Technical Disclosure Commons

Defensive Publications Series

August 2020

High-Strength Aluminum Alloys and Methods of Making the Same

Xavier Varone
Novelis Inc.

David Leyvraz
Novelis Inc.

Cyrille Bezencon
Novelis Inc.

Aurele Mariaux
Novelis Inc.

HIGH-STRENGTH ALUMINUM ALLOYS AND METHODS OF MAKING THE SAME

FIELD

This disclosure relates to the fields of material science, material chemistry, metallurgy, aluminum alloys, aluminum fabrication, and related fields. More specifically, the disclosure provides novel aluminum alloys that can be used in a variety of applications, including, for example, as automotive and/transportation parts.

BACKGROUND

Aluminum alloys that can be used in multiple applications, including in transportation, are desirable. Such alloys should exhibit high strength while also maintaining high elongation. Producing such alloys has proven to be a challenge, as such alloys may overage, resulting in a change of properties over time, especially at medium to low (room) temperature. Additionally, such alloys may require post-forming heat treatments or paint-baking in order to achieve high strength, which may add additional otherwise unneeded steps to the production process.
High strength, high elongation alloys are desirable for improved product performance. However, identifying alloy compositions and processing conditions that will provide such an alloy that addresses these failures has proven to be a challenge.

Aluminum strips with a variation in the weight percentage of zinc throughout the strip are known. High zinc content alloys are also known. The known alloys, however, either require additional post-forming heat treatments or paint-baking or do not attain the desirable high elongation.

SUMMARY

Provided herein are novel aluminum alloys that exhibit high strength and high elongation. The aluminum alloys described herein comprise about 14 – 50 wt. % Zn, at least one of about 1 – 15 wt. % Si or about 0.5 – 5 wt. % Cu, up to about 2 wt. % Mg, up to about 0.15 wt. % of impurities, and Al. In some examples, the aluminum alloys comprise about 14 – 50 wt. % Zn, about 3 – 12 wt. % Si, up to about 5 wt. % Cu, up to about 2 wt. % Mg, up to about 0.15 wt. % of impurities, and Al. In some examples, the aluminum alloys comprise about 14 – 50 wt. % Zn,

about 5 – 10 wt. % Si, up to about 5 wt. % Cu, up to about 2 wt. % Mg, up to about 0.15 wt. % of impurities, and Al. In some examples, the aluminum alloy comprises about 14 – 50 wt. % Zn, about 1 – 15 wt. % Si, about 0.5 – 5 wt. % Cu, up to about 2 wt. % Mg, up to about 0.15 wt. % of impurities, and Al. In some examples, the aluminum alloy comprises about 14 – 40 wt. % Zn, at least one of about 1 – 15 wt. % Si or about 0.5 – 5 wt. % Cu, up to about 2 wt. % Mg, up to about 0.15 wt. % of impurities, and Al. In some examples, the aluminum alloy comprises about 14 – 50 wt. % Zn, at least one of about 1 – 15 wt. % Si or about 0.5 – 5 wt. % Cu, up to about 2 wt. % Mg, up to about 1.5 wt. % Mn, up to about 1 wt. % Cr, up to about 0.3 wt. % Fe, up to about 1 wt. % V, up to about 0.15 wt. % of impurities, and Al. The alloy can be produced by casting (e.g., direct chill casting or continuous casting), homogenization, hot rolling, and optionally, cold rolling, and/or annealing. The alloy can be in an F temper or a T4 temper.

The yield strength of the alloy is at least about 300 MPa. The elongation of the alloy can be at least about 10 %.

Also provided herein are products comprising the aluminum alloy as described herein. The products can include an automotive and/or transportation part, including structural and inner parts which would not be exposed to a paint bake step. Optionally, the aluminum alloy can be used as part of a composite part, such as in combination with a carbon fiber reinforced polymer (CFRP).

Further provided herein are methods of producing an aluminum alloy product. The methods include the steps of casting an aluminum alloy as described herein to form a cast aluminum alloy, homogenizing the cast aluminum alloy, and hot rolling the cast aluminum alloy to produce an aluminum alloy product. Optionally, the methods further include a step of cold rolling and annealing the aluminum alloy product. Products (e.g., automotive parts) obtained according to the methods are also provided herein.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a graph of the yield strength of exemplary alloys described herein provided in F temper and after full annealing subjected to strength testing.

Figure 2 is a graph of the elongation and yield strength of exemplary alloys described herein coupled with comparative 6xxx series alloys described herein and subjected to elongation and strength testing.

Figure 3 is a graph of the elongation and yield strength of exemplary allows described herein coupled with comparative 7xxx series alloys described herein and subjected to elongation and strength testing.

DETAILED DESCRIPTION

Described herein are high-strength aluminum alloys and methods of making and processing the same. The aluminum alloys described herein exhibit improved mechanical strength and improved elongation. The alloys provided herein include a zinc constituent and can be especially useful when no post-forming heat treatment or paint-bake steps are desired. The alloys provided herein also comprise one or more of silicon and copper. Other elements, including manganese, chromium, vanadium, and titanium, may be included. The disclosed alloy compositions provide a material having high mechanical strength, regardless of temper. The alloys may be hot formed at varied temperatures and can be used at medium or low temperatures without experiencing a change in properties over time.

Alloy Compositions

Described below are novel aluminum alloys. In certain aspects, the alloys exhibit high strength and high elongation. The properties of the alloys are achieved due to the elemental compositions of the alloys as well as the methods of processing the alloys to produce the described sheets, plates, and shates. Specifically, increased zinc (Zn) content in combination with copper and/or silicon provides alloys that exhibit high strength and elongation at room temperature. The alloys do not require additional post-treatment heat forming or paint baking, providing for increased flexibility in their end uses, i.e., in products where the alloys would not be exposed to a paint bake, in products where quenching is not desirable, and in products where medium temperature stability (such as from 150 to 300° C) is desirable. Such products, described herein, may include automotive and/or transportation parts and specialty products.

Generally, it is understood that a zinc content of greater than 2.0 wt. % or even 3.0 wt. % is not desirable, as such amounts can have a detrimental effect on conductivity and self-corrosion rates. In the alloys described herein, however, the zinc content is at least 14 wt. % and when combined with copper and/or silicon, it has been found that there is a beneficial effect to increased zinc content in terms of strength and elongation. Without being bound by theory, it is believed that the combination of copper and zinc may result in high strength alloys because there is no copper-zinc precipitate in aluminum.

The alloys and methods described herein can be used in industrial applications including sacrificial parts, heat dissipation, packaging, and building materials. The alloys described herein are alloys may lie outside of the standard aluminum industry series or AA descriptors but have comparable or superior yield strength and/or elongation.

In some examples, the alloys can have the following elemental composition as provided in Table 1.

Table 1

Element	Weight Percentage (wt. %)
Zn	14 – 50.0
Si	1 – 15
Mn	0.00 – 1.5
Mg	0.00 – 2
Cr	0.00 – 1
V	0.00 – 1
Fe	0.00 – 0.30
Ti	0.00 – 0.10
Others	0 – 0.05 (each) 0 – 0.15 (total)
Al	Remainder

In some examples, the alloys can have the following elemental composition as provided in Table 2.

Table 2

Element	Weight Percentage (wt. %)
Zn	14 – 50.0
Cu	0.5 – 5
Mn	0.00 – 1.5
Mg	0.00 – 2

Cr	0.00 – 1
V	0.00 – 1
Fe	0.00 – 0.30
Ti	0.00 – 0.10
Others	0 – 0.05 (each) 0 – 0.15 (total)
Al	Remainder

In some examples, the alloys can have the following elemental composition as provided in Table 3.

Table 3

Element	**Weight Percentage (wt. %)**
Zn	14 – 50.0
Si	1 – 15
Cu	0.5 – 5
Mn	0.00 – 1.5
Mg	0.00 – 2
Cr	0.00 – 1
V	0.00 – 1
Fe	0.00 – 0.30
Ti	0.00 – 0.10
Others	0 – 0.05 (each) 0 – 0.15 (total)
Al	Remainder

In some examples, the alloys can have the following elemental composition as provided in Table 4.

Table 4

Element	**Weight Percentage (wt. %)**
Zn	14 – 50.0

Si	3 – 12
Cu	0.00 – 5
Mn	0.00 – 1.5
Mg	0.00 – 2
Cr	0.00 – 1
V	0.00 – 1
Fe	0.00 – 0.30
Ti	0.00 – 0.10
Others	0 – 0.05 (each) 0 – 0.15 (total)
Al	Remainder

In some examples, the alloys can have the following elemental composition as provided in Table 5.

Table 5

Element	**Weight Percentage (wt. %)**
Zn	14 – 50.0
Si	0.00 – 15
Cu	0.5 – 5
Mn	0.00 – 1.5
Mg	0.00 – 2
Cr	0.00 – 1
V	0.00 – 1
Fe	0.00 – 0.30
Ti	0.00 – 0.10
Others	0 – 0.05 (each) 0 – 0.15 (total)
Al	Remainder

In some examples, the alloy includes zinc (Zn) in an amount from about 14 % to about 50 % (e.g., from about 14 % to about 45 %, from about 14 % to about 40 %, from about 20 % to about 50 %, or from about 25 % to about 50 %) based on the total weight of the alloy. For example, the alloy can include about 14 %, about 14.25 %, about 14.5 %, about 14.75 %, about 15 %, about 15.25 %, about 15.5 %, about 15.75 %, about 16 %, about 16.25 %, about 16.5 %, about 16.75 %, about 17 %, about 17.25 %, about 17.5 %, about 17.75 %, about 18 %, about 18.25 %, about 18.5 %, about 18.75 %, about 19 %, about 19.25 %, about 19.5 %, about 19.75 %, about 20 %, about 20.25 %, about 20.5 %, about 20.75 %, about 21 %, about 21.25 %, about 21.5 %, about 21.75 %, about 22 %, about 22.25 %, about 22.5 %, about 22.75 %, about 23 %, about 23.25 %, about 23.5 %, about 23.75 %, about 24 %, about 24.25 %, about 24.5 %, about 24.75 %, about 25 %, about 25.25 %, about 25.5 %, about 25.75 %, about 26 %, about 26.25 %, about 26.5 %, about 26.75 %, about 27 %, about 27.25 %, about 27.5 %, about 27.75 %, about 28 %, about 28.25 %, about 28.5 %, about 28.75 %, about 29 %, about 29.25 %, about 29.5 %, about 29.75 %, about 30 %, about 30.25 %, about 30.5 %, about 30.75 %, about 31 %, about 31.25 %, about 31.5 %, about 31.75 %, about 32 %, about 32.25 %, about 32.5 %, about 32.75 %, about 33 %, about 33.25 %, about 33.5 %, about 33.75 %, about 34 %, about 34.25 %, about 34.5 %, about 34.75 %, about 35 %, about 35.25 %, about 35.5 %, about 35.75 %, about 36 %, about 36.25 %, about 36.5 %, about 36.75 %, about 37 %, about 37.25 %, about 37.5 %, about 37.75 %, about 38 %, about 38.25 %, about 38.5 %, about 38.75 %, about 39 %, about 39.25 %, about 39.5 %, about 39.75 %, about 40 %, about 40.25 %, about 40.5 %, about 40.75 %, about 41 %, about 41.25 %, about 41.5 %, about 41.75 %, about 42 %, about 42.25 %, about 42.5 %, about 42.75 %, about 43 %, about 43.25 %, about 43.5 %, about 43.75 %, about 44 %, about 44.25 %, about 44.5 %, about 44.75 %, about 45 %, about 45.25 %, about 45.5 %, about 45.75 %, about 46 %, about 46.25 %, about 46.5 %, about 46.75 %, about 47 %, about 47.25 %, about 47.5 %, about 47.75 %, about 48 %, about 48.25 %, about 48.5 %, about 48.75 %, about 49 %, about 49.25 %, about 49.5 %, about 49.75 %, and/or about 50 % Zn. The zinc content can improve the yield strength and elongation of the aluminum alloys described herein. Specifically, when zinc is incorporated at a level as described herein, such as from 14 % to 50 %, the alloys exhibit enhanced yield strength and elongation without requiring post-forming heat treatment or paint baking as compared to alloys typically used in industrial processes (e.g., 6xxx series and 7xxx series alloys). All percentages are expressed in wt. %.

In some examples, the disclosed alloy includes silicon (Si) in an amount of up to 15 % (e.g., from about 1 % to about 15 %, from about 3 % to about 15 %, or from about 3 % to about

12 %) based on the total weight of the alloy. For example, the alloy can include about 1 %, about 1.25 %, about 1.5 %, about 1.75 %, about 2 %, about 2.25 %, about 2.5 %, about 2.75 %, about 3 %, about 3.25 %, about 3.5 %, about 3.75 %, about 4 %, about 4.25 %, about 4.5 %, about 4.75 %, about 5 %, about 5.25 %, about 5.5 %, about 5.75 %, about 6 %, about 6.25 %, about 6.5 %, about 6.75 %, about 7 %, about 7.25 %, about 7.5 %, about 7.75 %, about 8 %, about 8.25 %, about 8.5 %, about 8.75 %, about 9 %, about 9.25 %, about 9.5 %, about 9.75 %, about 10 %, about 10.25 %, about 10.5 %, about 10.75 %, about 11 %, about 11.25 %, about 11.5 %, about 11.75 %, about 12 %, about 12.25 %, about 12.5 %, about 12.75 %, about 13 %, about 13.25 %, about 13.5 %, about 13.75 %, about 14 %, about 14.25 %, about 14.5 %, about 14.75 %, and/or about 15 % Si. In some cases, Si is not present in the alloy (i.e., 0 %). All percentages are expressed in wt. %.

In some examples, the disclosed alloy includes copper (Cu) in an amount of up to about 5 % (e.g., from about 0.5 % to about 5 %, from about 0.75 % to about 5 %, from about 1 % to about 5 %, or from about 1 % to about 3 %) based on the total weight of the alloy. For example, the alloy can include about 0.5 %, about 0.6 %, about 0.7 %, about 0.8 %, about 0.9 %, about 1 %, about 1.1 %, about 1.2 %, about 1.3 %, about 1.4 %, about 1.5 %, about 1.6 %, about 1.7 %, about 1.8 %, about 1.9 %, about 2 %, about 2.1 %, about 2.2 %, about 2.3 %, about 2.4 %, about 2.5 %, about 2.6 %, about 2.7 %, about 2.8 %, about 2.9 %, about 3 %, about 3.1 %, about 3.2 %, about 3.3 %, about 3.4 %, about 3.5 %, about 3.6 %, about 3.7 %, about 3.8 %, about 3.9 %, about 4 %, about 4.1 %, about 4.2 %, about 4.3 %, about 4.4 %, about 4.5 %, about 4.6 %, about 4.7 %, about 4.8 %, about 4.9 %, and/or about 5 % Cu. In some cases, Cu is not present in the alloy (i.e., 0 %). All percentages are expressed in wt. %.

In some examples, the alloy can include manganese (Mn) in an amount of up to 1.5 % (e.g., from about 0.1 % to about 1.25 %, from about 0.25 % to about 1.00 %, or from about 0.5 % to about 1 %) based on the total weight of the alloy. For example, the alloy can include 0 %, about 0.05 %, about 0.1 %, about 0.15 %, about 0.2 %, about 0.25 %, about 0.3 %, about 0.35 %, about 0.4 %, about 0.45 %, about 0.5 %, about 0.55 %, about 0.6 %, about 0.65 %, about 0.7 %, about 0.75 %, about 0.8 %, about 0.85 %, about 0.9 %, about 0.95 %, about 1 %, about 1.05 %, about 1.1 %, about 1.15 %, about 1.2 %, about 1.25 %, about 1.3 %, about 1.35 %, about 1.4 %, about 1.45 %, and/or about 1.5 % Mn. In some cases, Mn is not present in the alloy (i.e., 0 %). All percentages are expressed in wt. %.

In some examples, the alloy can include magnesium (Mg) in an amount up to about 2 % (e.g., from about 0.1 % to about 2 %, from about 0.25 % to about 2 %, or from about 0.25 % to about 1.5 %) based on the total weight of the alloy. For example, the alloy can include 0 %, about 0.05 %, about 0.1 %, about 0.15 %, about 0.2 %, about 0.25 %, about 0.3 %, about 0.35 %, about 0.4 %, about 0.45 %, about 0.5 %, about 0.55 %, about 0.6 %, about 0.65 %, about 0.7 %, about 0.75 %, about 0.8 %, about 0.85 %, about 0.9 %, about 0.95 %, about 1 %, about 1.05 %, about 1.1 %, about 1.15 %, about 1.2 %, about 1.25 %, about 1.3 %, about 1.35 %, about 1.4 %, about 1.45 %, about 1.5 %, about 1.55 %, about 1.6 %, about 1.65 %, about 1.7 %, about 1.75 %, about 1.8 %, about 1.85 %, about 1.9 %, about 1.95 %, and/or about 2 % Mg. In some cases, Mg is not present in the alloy (i.e., 0 %). All percentages are expressed in wt. %.

In some examples, the alloy includes chromium (Cr) in an amount up to about 1 % (e.g., from 0 % to about 0.95 %, from about 0.001 % to about 0.75 %, or from about 0.01 % to about 0.5 %) based on the total weight of the alloy. For example, the alloy can include about 0.001 %, about 0.002 %, about 0.003 %, about 0.004 %, about 0.005 %, about 0.006 %, about 0.007 %, about 0.008 %, about 0.009 %, about 0.01 %, about 0.02 %, about 0.03 %, about 0.04 %, about 0.05 %, about 0.06 %, about 0.07 %, about 0.08 %, about 0.09 %, about 0.1 %, about 0.125 %, about 0.15 %, about 0.175 %, about 0.2 %, about 0.225 %, about 0.25 %, about 0.275 %, about 0.3 %, about 0.325 %, about 0.35 %, about 0.375 %, about 0.4 %, about 0.425 %, about 0.45 %, about 0.475 %, about 0.5 %, about 0.525 %, about 0.55 %, about 0.575 %, about 0.6 %, about 0.625 %, about 0.65 %, about 0.675 %, about 0.7 %, about 0.725 %, about 0.75 %, about 0.775 %, about 0.8 %, about 0.825 %, about 0.85 %, about 0.875 %, about 0.9 %, about 0.925 %, about 0.95 %, about 0.975 %, and/or about 1 % Cr. In some cases, Cr is not present in the alloy (i.e., 0 %). All percentages are expressed in wt. %.

In some examples, the alloy includes vanadium (V) in an amount up to about 1 % (e.g., from 0 % to about 0.95 %, from about 0.001 % to about 0.75 %, or from about 0.01 % to about 0.5 %) based on the total weight of the alloy. For example, the alloy can include about 0.001 %, about 0.002 %, about 0.003 %, about 0.004 %, about 0.005 %, about 0.006 %, about 0.007 %, about 0.008 %, about 0.009 %, about 0.01 %, about 0.02 %, about 0.03 %, about 0.04 %, about 0.05 %, about 0.06 %, about 0.07 %, about 0.08 %, about 0.09 %, about 0.1 %, about 0.125 %, about 0.15 %, about 0.175 %, about 0.2 %, about 0.225 %, about 0.25 %, about 0.275 %, about 0.3 %, about 0.325 %, about 0.35 %, about 0.375 %, about 0.4 %, about 0.425 %, about 0.45 %, about 0.475 %, about 0.5 %, about 0.525 %, about 0.55 %, about 0.575 %, about 0.6 %, about 0.625 %, about 0.65 %, about 0.675 %, about 0.7 %, about 0.725 %, about 0.75 %, about 0.775 %, about 0.8 %, about 0.825 %, about 0.85 %, about 0.875 %, about 0.9 %, about 0.925 %, about 0.95 %, about 0.975 %, and/or about 1 % V. In some cases, V is not present in the alloy (i.e., 0 %). All percentages are expressed in wt. %.

In some examples, the alloy includes iron (Fe) in an amount up to about 0.30 % (e.g., from 0 % to about 0.25 %, from about 0.001 % to about 0.3 %, or from about 0.01 % to about 0.25 %) based on the total weight of the alloy. For example, the alloy can include about 0.001 %, about 0.002 %, about 0.003 %, about 0.004 %, about 0.005 %, about 0.006 %, about 0.007 %, about 0.008 %, about 0.009 %, about 0.01 %, about 0.02 %, about 0.03 %, about 0.04 %, about 0.05 %, about 0.06 %, about 0.07 %, about 0.08 %, about 0.09 %, about 0.1 %, about 0.11 %, about 0.12 %, about 0.13 %, about 0.14 %, about 0.15 %, about 0.16 %, about 0.17 %, about 0.18 %, about 0.19 %, about 0.20 %, about 0.21 %, about 0.22 %, about 0.23 %, about 0.24 %, about 0.25 %, about 0.26 %, about 0.27 %, about 0.28 %, about 0.29 %, or about 0.30 % Fe. In some cases, Fe is not present in the alloy (i.e., 0 %). All percentages are expressed in wt. %.

In some examples, the alloy includes titanium (Ti) in an amount up to about 0.10 % (e.g., from 0 % to about 0.05 %, from about 0.001 % to about 0.04 %, or from about 0.01 % to about 0.03 %) based on the total weight of the alloy. For example, the alloy can include about 0.001 %, about 0.002 %, about 0.003 %, about 0.004 %, about 0.005 %, about 0.006 %, about 0.007 %, about 0.008 %, about 0.009 %, about 0.01 %, about 0.02 %, about 0.03 %, about 0.04 %, about 0.05 %, about 0.06 %, about 0.07 %, about 0.08 %, about 0.09 %, or about 0.1 % Ti. In some cases, Ti is not present in the alloy (i.e., 0 %). All percentages are expressed in wt. %.

Optionally, the alloy compositions can further include other minor elements, sometimes referred to as impurities, in amounts of about 0.05 % or below, 0.04 % or below, 0.03 % or below, 0.02 % or below, or 0.01 % or below each. These impurities may include, but are not limited to, Ga, Ni, Sc, Ag, B, Bi, Zr, Li, Pb, Sn, Ca, Hf, Sr, or combinations thereof. Accordingly, Ga, Ni, Sc, Ag, B, Bi, Zr, Li, Pb, Sn, Ca, Hf, or Sr may be present in an alloy in amounts of 0.05 % or below, 0.04 % or below, 0.03 % or below, 0.02 % or below, or 0.01 % or below. In certain aspects, the sum of all impurities does not exceed 0.15 % (e.g., 0.1 %). All percentages are expressed in wt. %. In certain aspects, the remaining percentage of the alloy is aluminum.

Optionally, exemplary aluminum alloys as described herein can include about 14 – 50 % Zn (e.g., about 14 – 40 % Zn), at least one of about 1 – 15 % Si or about 0.5 –5 % Cu, up to 2 % Mg, up to about 0.15 % of impurities, and Al. For example, an exemplary alloy includes 14 – 17 % Zn, 1 – 3 % Cu, 1 – 5 % Mg, up to 0.15 % total impurities, and Al. In some examples, an exemplary alloy includes 30 – 40 % Zn, 1 – 3 % Cu, up to 0.15 % total impurities, and Al. In some examples, an exemplary alloy includes 15 % Zn, 9 % Si, 2 % Cu, up to 0.15 % total impurities, and Al. In some examples, an exemplary alloy includes 25 % Zn, 7 % Si, up to 0.15 % total impurities, and Al. In some examples, an exemplary alloy includes 25 % Zn, 7 % Si, 2 % Cu, up to 0.15 % total impurities, and Al. In some examples, an exemplary alloy includes 35 % Zn, 5 % Si, up to 0.15 % total impurities, and Al.

Alloy Properties

The mechanical properties of the aluminum alloy can be controlled by various processing conditions depending on the desired use. The alloy can be produced (or provided in) an F temper (e.g., as fabricated). Optionally, the alloy can be produced (or provided) in an H temper (e.g., HX1, HX2, HX3 HX4, HX5, HX6, HX7, HX8, or HX9 tempers). As one example, the alloy can be produced (or provided) in the H19 temper. H19 temper refers to products that are cold rolled. As another example, the alloy can be produced (or provided) in the H23 temper. H23 temper refers to products that are cold rolled and partially annealed. As a further example, the alloy can be produced (or provided) in the O temper. O temper refers to products that are fully annealed. As yet another example, the alloy can be produced (or provided) in T temper. T temper refers to products that are thermally treated. Suitable T tempers include T1, T2, T3, T31, T351, T3511, T36, T37, T4, T451, T4511, T5, T51, T52, T54, T6, T61, T611, T62, T651, T6510, T6511, T652, T7, T73, T7351, T73511, T7352, T8, T81, T851, T8511, T86, T87, T9 and T10.

In some non-limiting examples, the disclosed alloys have high strength in the F tempers and in the O temper. In some non-limiting examples, the disclosed alloys have high strength and elongation in the F and O tempers compared to conventional 6xxx and 7xxx series aluminum alloys.

In certain aspects, the aluminum alloys can have a yield strength (YS) of at least about 150 MPa. In non-limiting examples, the yield strength is at least about 150 MPa, at least about 160 MPa, at least about 170 MPa, at least about 180 MPa, at least about 190 MPa, at least about 200 MPa, at least about 210 MPa, at least about 220 MPa, at least about 230 MPa, at least about

240 MPa, at least about 250 MPa, at least about 260 MPa, at least about 270 MPa, at least about 280 MPa, at least about 290 MPa, at least about 300 MPa, at least about 310 MPa, at least about 320 MPa, at least about 330 MPa, at least about 340 MPa, at least about 350 MPa, at least about 360 MPa, at least about 370 MPa, at least about 380 MPa, at least about 390 MPa, at least about 400 MPa, at least about 410 MPa, at least about 420 MPa, at least about 430 MPa, at least about 440 MPa, at least about 450 MPa, at least about 460 MPa, at least about 470 MPa, at least about 480 MPa, at least about 490 MPa, at least about 500 MPa, at least about 510 MPa, at least about 520 MPa, at least about 530 MPa, at least about 540 MPa, at least about 550 MPa, at least about 560 MPa, at least about 570 MPa, at least about 580 MPa, at least about 590 MPa, at least about 600 MPa, at least about 610 MPa, at least about 620 MPa, at least about 630 MPa, at least about 640 MPa, at least about 650 MPa, at least about 660 MPa, at least about 670 MPa, at least about 680 MPa, at least about 690 MPa, and/or at least about 700 MPa or anywhere in between. In some cases, the yield strength is from about 150 MPa to about 900 MPa. For example, the yield strength can be from about 150 MPa to about 850 MPa, from about 200 MPa to about 650 MPa, or from about 300 MPa to about 500 MPa.

The yield strength will vary based on the tempers of the alloys. In some examples, the alloys described herein provided in an O temper can have a yield strength of from at least about 70 MPa to about 200 MPa. In non-limiting examples, the yield strength of the alloys in O temper is at least about 150 MPa, at least about 160 MPa, at least about 170 MPa, at least about 180 MPa, at least about 190 MPa, at least about 200 MPa, at least about 210 MPa, at least about 220 MPa, at least about 230 MPa, at least about 240 MPa, at least about 250 MPa, at least about 260 MPa, at least about 270 MPa, at least about 280 MPa, at least about 290 MPa, at least about 300 MPa, at least about 310 MPa, at least about 320 MPa, at least about 330 MPa, at least about 340 MPa, at least about 350 MPa, at least about 360 MPa, at least about 370 MPa, at least about 380 MPa, at least about 390 MPa, at least about 400 MPa, at least about 410 MPa, at least about 420 MPa, at least about 430 MPa, at least about 440 MPa, at least about 450 MPa, at least about 460 MPa, at least about 470 MPa, at least about 480 MPa, at least about 490 MPa, at least about 500 MPa, at least about 510 MPa, at least about 520 MPa, at least about 530 MPa, at least about 540 MPa, at least about 550 MPa, at least about 560 MPa, at least about 570 MPa, at least about 580 MPa, at least about 590 MPa, at least about 600 MPa, at least about 610 MPa, at least about 620 MPa, at least about 630 MPa, at least about 640 MPa, at least about 650 MPa, at least about 660

MPa, at least about 670 MPa, at least about 680 MPa, at least about 690 MPa, and/or at least about 700 MPa or anywhere in between.

In some further examples, the alloys described herein in an F temper can have a yield strength of at least about 300 MPa, at least about 310 MPa, at least about 320 MPa, at least about 330 MPa, at least about 340 MPa, at least about 350 MPa, at least about 360 MPa, at least about 370 MPa, at least about 380 MPa, at least about 390 MPa, at least about 400 MPa, at least about 410 MPa, at least about 420 MPa, at least about 430 MPa, at least about 440 MPa, at least about 450 MPa, at least about 460 MPa, at least about 470 MPa, at least about 480 MPa, at least about 490 MPa, at least about 500 MPa, at least about 510 MPa, at least about 520 MPa, at least about 530 MPa, at least about 540 MPa, at least about 550 MPa, at least about 560 MPa, at least about 570 MPa, at least about 580 MPa, at least about 590 MPa, at least about 600 MPa, at least about 610 MPa, at least about 620 MPa, at least about 630 MPa, at least about 640 MPa, at least about 650 MPa, at least about 660 MPa, at least about 670 MPa, at least about 680 MPa, at least about 690 MPa, and/or at least about 700 MPa or anywhere in between.

In some further examples, the alloys described herein in a T temper can have a yield strength of at least about 300 MPa, at least about 310 MPa, at least about 320 MPa, at least about 330 MPa, at least about 340 MPa, at least about 350 MPa, at least about 360 MPa, at least about 370 MPa, at least about 380 MPa, at least about 390 MPa, at least about 400 MPa, at least about 410 MPa, at least about 420 MPa, at least about 430 MPa, at least about 440 MPa, at least about 450 MPa, at least about 460 MPa, at least about 470 MPa, at least about 480 MPa, at least about 490 MPa, at least about 500 MPa, at least about 510 MPa, at least about 520 MPa, at least about 530 MPa, at least about 540 MPa, at least about 550 MPa, at least about 560 MPa, at least about 570 MPa, at least about 580 MPa, at least about 590 MPa, at least about 600 MPa, at least about 610 MPa, at least about 620 MPa, at least about 630 MPa, at least about 640 MPa, at least about 650 MPa, at least about 660 MPa, at least about 670 MPa, at least about 680 MPa, at least about 690 MPa, and/or at least about 700 MPa or anywhere in between.

In certain aspects, the aluminum alloys can have an ultimate tensile strength (UTS) of at least about 170 MPa. In non-limiting examples, the UTS is at least about 170 MPa, at least about 180 MPa, at least about 190 MPa, at least about 200 MPa, at least about 210 MPa, at least about 220 MPa, at least about 230 MPa, at least about 240 MPa, at least about 250 MPa, at least about 260 MPa, at least about 270 MPa, at least about 280 MPa, at least about 290 MPa, at least about

300 MPa, at least about 310 MPa, at least about 320 MPa, at least about 330 MPa, at least about 340 MPa, at least about 350 MPa, at least about 360 MPa, at least about 370 MPa, at least about 380 MPa, at least about 390 MPa, at least about 400 MPa, at least about 410 MPa, at least about 420 MPa, at least about 430 MPa, at least about 440 MPa, at least about 450 MPa, at least about 460 MPa, at least about 470 MPa, at least about 480 MPa, at least about 490 MPa, at least about 500 MPa, or anywhere in between,. In some cases, the UTS is from about 200 MPa to about 600 MPa. For example, the UTS can be from about 200 MPa to about 575 MPa, from about 225 MPa to about 550 MPa, from about 250 MPa to about 550 MPa, from about 300 MPa to about 550 MPa, or from about 300 MPa to about 500 MPa.

In some examples, the alloys described herein provided in an O temper can have an UTS of from at least about 170 MPa, at least about 180 MPa, at least about 190 MPa, at least about 200 MPa, at least about 210 MPa, at least about 220 MPa, at least about 230 MPa, at least about 240 MPa, at least about 250 MPa, at least about 260 MPa, at least about 270 MPa, at least about 280 MPa, at least about 290 MPa, at least about 300 MPa, at least about 310 MPa, at least about 320 MPa, at least about 330 MPa, at least about 340 MPa, at least about 350 MPa, at least about 360 MPa, at least about 370 MPa, at least about 380 MPa, at least about 390 MPa, at least about 400 MPa, at least about 410 MPa, at least about 420 MPa, at least about 430 MPa, at least about 440 MPa, at least about 450 MPa, at least about 460 MPa, at least about 470 MPa, at least about 480 MPa, at least about 490 MPa, at least about 500 MPa, or anywhere in between,. In some cases, the UTS in O temper is from about 200 MPa to about 600 MPa. For example, the UTS can be from about 200 MPa to about 575 MPa, from about 225 MPa to about 550 MPa, from about 250 MPa to about 550 MPa, from about 300 MPa to about 550 MPa, or from about 300 MPa to about 500 MPa in O temper.

In some further examples, the alloys described herein in an F temper can have an UTS of at least about 170 MPa, at least about 180 MPa, at least about 190 MPa, at least about 200 MPa, at least about 210 MPa, at least about 220 MPa, at least about 230 MPa, at least about 240 MPa, at least about 250 MPa, at least about 260 MPa, at least about 270 MPa, at least about 280 MPa, at least about 290 MPa, at least about 300 MPa, at least about 310 MPa, at least about 320 MPa, at least about 330 MPa, at least about 340 MPa, at least about 350 MPa, at least about 360 MPa, at least about 370 MPa, at least about 380 MPa, at least about 390 MPa, at least about 400 MPa, at least about 410 MPa, at least about 420 MPa, at least about 430 MPa, at least about 440 MPa, at least about 450 MPa, at least about 460 MPa, at least about 470 MPa, at least about 480 MPa, at least about 490 MPa, at least about 500 MPa, or anywhere in between. In some cases, the UTS in F temper is from about 200 MPa to about 600 MPa. For example, the UTS in F temper can be from about 200 MPa to about 575 MPa, from about 225 MPa to about 550 MPa, from about 250 MPa to about 550 MPa, from about 300 MPa to about 550 MPa, or from about 300 MPa to about 500 MPa.

In some further examples, the alloys described herein in a T temper can have an UTS of at least about 170 MPa, at least about 180 MPa, at least about 190 MPa, at least about 200 MPa, at least about 210 MPa, at least about 220 MPa, at least about 230 MPa, at least about 240 MPa, at least about 250 MPa, at least about 260 MPa, at least about 270 MPa, at least about 280 MPa, at least about 290 MPa, at least about 300 MPa, at least about 310 MPa, at least about 320 MPa, at least about 330 MPa, at least about 340 MPa, at least about 350 MPa, at least about 360 MPa, at least about 370 MPa, at least about 380 MPa, at least about 390 MPa, at least about 400 MPa, at least about 410 MPa, at least about 420 MPa, at least about 430 MPa, at least about 440 MPa, at least about 450 MPa, at least about 460 MPa, at least about 470 MPa, at least about 480 MPa, at least about 490 MPa, at least about 500 MPa, or anywhere in between. In some cases, the UTS in T temper is from about 200 MPa to about 600 MPa. For example, the UTS in T temper can be from about 200 MPa to about 575 MPa, from about 225 MPa to about 550 MPa, from about 250 MPa to about 550 MPa, from about 300 MPa to about 550 MPa, or from about 300 MPa to about 500 MPa.

In certain aspects, the alloy encompasses any yield strength that has sufficient formability to meet an elongation of about 9.75 % or greater in the O temper (e.g., about 10.0 % or greater). In certain examples, the elongation can be about 9.75 % or greater, about 10.0 % or greater, about 10.25 % or greater, about 10.5 % or greater, about 10.75 % or greater, about 11.0 % or greater, about 11.25 % or greater, about 11.5 % or greater, about 11.75 % or greater, about 12.0 % or greater, about 12.25 % or greater, about 12.5 % or greater, about 12.75 % or greater, about 13.0 % or greater, about 13.25 % or greater, about 13.5 % or greater, about 13.75 % or greater, about 14.0 % or greater, about 14.25 % or greater, about 14.5 % or greater, about 14.75 % or greater, about 15.0 % or greater, about 15.25 % or greater, about 15.5 % or greater, about 15.75 % or greater, about 16.0 % or greater, about 16.25 % or greater, about 16.5 % or greater, about 16.75 % or greater, about 17.0 % or greater, about 17.25 % or greater, about 17.5 % or greater, about 17.75 % or greater, about 18.0 % or greater, about 18.25 % or greater, about 18.5 % or greater, about 18.75 % or greater, about 19.0 % or greater, about 19.25 % or greater, about 19.5 % or greater, about 19.75 % or greater, about 20.0 % or greater, about 20.25 % or greater, about 20.5 % or greater, about 20.75 % or greater, about 21.0 % or greater, about 21.25 % or greater, about 21.5 % or greater, about 21.75 % or greater, about 22.0 % or greater, about 22.25 % or greater, about 22.5 % or greater, about 22.75 % or greater, about 23.0 % or greater, about 23.25 % or greater, about 23.5 % or greater, about 23.75 % or greater, about 24.0 % or greater, about 24.25 % or greater, about 24.5 % or greater, about 24.75 % or greater, about 25.0 % or greater, about 25.25 % or greater, about 25.5 % or greater, about 25.75 % or greater, about 26.0 % or greater, about 26.25 % or greater, about 26.5 % or greater, about 26.75 % or greater, about 27.0 % or greater, about 27.25 % or greater, about 27.5 % or greater, about 27.75 % or greater, about 28.0 % or greater, about 28.25 % or greater, about 28.5 % or greater, about 28.75 % or greater, about 29.0 % or greater, about 29.25 % or greater, about 29.5 % or greater, about 29.75 % or greater, or about 30.0 % or greater.

Methods of Preparing and Processing

In certain aspects, the disclosed alloy composition is a product of a disclosed method. Without intending to limit the disclosure, aluminum alloy properties are partially determined by the formation of microstructures during the alloy's preparation. In certain aspects, the method of preparation for an alloy composition may influence or even determine whether the alloy will have properties adequate for a desired application.

Casting

The alloy described herein can be cast using a casting method as known to those of skill in the art. For example, the casting process can include a Direct Chill (DC) casting process. The DC casting process is performed according to standards commonly used in the aluminum industry as known to one of skill in the art. The DC process can provide an ingot. Optionally, the ingot can be scalped before downstream processing. Optionally, the casting process can include a continuous casting (CC) process.

The cast aluminum alloy can then be subjected to further processing steps. For example, the processing methods as described herein can include the steps of homogenization, hot rolling, cold rolling, and/or annealing.

Homogenization

The homogenization step can include heating a cast aluminum alloy as described herein to attain a homogenization temperature of about, or at least about, 570 °C (e.g., at least about 570 °C, at least about 580 °C, at least about 590 °C, at least about 600 °C, at least about 610 °C, or anywhere in between). For example, the cast aluminum alloy can be heated to a temperature of from about 570 °C to about 620 °C, from about 575 °C to about 615 °C, from about 585 °C to about 610 °C, or from about 590 °C to about 605 °C. In some cases, the heating rate to the homogenization temperature can be about 100 °C/hour or less, about 75 °C/hour or less, about 50 °C/hour or less, about 40 °C/hour or less, about 30 °C/hour or less, about 25 °C/hour or less, about 20 °C/hour or less, about 15 °C/hour or less, or about 10 °C/hour or less. In other cases, the heating rate to the homogenization temperature can be from about 10 °C/min to about 100 °C/min (e.g., about 10 °C/min to about 90 °C/min, about 10 °C/min to about 70 °C/min, about 10 °C/min to about 60 °C/min, from about 20 °C/min to about 90 °C/min, from about 30 °C/min to about 80 °C/min, from about 40 °C/min to about 70 °C/min, or from about 50 °C/min to about 60 °C/min).

The cast aluminum alloy is then allowed to soak (i.e., held at the indicated temperature) for a period of time. According to one non-limiting example, the cast aluminum alloy is allowed to soak for up to about 5 hours (e.g., from about 10 minutes to about 5 hours, inclusively). For example, the cast aluminum alloy can be soaked at a temperature of at least 570 °C for 10 minutes, 20 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 4 hours, 5 hours, or anywhere in between.

The cast aluminum alloy can be cooled from the first temperature to a second temperature that is lower than the first temperature. In some examples, the second temperature is greater than about 555 °C (e.g., greater than about 560 °C, greater than about 565 °C, greater than about 570 °C, or greater than about 575 °C). For example, the cast aluminum alloy can be cooled to a second temperature of from about 555 °C to about 590 °C, from about 560 °C to about 575 °C, from about 565 °C to about 580 °C, from about 570 °C to about 585 °C, from about 565 °C to about 570 °C, from about 570 °C to about 590 °C, or from about 575 °C to about 585 °C. The cooling rate to the second temperature can be from about 10 °C/min to about 100 °C/min (e.g., from about 20 °C/min to about 90 °C/min, from about 30 °C/min to about 80 °C/min, from about 10 °C/min to about 90 °C/min, from about 10 °C/min to about 70 °C/min, from about 10 °C/min to about 60 °C/min, from about 40 °C/min to about 70 °C/min, or from about 50 °C/min to about 60 °C/min).

The cast aluminum alloy can then be allowed to soak at the second temperature for a period of time. In certain cases, the ingot is allowed to soak for up to about 5 hours (e.g., from 10 minutes to 5 hours, inclusively). For example, the ingot can be soaked at a temperature of from about 560 °C to about 590 °C for 10 minutes, 20 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 4 hours, 5 hours, or anywhere in between.

Hot Rolling

Following the homogenization step, a hot rolling step can be performed. In certain cases, the cast aluminum alloys are hot-rolled with a hot mill entry temperature range of about 560 °C to about 600 °C. For example, the entry temperature can be about 560 °C, about 565 °C, about 570 °C, about 575 °C, about 580 °C, about 585 °C, about 590 °C, about 595 °C, or about 600 °C. In certain cases, the hot roll exit temperature can range from about 290 °C to about 350 °C (e.g., from about 310 °C to about 340 °C). For example, the hot roll exit temperature can be about 290 °C, about 295 °C, about 300 °C, about 305 °C, about 310 °C, about 315 °C, about 320 °C, about 325 °C, about 330 °C, about 335 °C, about 340 °C, about 345 °C, about 350 °C, or anywhere in between.

In certain cases, the cast aluminum alloy can be hot rolled to an about 2 mm to about 15 mm thick gauge (e.g., from about 2.5 mm to about 12 mm thick gauge). For example, the cast aluminum alloy can be hot rolled to an about 2 mm thick gauge, about 2.5 mm thick gauge, about 3 mm thick gauge, about 3.5 mm thick gauge, about 4 mm thick gauge, about 5 mm thick gauge, about 6 mm thick gauge, about 7 mm thick gauge, about 8 mm thick gauge, about 9 mm thick gauge, about 10 mm thick gauge, about 11 mm thick gauge, about 12 mm thick gauge, about 13 mm thick gauge, about 14 mm thick gauge, or about 15 mm thick gauge. In certain cases, the cast aluminum alloy can be hot rolled to a gauge greater than 15 mm (i.e., a plate). In other cases, the cast aluminum alloy can be hot rolled to a gauge less than 4 mm (i.e., a sheet). In still other cases, the cast aluminum alloy can be hot rolled to a gauge from about 4 mm to about 15 mm (i.e., a shate).

Cold Rolling

A cold rolling step may optionally be performed following the hot rolling step. In certain aspects, the rolled product from the hot rolling step can be cold rolled to a sheet (e.g., below approximately 4.0 mm). In certain aspects, the rolled product is cold rolled to a thickness of about 0.4 mm to about 1.0 mm, about 1.0 mm to about 3.0 mm, or about 3.0 mm to less than about 4.0 mm. In certain aspects, the alloy is cold rolled to about 3.5 mm or less, about 3 mm or less, about 2.5 mm or less, about 2 mm or less, about 1.5 mm or less, about 1 mm or less, about 0.5 mm or less, about 0.4 mm or less, about 0.3 mm or less, about 0.2 mm or less, or about 0.1 mm or less. For example, the rolled product can be cold rolled to about 0.1 mm, about 0.2 mm, about 0.3 mm, about 0.4 mm, about 0.5 mm, about 0.6 mm, about 0.7 mm, about 0.8 mm, about 0.9 mm, about 1.0 mm, about 1.1 mm, about 1.2 mm, about 1.3 mm, about 1.4 mm, about 1.5 mm, about 1.6 mm, about 1.7 mm, about 1.8 mm, about 1.9 mm, about 2.0 mm, about 2.1 mm, about 2.2 mm, about 2.3 mm, about 2.4 mm, about 2.5 mm, about 2.6 mm, about 2.7 mm, about 2.8 mm, about 2.9 mm, about 3.0 mm, about 3.1 mm, about 3.2 mm, about 3.3 mm, about 3.4 mm, about 3.5 mm, about 3.6 mm, about 3.7 mm, about 3.8 mm, about 3.9 mm, about 4.0 mm, or anywhere in between.

In one case, the method for processing the aluminum alloys as described herein can include the following steps. A homogenization step can be performed by heating a cast aluminum alloy as described herein to attain a homogenization temperature of about 590 °C over a time period of about 12 hours, wherein the cast aluminum alloys are allowed to soak at a temperature of about 590 °C for about 2 hours. The cast aluminum alloys can then be cooled to about 580 °C and allowed to soak for about 2 hours at 580 °C. The cast aluminum alloys can then be hot rolled to a gauge of about 2.5 mm thick. The cast aluminum alloys can then be cold rolled to a gauge of less than about 1.0 mm thick (e.g., about 1.0 mm or less or about 0.15 mm or less), providing an aluminum alloy sheet.

Annealing

Optionally, the aluminum alloy sheet can be annealed by heating the sheet from room temperature to an annealing temperature of from about 200 °C to about 400 °C (e.g., from about 210 °C to about 375 °C, from about 220 °C to about 350 °C, from about 225 °C to about 345 °C, or from about 250 °C to about 320 °C). In some cases, the heating rate to the annealing temperature can be about 100 °C/hour or less, about 75 °C/hour or less, about 50 °C/hour or less, about 40 °C/hour or less, about 30 °C/hour or less, about 25 °C/hour or less, about 20 °C/hour or less, about 15 °C/hour or less, or about 10 °C/hour or less. The sheet can soak at the temperature for a period of time. In certain aspects, the sheet is allowed to soak for up to approximately 6 hours (e.g., from about 10 seconds to about 6 hours, inclusively). For example, the sheet can be soaked at the temperature of from about 230 °C to about 370 °C for about 20 seconds, about 25 seconds, about 30 seconds, about 35 seconds, about 40 seconds, about 45 seconds, about 50 seconds, about 55 seconds, about 60 seconds, about 65 seconds, about 70 seconds, about 75 seconds, about 80 seconds, about 85 seconds, about 90 seconds, about 95 seconds, about 100 seconds, about 105 seconds, about 110 seconds, about 115 seconds, about 120 seconds, about 125 seconds, about 130 seconds, about 135 seconds, about 140 seconds, about 145 seconds, about 150 seconds, about 5 minutes, about 10 minutes, about 15 minutes, about 20 minutes, about 25 minutes, about 30 minutes, about 35 minutes, about 40 minutes, about 45 minutes, about 50 minutes, about 55 minutes, about 60 minutes, about 65 minutes, about 70 minutes, about 75 minutes, about 80 minutes, about 85 minutes, about 90 minutes, about 95 minutes, about 100 minutes, about 105 minutes, about 110 minutes, about 115 minutes, about 120 minutes, about 2.5 hours, about 3 hours, about 3.5 hours, about 4 hours, about 4.5 hours, about 5 hours, about 5.5 hours, about 6 hours, or anywhere in between. In some examples, the sheet is not annealed.

In some examples, the sheet is heated to an annealing temperature of about 200 °C to about 400 °C at a constant rate of about 40 °C/hour to about 50 °C/hour. In some aspects, the sheet is allowed to soak at the annealing temperature for about 3 hours to about 5 hours (e.g., for about 4 hours). In some cases, the sheet is cooled from the annealing temperature at a constant rate of about 40 °C/hour to about 50 °C/hour. In some examples, the sheet is not annealed.

Methods of Using

The alloys and methods described herein can be used in automotive and/or transportation applications, including motor vehicle, aircraft, and railway applications, or any other desired application. In some examples, the alloys and methods can be used to prepare motor vehicle body part products, such as safety cages, bodies-in-white, crash rails, bumpers, side beams, roof beams, cross beams, pillar reinforcements (e.g., A-pillars, B-pillars, and C-pillars), inner panels, outer panels, side panels, inner hoods, outer hoods, or trunk lid panels. The aluminum alloys and methods described herein can also be used in aircraft or railway vehicle applications, to prepare, for example, external and internal panels.

The alloys and methods described herein can also be used in electronics applications, to prepare, for example, external and internal encasements. For example, the alloys and methods described herein can also be used to prepare housings for electronic devices, including mobile phones and tablet computers. In some examples, the alloys can be used to prepare housings for the outer casing of mobile phones (e.g., smart phones) and tablet bottom chassis.

The alloys and methods described herein can also be used as part of a composite part, such as in combination with a carbon fiber reinforced polymer (CFRP). For example, the CFRP could be added as a patch before or after stamping, such as by using the process described in , or the alloys described herein could be joined to other CFRP parts.

The following examples will serve to further illustrate the present invention without, however, constituting any limitation thereof. On the contrary, it is to be clearly understood that resort may be had to various embodiments, modifications and equivalents thereof which, after reading the description herein, may suggest themselves to those skilled in the art without departing from the spirit of the invention. During the studies described in the following examples, conventional procedures were followed, unless otherwise stated. Some of the procedures are described below for illustrative purposes.

EXAMPLES

Example 1: Yield Strength of Alloys in F Temper and After Annealing

Exemplary alloys, as shown in Table 6, were prepared according to the methods described herein. Alloys 1, 2, 3, and 4 are exemplary alloys created according to methods described herein. The yield strength of each sample was tested in F temper and after full annealing at 450 °C for 1 hour. The testing was performed according to ASTM B557 standards.

Table 6

Sample	Zinc (wt. %)	Silicon (wt. %)	Copper (wt. %)
1	15	9	2
2	25	7	--
3	25	7	2
4	35	5	--

The yield strength results are shown in FIG. 1. As shown in FIG. 1, each Sample, in F temper, had a yield strength of greater than 350 MPa. After full annealing, Sample 2 had a yield strength of just under 300 MPa. By adding 2 wt. % copper to Sample 2, the yield strength after full annealing (Sample 3) increased to over 300 MPa. By increasing the zinc content as shown in Sample 4, the yield strength, after full annealing, was also over 300 MPa, even with copper omitted.

Example 2: Comparison of Elongation and Yield Strength of AlZnSi Alloy with 6xxx Series Alloy

An exemplary aluminum alloy comprising silicon and zinc was compared to a 6xxx series aluminum alloy comprising silicon and magnesium. The elongation at failure and strength at failure were measured. The results are shown in FIG. 2.

The aluminum alloys described herein provide high-zinc content which enables the manufacture of aluminum alloys with high strength at room temperature. The alloys need not be subjected to post-forming heat-treatment or to paint-bake. They may be used in automotive parts and as parts of mixed assemblies which only go through low- or mid-temperature curing. The aluminum alloys described herein can also be used in other situations where high mechanical strength is desired.

Example 3: Comparison of Elongation and Yield Strength of AlZnCu Alloy with 6xxx Series Alloy

An exemplary aluminum alloy comprising copper and zinc was compared to a 7xxx series aluminum alloy comprising silicon and magnesium. Additionally, an exemplary aluminum alloy comprising copper, zinc and magnesium was compared to a 7xxx series aluminum alloy comprising silicon and magnesium. The elongation at failure and strength at failure were measured. The results are shown in FIG. 3.

The aluminum alloys described herein provide high-zinc content which enables the manufacture of aluminum alloys with high strength at room temperature. The alloys need not be subjected to post-forming heat-treatment or to paint-bake. They may be used in automotive parts and as parts of mixed assemblies which only go through low- or mid-temperature curing. The aluminum alloys described herein can also be used in other situations where high mechanical strength is desired.

Example 4:

Four exemplary aluminum alloys were prepared using the following process. The alloys were cast and then homogenized at 400°C, hot rolled to 2.0 mm, and then annealed at 400°C for one hour. Next, annealed alloy was aged at 160°C for 6 hours, cold rolled to 1.5 mm, and then warm-formed from 300-450°C.

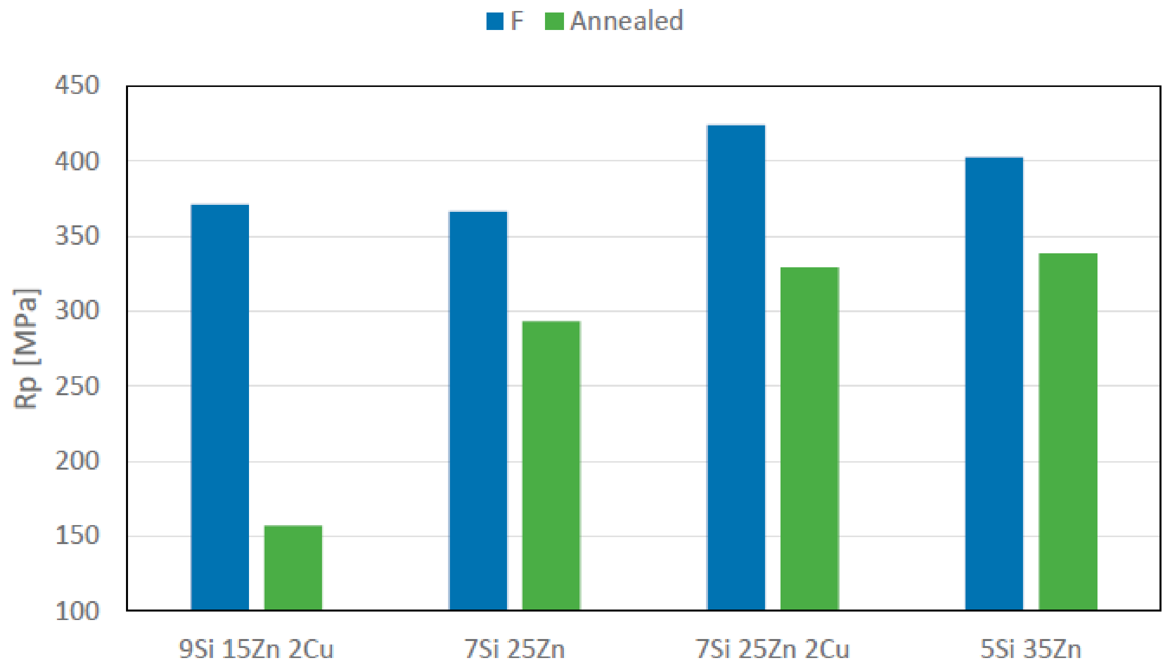
F
Annealed
Rp [MPa]
450
400
350
300
250
200
150
100
9Si 15Zn 2Cu
7Si 25Zn
7Si 25Zn 2Cu
5Si 35Zn

FIG. 1

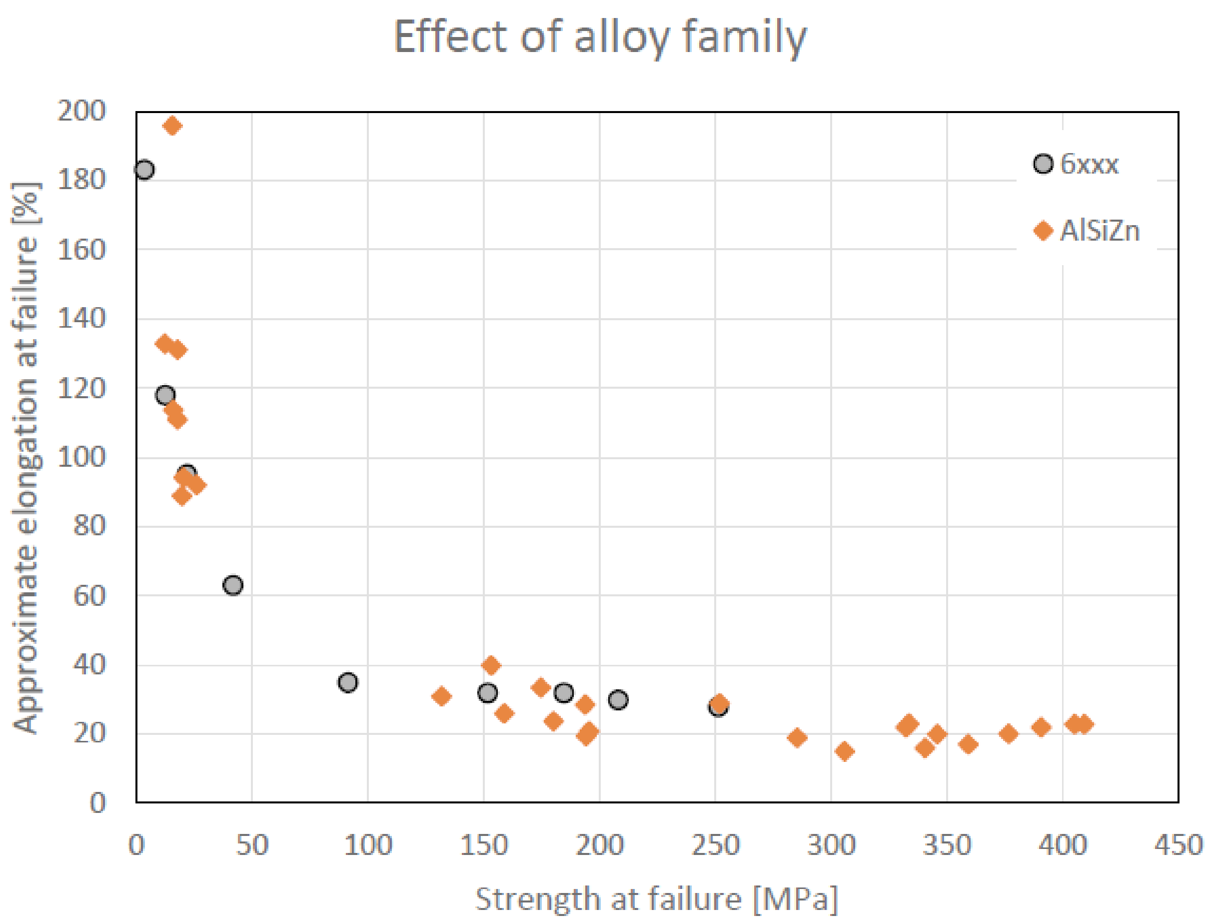
Effect of alloy family
Approximate elongation at failure [%]
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
Strength at failure [MPa]
6xxx
AlSiZn

FIG. 2

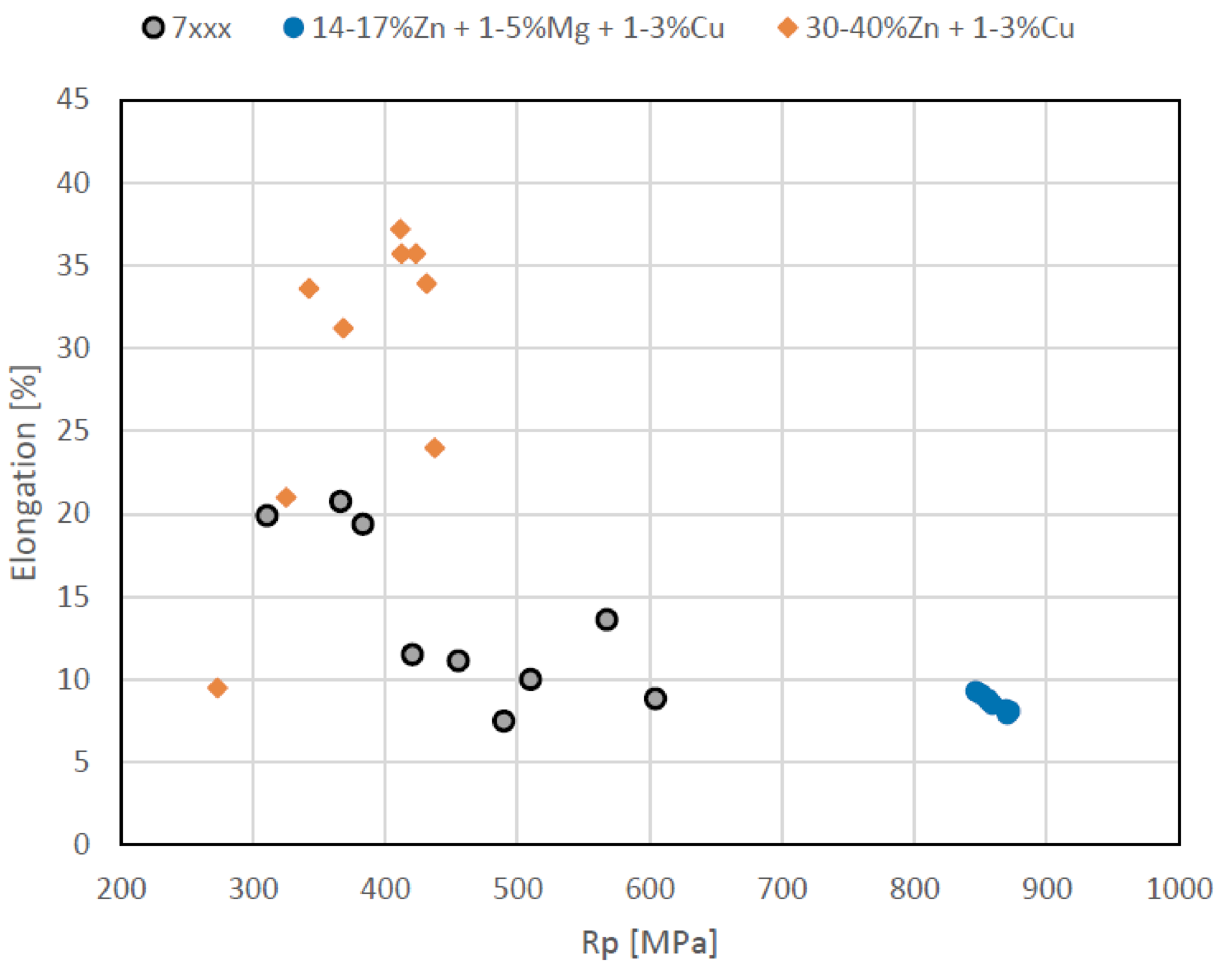
7xxx
14-17%Zn + 1-5%Mg + 1-3%Cu
30-40%Zn + 1-3%Cu
Elongation [%]
45
40
35
30
25
20
15
10
5
0
200
300
400
500
600
700
800
900
1000
Rp [MPa]

FIG. 3