONDA MOTOR CO.) * abstract * -----	1-6	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B22F
C22C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 OCTOBER 1992	LIPPENS M.H.

CATEGORY OF CITED DOCUMENTS

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