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Canadian Intellectual Property Office

CA 3066252 C 2022/11/01

(11)(21) **3 066 252**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(86) Date de dépôt PCT/PCT Filing Date: 2018/06/21
(87) Date publication PCT/PCT Publication Date: 2018/12/27
(45) Date de délivrance/Issue Date: 2022/11/01
(85) Entrée phase nationale/National Entry: 2019/12/04
(86) N° demande PCT/PCT Application No.: US 2018/038838
(87) N° publication PCT/PCT Publication No.: 2018/237196
(30) Priorités/Priorities: 2017/06/21 (US62/523,128); 2017/10/12 (US62/571,401)

(51) Cl.Int./Int.Cl. *C22C 21/10* (2006.01), *C22F 1/053* (2006.01)

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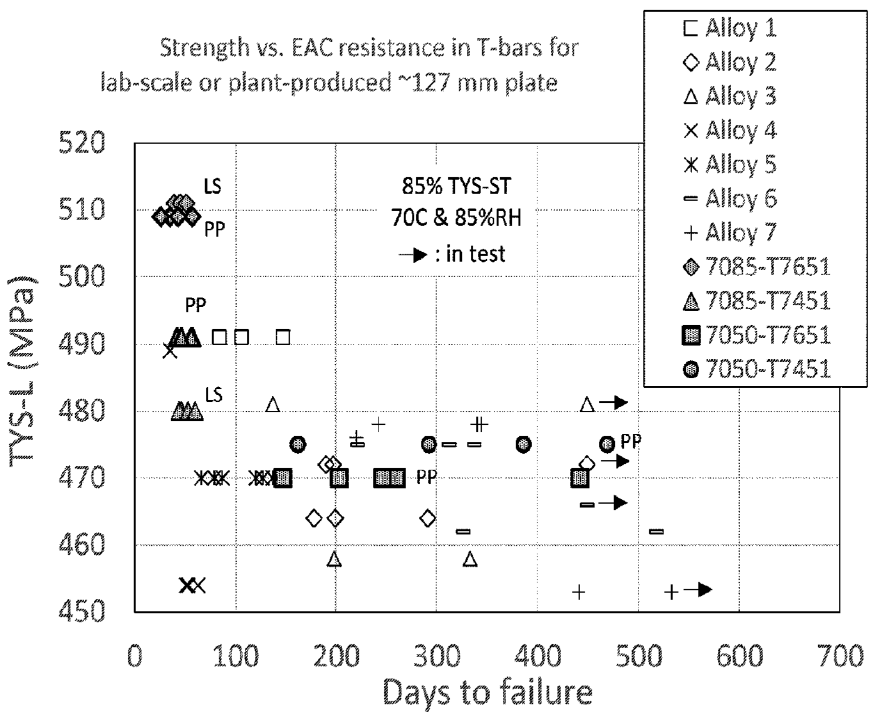
(54) Titre : ALLIAGES D'ALUMINIUM 7XXX CORROYES EPAIS PERFECTIONNES ET LEURS PROCEDES DE PRODUCTION
(54) Title: IMPROVED THICK WROUGHT 7XXX ALUMINUM ALLOYS, AND METHODS FOR MAKING THE SAME



(57) Abrégé/Abstract:
Disclosed are improved thick wrought 7xxx aluminum alloy products, and methods for producing the same. The new 7xxx aluminum alloy products may realize an improved combination of environmentally assisted crack resistance and at least one of strength, elongation, and fracture toughness, among other properties. The new 7xxx aluminum alloy products generally include high amounts of manganese. The new 7xxx aluminum alloy products thus generally include from 0.15 to 0.50 wt. % Mn in combination with 5.5-7.5 wt. % Zn, 0.95-2.20 wt. % Mg, and 1.50-2.40 wt. % Cu.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

REVISED VERSION

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 December 2018 (27.12.2018)

WIPO | PCT

(10) International Publication Number
WO 2018/237196 A9

(51) International Patent Classification:
C22C 21/10 (2006.01) *C22F 1/053* (2006.01)

(21) International Application Number:
PCT/US2018/038838

(22) International Filing Date:
21 June 2018 (21.06.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/523,128 21 June 2017 (21.06.2017) US
62/571,401 12 October 2017 (12.10.2017) US

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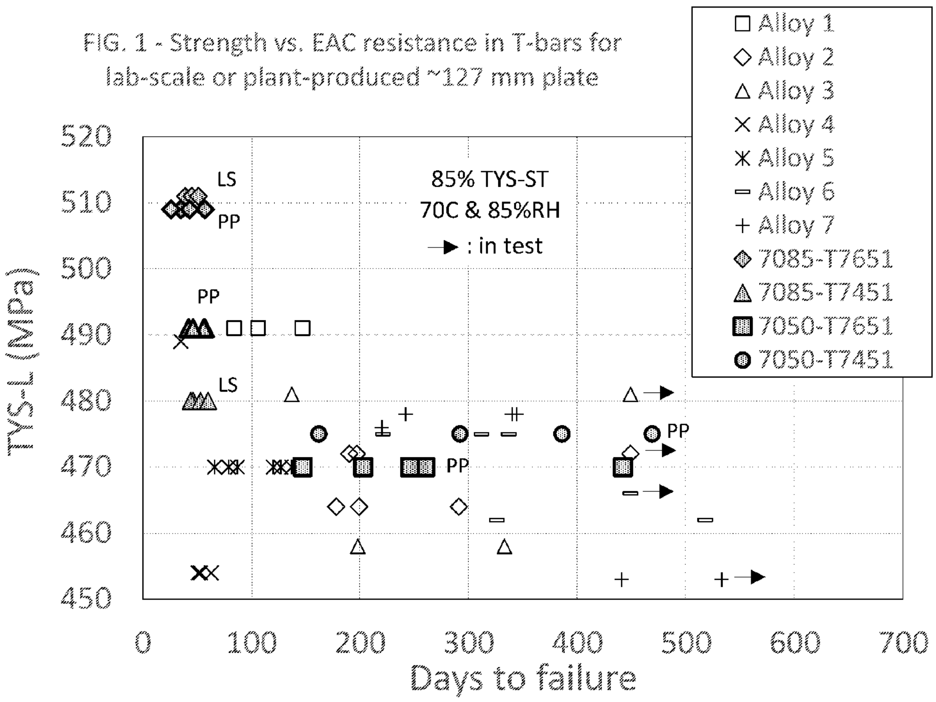
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,

(54) Title: IMPROVED THICK WROUGHT 7XXX ALUMINUM ALLOYS, AND METHODS FOR MAKING THE SAME



(57) Abstract: Disclosed are improved thick wrought 7xxx aluminum alloy products, and methods for producing the same. The new 7xxx aluminum alloy products may realize an improved combination of environmentally assisted crack resistance and at least one of strength, elongation, and fracture toughness, among other properties. The new 7xxx aluminum alloy products generally include high amounts of manganese. The new 7xxx aluminum alloy products thus generally include from 0.15 to 0.50 wt. % Mn in combination with 5.5-7.5 wt. % Zn, 0.95-2.20 wt. % Mg, and 1.50-2.40 wt. % Cu.

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HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*
— *with amended claims and statement (Art. 19(1))*

(88) Date of publication of the revised international search report:
21 February 2019 (21.02.2019)

(15) Information about Correction:
see Notice of 21 February 2019 (21.02.2019)

IMPROVED THICK WROUGHT 7XXX ALUMINUM ALLOYS, AND METHODS FOR MAKING THE SAME

[001]

FIELD OF THE INVENTION

[002] The present patent application relates to improved thick wrought 7xxx aluminum alloy products and methods for producing the same.

BACKGROUND

[003] Aluminum alloys are useful in a variety of applications. However, improving one property of an aluminum alloy without degrading another property is elusive. For example, it is difficult to increase the strength of a wrought aluminum alloy without affecting other properties such as fracture toughness or corrosion resistance. 7xxx (Al-Zn-Mg based) are prone to corrosion. *See, e.g.*, Bonn, W. Grubl, "*The stress corrosion behaviour of high strength AlZnMg alloys*," Paper held at the International Meeting of Associazione Italiana di Metallurgie, "Aluminum Alloys in Aircraft Industries," Turin, October 1976.

SUMMARY OF THE DISCLOSURE

[004] Broadly, the present patent application relates to improved thick wrought 7xxx aluminum alloy products, and methods for producing the same. The new thick wrought 7xxx aluminum alloy products ("the new 7xxx aluminum alloy products") may realize an improved combination of environmentally assisted crack resistance and at least one of strength, elongation, and fracture toughness, among other properties.

[005] The new 7xxx aluminum alloy products generally include high amounts of manganese. Manganese in combination with appropriate amounts of zinc, magnesium, and copper has been found to facilitate production of thick 7xxx aluminum alloy products having a high resistance to environmentally assisted cracking. The new 7xxx aluminum alloy products thus generally include (and in some instances consist of, or consist essentially of) from 0.15 to 0.50 wt. % Mn in combination with 5.5-7.5 wt. % Zn, 0.95-2.20 wt. % Mg, and

Date Reçue/Date Received 2021-08-05

1.50-2.40 wt. % Cu. The new wrought 7xxx aluminum alloy products are generally at least 1.5 inches thick, and may be up to 12 inches thick, and realize resistance to environmentally assisted cracking in the short transverse (ST) direction, which resistance is important for aerospace and other applications, especially those with structural loading in the short transverse (ST) direction. Such thick, wrought 7xxx aluminum alloy product generally also realize good strength, elongation, fracture toughness and crack-deviation resistance properties. Thus, the new wrought 7xxx aluminum alloy products generally realize an improved combination of corrosion resistance and at least one of strength, elongation, fracture toughness and crack-deviation resistance. In addition to manganese, zinc, magnesium and copper, the new 7xxx aluminum alloy products may include normal grain structure control materials, grain refiners, and impurities. For instance, the new 7xxx aluminum alloy products may include one or more of Zr, Cr, Sc, and Hf as grain structure control materials (e.g., from 0.05-0.25 wt. % each of one or more of Zr, Cr, Sc, and Hf), limiting the total amounts of these elements such that large primary particles do not form in the alloy. As another example, the new 7xxx aluminum alloy products may include up to 0.15 wt. % Ti as a grain refiner, optionally with some of the titanium in the form of TiB_2 and/or TiC. The new 7xxx aluminum alloy products may include up to 0.20 wt. % Fe and up to 0.15 wt. % Si as impurities. Lower amounts of iron and silicon may be used. The balance of the new 7xxx aluminum alloy products is generally aluminum and other unavoidable impurities (other than iron and silicon).

[006] As noted above, the new 7xxx aluminum alloy products generally include from 0.15 to 0.50 wt. % Mn. The new 7xxx aluminum alloy products generally include a sufficient amount of the manganese to facilitate realization of environmentally assisted crack resistance (EAC resistance) in the new 7xxx aluminum alloy products. In one embodiment, a new 7xxx aluminum alloy product includes at least 0.18 wt. % Mn to facilitate EAC resistance. In another embodiment, a new 7xxx aluminum alloy product includes at least 0.20 wt. % Mn. In yet another embodiment, a new 7xxx aluminum alloy product includes at least 0.22 wt. % Mn. In another embodiment, a new 7xxx aluminum alloy product includes at least 0.25 wt. % Mn. In yet another embodiment, a new 7xxx aluminum alloy product includes at least 0.275 wt. % Mn.

[007] The amount of manganese should be limited to restrict imparting undue quench sensitivity to the new 7xxx aluminum alloy products. In one embodiment, a new 7xxx aluminum alloy product includes not greater than 0.45 wt. % Mn. In another embodiment, a new 7xxx aluminum alloy product includes not greater than 0.40 wt. % Mn. In yet another

embodiment, a new 7xxx aluminum alloy product includes not greater than 0.375 wt. % Mn. In another embodiment, a new 7xxx aluminum alloy product includes not greater than 0.35 wt. % Mn. In another embodiment, a new 7xxx aluminum alloy product includes not greater than 0.325 wt. % Mn. In yet another embodiment, a new 7xxx aluminum alloy product includes not greater than 0.30 wt. % Mn.

[008] As noted above, the new 7xxx aluminum alloy products generally include tailored amounts of zinc, magnesium and copper, in addition to the manganese, to facilitate realization of EAC resistance in combination with good strength and/or fracture toughness properties, among others. In this regard, the new 7xxx aluminum alloy products generally include from 0.15 to 0.50 wt. % Mn, such as any of the manganese limits / ranges described above, in combination with 5.5-7.5 wt. % Zn, 0.95-2.20 wt. % Mg, and 1.50-2.4 wt. % Cu. In one embodiment, the new 7xxx aluminum alloy products generally include from 0.15 to 0.50 wt. % Mn, such as any of the manganese limits / ranges described above, in combination with 5.5-7.2 wt. % Zn, 1.05-2.05 wt. % Mg, and 1.5-2.2 wt. % Cu.

[009] As noted above, the new 7xxx aluminum alloy products generally include from 5.5 to 7.5 wt. % Zn. In one embodiment, a new alloy includes not greater than 7.4 wt. % Zn. In another embodiment, a new alloy includes not greater than 7.3 wt. % Zn. In yet another embodiment, a new alloy includes not greater than 7.2 wt. % Zn. In another embodiment, a new alloy includes not greater than 7.1 wt. % Zn. In another embodiment, a new alloy includes not greater than 7.0 wt. % Zn. In yet another embodiment, a new alloy includes not greater than 6.9 wt. % Zn. In another embodiment, a new alloy includes not greater than 6.8 wt. % Zn. In yet another embodiment, a new alloy includes not greater than 6.7 wt. % Zn. In one embodiment, a new alloy includes at least 5.5 wt. % Zn. In another embodiment, a new alloy includes at least 5.75 wt. % Zn. In yet another embodiment, a new alloy includes at least 6.0 wt. % Zn. In another embodiment, a new alloy includes at least 6.25 wt. % Zn. In another embodiment, a new alloy includes at least 6.375 wt. % Zn. In another embodiment, a new alloy includes at least 6.5 wt. % Zn.

[0010] As noted above, the new 7xxx aluminum alloy products generally include from 1.5 to 2.4 wt. % Cu. In one embodiment, a new alloy includes not greater than 2.3 wt. % Cu. In another embodiment, a new alloy includes not greater than 2.2 wt. % Cu. In one embodiment, a new alloy includes not greater than 2.1 wt. % Cu. In another embodiment, a new alloy includes not greater than 2.0 wt. % Cu. In one embodiment, a new alloy includes at least 1.55 wt. % Cu. In another embodiment, a new alloy includes at least 1.60 wt. % Cu. In yet another embodiment, a new alloy includes at least 1.65 wt. % Cu. In yet another embodiment, a new alloy includes at least 1.70 wt. % Cu. In yet another embodiment, a new alloy includes at least 1.75 wt. % Cu. In another embodiment, a new alloy includes at least 1.80 wt. % Cu.

[0011] As noted above, the new 7xxx aluminum alloy products generally include from 0.95 to 2.2 wt. % Mg. In one embodiment, a new alloy includes at least 1.05 wt. % Mg. In another embodiment, a new alloy includes at least 1.15 wt. % Mg. In yet another embodiment, a new alloy includes at least 1.25 wt. % Mg. In another embodiment, a new alloy includes at least 1.35 wt. % Mg. In yet another embodiment, a new alloy includes at least 1.40 wt. % Mg. In another embodiment, a new alloy includes at least 1.45 wt. % Mg. In yet another embodiment, a new alloy includes at least 1.50 wt. % Mg. In another embodiment, a new alloy includes at least 1.55 wt. % Mg. In another embodiment, a new alloy includes at least 1.60 wt. % Mg. In yet another embodiment, a new alloy includes at least 1.65 wt. % Mg. In another embodiment, a new alloy includes at least 1.70 wt. % Mg. In one embodiment, a new alloy includes not greater than 2.15 wt. % Mg. In another embodiment, a new alloy includes not greater than 2.10 wt. % Mg. In yet another embodiment, a new alloy includes not greater than 2.05 wt. % Mg. In another embodiment, a new alloy includes not greater than 2.00 wt. % Mg. In another embodiment, a new alloy includes not greater than 1.95 wt. % Mg. In yet another embodiment, a new alloy includes not greater than 1.90 wt. % Mg.

[0012] In one embodiment, a first 7xxx aluminum alloy product includes from 5.5 - 7.5 wt. % Zn, 1.7 - 2.2 wt. % Mg and 1.5 - 2.4 wt. % Cu. In one embodiment, the first 7xxx aluminum alloy product includes not greater than 7.2 wt. % Zn or not greater than 7.0 wt. % Zn (e.g., to facilitate improved EAC resistance). In one embodiment, the first 7xxx aluminum alloy product comprises 6.0 - 7.0 wt. % Zn.

[0013] In another embodiment, a second 7xxx aluminum alloy product includes from 5.5 - 7.5 wt. % Zn, 1.35 - 1.7 wt. % Mg and 1.5 - 2.1 wt. % Cu. The first 7xxx aluminum alloy product may realize, for instance, higher strength than the second aluminum alloy product, but possibly at the expense of reduced fracture toughness and/or reduced elongation. In one embodiment, the second 7xxx aluminum alloy product includes not greater than 7.2 wt. % Zn or not greater than 7.0 wt. % Zn (e.g., to facilitate improved EAC resistance). In one embodiment, the second 7xxx aluminum alloy product comprises 6.0 - 7.0 wt. % Zn.

[0014] In another embodiment, a third 7xxx aluminum alloy product includes from 5.5 - 7.5 wt. % Zn, 1.7 - 2.2 wt. % Mg and 1.5 - 1.8 wt. % Cu. This third 7xxx aluminum alloy product may be a lower strength zone of the first 7xxx aluminum alloy product region. In one embodiment, the third 7xxx aluminum alloy product includes not greater than 7.2 wt. % Zn or not greater than 7.0 wt. % Zn (e.g., to facilitate improved EAC resistance). In one embodiment, the third 7xxx aluminum alloy product comprises 6.0 - 7.0 wt. % Zn.

[0015] In another embodiment, a fourth 7xxx aluminum alloy product includes from 5.5 - 7.5 wt. % Zn, 1.7 - 2.2 wt. % Mg and 1.8 - 2.0 wt. % Cu. This forth 7xxx aluminum alloy product may be a middle strength zone of the first 7xxx aluminum alloy product region. In one embodiment, the fourth 7xxx aluminum alloy product includes not greater than 7.2 wt. % Zn or not greater than 7.0 wt. % Zn (e.g., to facilitate improved EAC resistance). In one embodiment, the fourth 7xxx aluminum alloy product comprises 6.0 - 7.0 wt. % Zn.

[0016] In another embodiment, a fifth 7xxx aluminum alloy product includes from 5.5 - 7.5 wt. % Zn, 1.7 - 2.2 wt. % Mg and 2.0 - 2.4 wt. % Cu. This fifth 7xxx aluminum alloy product may be a higher strength zone of the first 7xxx aluminum alloy product region. In one embodiment, a fifth 7xxx aluminum alloy product includes 2.0 - 2.2 wt. % Cu. In one embodiment, the fifth 7xxx aluminum alloy product includes not greater than 7.2 wt. % Zn or not greater than 7.0 wt. % Zn (e.g., to facilitate improved EAC resistance). In one embodiment, the fifth 7xxx aluminum alloy product comprises 6.0 - 7.0 wt. % Zn.

[0017] The third 7xxx aluminum alloy product may realize higher toughness and/or elongation as compared to the fourth or fifth aluminum alloy products. The fourth 7xxx aluminum alloy product may realize higher toughness and/or elongation as compared to the fifth aluminum alloy products.

[0018] In one embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 2.9 wt. %. In another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.0 wt. %. In yet another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.1 wt. %. In another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.2 wt. %. In another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.3 wt. %. In yet another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.35 wt. %. In another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.4 wt. %. In yet another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.45 wt. %. In another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.5 wt. %. In yet another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.55 wt. %. In another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.6 wt. %. In yet another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.65 wt. %. In another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.7 wt. %.

[0019] In one embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.5 wt. %. In another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.4 wt. %. In yet another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.3 wt. %. In another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.2 wt. %. In yet another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.1 wt. %. In another embodiment, a new alloy includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.0 wt. %.

[0020] In one embodiment, the amounts of zinc, magnesium and copper within the 7xxx aluminum alloy product satisfy the relationship: $2.362 \leq Mg+0.429*Cu+0.067*Zn \leq 3.062$. In another embodiment, the amounts of zinc, magnesium and copper within the 7xxx aluminum alloy product satisfy the relationship: $2.502 \leq Mg+0.429*Cu+0.067*Zn \leq 2.912$. In yet another embodiment, the amounts of zinc, magnesium and copper within the 7xxx aluminum alloy product satisfy the relationship: $2.662 \leq Mg+0.429*Cu+0.067*Zn \leq 3.062$. In another embodiment, the amounts of zinc, magnesium and copper within the 7xxx aluminum alloy product satisfy the relationship: $2.662 \leq Mg+0.429*Cu+0.067*Zn \leq 2.912$. Any of the zinc, magnesium, and copper amounts described in the preceding paragraphs may be used in combination with the above-shown empirical relationships.

[0021] In one approach, the amounts of zinc and magnesium within the 7xxx aluminum alloy product are such that the weight ratio of zinc-to-magnesium is not greater than 5.25:1 (i.e., (wt. % Zn / wt. % Mg) $\leq$ 5.25:1). In one embodiment, a weight ratio of zinc-to-magnesium is not greater than 5.00:1 (i.e., (wt. % Zn / wt. % Mg) $\leq$ 5.00:1). In another embodiment, a weight ratio of zinc-to-magnesium is not greater than 4.75:1 (i.e., (wt. % Zn / wt. % Mg) $\leq$ 4.75:1). In yet another embodiment, a weight ratio of zinc-to-magnesium is not greater than 4.60:1 (i.e., (wt. % Zn / wt. % Mg) $\leq$ 4.60:1). In another embodiment, a weight ratio of zinc-to-magnesium is not greater than 4.50:1 (i.e., (wt. % Zn / wt. % Mg) $\leq$ 4.50:1). In yet another embodiment, a weight ratio of zinc-to-magnesium is not greater than 4.40:1

(i.e., (wt. % Zn / wt. % Mg) ≤ 4.40:1). In another embodiment, a weight ratio of zinc-to-magnesium is not greater than 4.35:1 (i.e., (wt. % Zn / wt. % Mg) ≤ 4.35:1). In yet another embodiment, a weight ratio of zinc-to-magnesium is not greater than 4.30:1 (i.e., (wt. % Zn / wt. % Mg) ≤ 4.30:1). In another embodiment, a weight ratio of zinc-to-magnesium is not greater than 4.25:1 (i.e., (wt. % Zn / wt. % Mg) ≤ 4.25:1). In yet another embodiment, a weight ratio of zinc-to-magnesium is not greater than 4.20:1 (i.e., (wt. % Zn / wt. % Mg) ≤ 4.20:1). In another embodiment, a weight ratio of zinc-to-magnesium is not greater than 4.15:1 (i.e., (wt. % Zn / wt. % Mg) ≤ 4.15:1). In yet another embodiment, a weight ratio of zinc-to-magnesium is not greater than 4.10:1 (i.e., (wt. % Zn / wt. % Mg) ≤ 4.10:1). In another embodiment, a weight ratio of zinc-to-magnesium is not greater than 4.00:1 (i.e., (wt. % Zn / wt. % Mg) ≤ 4.00:1). In yet another embodiment, a weight ratio of zinc-to-magnesium is not greater than 3.95:1 (i.e., (wt. % Zn / wt. % Mg) ≤ 3.95:1). In another embodiment, a weight ratio of zinc-to-magnesium is not greater than 3.90:1 (i.e., (wt. % Zn / wt. % Mg) ≤ 3.90:1).

[0022] In one approach, the amounts of zinc and magnesium within the 7xxx aluminum alloy product are such that the weight ratio of zinc-to-magnesium is at least 3.0:1 (i.e., (wt. % Zn / wt. % Mg) ≥ 3.0:1). In one embodiment, the amounts of zinc and magnesium within the 7xxx aluminum alloy product are such that the weight ratio of zinc-to-magnesium is at least 3.25:1 (i.e., (wt. % Zn / wt. % Mg) ≥ 3.25:1). In another embodiment, the amounts of zinc and magnesium within the 7xxx aluminum alloy product are such that the weight ratio of zinc-to-magnesium is at least 3.33:1 (i.e., (wt. % Zn / wt. % Mg) ≥ 3.33:1). In yet another embodiment, the amounts of zinc and magnesium within the 7xxx aluminum alloy product are such that the weight ratio of zinc-to-magnesium is at least 3.45:1 (i.e., (wt. % Zn / wt. % Mg) ≥ 3.45:1). In another embodiment, the amounts of zinc and magnesium within the 7xxx aluminum alloy product are such that the weight ratio of zinc-to-magnesium is at least 3.55:1 (i.e., (wt. % Zn / wt. % Mg) ≥ 3.55:1). In yet another embodiment, the amounts of zinc and magnesium within the 7xxx aluminum alloy product are such that the weight ratio of zinc-to-magnesium is at least 3.60:1 (i.e., (wt. % Zn / wt. % Mg) ≥ 3.60:1).

[0023] As noted above, the new 7xxx aluminum alloy product may include one or more of Zr, Cr, Sc, and Hf as grain structure control materials (e.g., from 0.05-0.25 wt. % each of one or more of Zr, Cr, Sc, and Hf), limiting the total amounts of these elements such that large primary particles do not form in the alloy. Grain structure control materials may, for instance, facilitate an appropriate grain structure (e.g., an unrecrystallized grain structure). When employed, a new 7xxx aluminum alloy product generally includes at least 0.05 wt. %

of the grain structure control materials. In one embodiment, a new 7xxx aluminum alloy product includes at least 0.07 wt. % of the grain structure control materials. In another embodiment, a new 7xxx aluminum alloy product includes at least 0.09 wt. % of the grain structure control materials. When employed, a new 7xxx aluminum alloy product generally includes not greater than 1.0 wt. % of the grain structure control materials. In one embodiment, a new 7xxx aluminum alloy product includes not greater than 0.75 wt. % of the grain structure control materials. In yet another embodiment, a new 7xxx aluminum alloy product includes not greater than 0.50 wt. % of the grain structure control materials. In one embodiment, the grain structure control materials are selected from the group consisting of Zr, Cr, Sc, and Hf. In another embodiment, the grain structure control materials are selected from the group consisting of Zr and Cr. In another embodiment, the grain structure control material is Zr. In another embodiment, the grain structure control material is Cr.

[0024] In one embodiment, the grain structure control materials comprise both Zr and Cr, and a new 7xxx aluminum alloy product includes at least 0.07 wt. % Zr and at least 0.07 wt. % Cr, wherein the wt. % Zr plus the wt. % Cr is not greater than 0.40 wt. % (i.e., wt. % Zr + wt. % Cr $\leq$ 0.40 wt. %). In another embodiment, the grain structure control materials comprise both Zr and Cr, and a new 7xxx aluminum alloy product includes at least 0.07 wt. % Zr and at least 0.07 wt. % Cr, wherein the wt. % Zr plus the wt. % Cr is not greater than 0.35 wt. % (i.e., wt. % Zr + wt. % Cr $\leq$ 0.35 wt. %). In another embodiment, the grain structure control materials comprise both Zr and Cr, and a new 7xxx aluminum alloy product includes at least 0.07 wt. % Zr and at least 0.07 wt. % Cr, wherein the wt. % Zr plus the wt. % Cr is not greater than 0.30 wt. % (i.e., wt. % Zr + wt. % Cr $\leq$ 0.30 wt. %). In another embodiment, the grain structure control materials comprise both Zr and Cr, and a new 7xxx aluminum alloy product includes at least 0.07 wt. % Zr and at least 0.07 wt. % Cr, wherein the wt. % Zr plus the wt. % Cr is not greater than 0.25 wt. % (i.e., wt. % Zr + wt. % Cr $\leq$ 0.25 wt. %). In another embodiment, the grain structure control materials comprise both Zr and Cr, and a new 7xxx aluminum alloy product includes at least 0.07 wt. % Zr and at least 0.07 wt. % Cr, wherein the wt. % Zr plus the wt. % Cr is not greater than 0.20 wt. % (i.e., wt. % Zr + wt. % Cr $\leq$ 0.20 wt. %). In any of these embodiment, a new 7xxx aluminum alloy product may include at least 0.09 wt. % of at least one of Zr and Cr. In any of these embodiments, a new 7xxx aluminum alloy product may include at least 0.09 wt. % of both Zr and Cr.

[0025] In one embodiment, the grain structure control material is Zr, and a new 7xxx aluminum alloy product includes from 0.07 to 0.18 wt. % Zr. In another embodiment, the grain structure control material is Zr, and a new 7xxx aluminum alloy product includes from 0.07 to 0.16 wt. % Zr. In yet another embodiment, the grain structure control material is Zr, and a new 7xxx aluminum alloy product includes from 0.08 to 0.15 wt. % Zr. In another embodiment, the grain structure control material is Zr, and a new 7xxx aluminum alloy product includes from 0.09 to 0.14 wt. % Zr. In embodiments where the grain structure control material is Zr, a new 7xxx aluminum alloy product generally contains low amounts of the Cr, Sc, and Hf (e.g., ≤ 0.04 wt. % each of Cr, Sc, and Hf.). In one embodiment, a new 7xxx aluminum alloy product contains not greater than 0.03 wt. % each of Cr, Sc, and Hf. In another embodiment, a new 7xxx aluminum alloy product contains not greater than 0.02 wt. % each of Cr, Sc, and Hf. In another embodiment, a new 7xxx aluminum alloy product contains not greater than 0.01 wt. % each of Cr, Sc, and Hf. In another embodiment, a new 7xxx aluminum alloy product contains not greater than 0.005 wt. % each of Cr, Sc, and Hf.

[0026] In one embodiment, the grain structure control material is Cr, and a new 7xxx aluminum alloy product includes from 0.07 to 0.25 wt. % Cr. In another embodiment, the grain structure control material is Cr, and a new 7xxx aluminum alloy product includes from 0.07 to 0.20 wt. % Cr. In yet another embodiment, the grain structure control material is Cr, and a new 7xxx aluminum alloy product includes from 0.08 to 0.15 wt. % Cr. In another embodiment, the grain structure control material is Cr, and a new 7xxx aluminum alloy product includes from 0.10 to 0.15 wt. % Cr. In other embodiments, a new 7xxx aluminum alloy product contains low amounts of Cr (e.g., ≤ 0.04 wt. % Cr.) In one embodiment, a new 7xxx aluminum alloy product contains not greater than 0.03 wt. % Cr. In another embodiment, a new 7xxx aluminum alloy product contains not greater than 0.02 wt. % Cr. In yet another embodiment, a new 7xxx aluminum alloy product contains not greater than 0.01 wt. % Cr. In another embodiment, a new 7xxx aluminum alloy product contains not greater than 0.005 wt. % Cr.

[0027] In some embodiments, a new 7xxx aluminum alloy includes low amounts of zirconium (e.g., ≤ 0.04 wt. % Zr). In one embodiment, a new 7xxx aluminum alloy product contains not greater than 0.03 wt. % Zr. In another embodiment, a new 7xxx aluminum alloy product contains not greater than 0.02 wt. % Zr. In yet another embodiment, a new 7xxx aluminum alloy product contains not greater than 0.01 wt. % Zr. In another embodiment, a new 7xxx aluminum alloy product contains not greater than 0.005 wt. % Zr.

[0028] As noted above, the new 7xxx aluminum alloy product may include up to 0.15 wt. % Ti. Titanium may be used to facilitate grain refining during casting, such as by using TiB_2

or TiC. Elemental titanium may also or alternatively be used. In one embodiment, the new 7xxx aluminum alloy product includes from 0.005 to 0.025 wt. % Ti.

[0029] As noted above, the new 7xxx aluminum alloy product may include up to 0.15 wt. % Si and up to 0.20 wt. % Fe as impurities. The amount of silicon and iron may be limited so as to avoid detrimentally impacting the combination of strength, fracture toughness and crack deviation resistance. In one embodiment, the new 7xxx aluminum alloy product may include up to 0.12 wt. % Si and up to 0.15 wt. % Fe as impurities. In another embodiment, the new 7xxx aluminum alloy product may include up to 0.10 wt. % Si and up to 0.12 wt. % Fe as impurities. In another embodiment, the new 7xxx aluminum alloy product may include up to 0.08 wt. % Si and up to 0.10 wt. % Fe as impurities. In yet another embodiment, the new 7xxx aluminum alloy product may include up to 0.06 wt. % Si and up to 0.08 wt. % Fe as impurities. In yet another embodiment, the new 7xxx aluminum alloy product may include up to 0.04 wt. % Si and up to 0.06 wt. % Fe as impurities. In another embodiment, the new 7xxx aluminum alloy product may include up to 0.03 wt. % Si and up to 0.05 wt. % Fe as impurities.

[0030] As noted above, the new 7xxx aluminum alloy product has a thickness of from 1.5 to 12.0 inches. In one embodiment, the new 7xxx aluminum alloy product has a thickness of from 2.0 to 10.0 inches. In another embodiment, the new 7xxx aluminum alloy product has a thickness of from 3.0 to 8.0 inches (7.62 - 20.3 cm). In another embodiment, the new 7xxx aluminum alloy product has a thickness of from 1.5 to 8.0 inches. In another embodiment, the new 7xxx aluminum alloy product has a thickness of from 1.5 to 6.0 inches. In another embodiment, the new 7xxx aluminum alloy product has a thickness of from 1.5 to 4.0 inches. In another embodiment, the new 7xxx aluminum alloy product has a thickness of from 2.0 to 8.0 inches. In another embodiment, the new 7xxx aluminum alloy product has a thickness of from 2.0 to 6.0 inches. In another embodiment, the new 7xxx aluminum alloy product has a thickness of from 3.0 to 6.0 inches. In another embodiment, the new 7xxx aluminum alloy product has a thickness of from 4.0 to 10.0 inches. In another embodiment, the new 7xxx aluminum alloy product has a thickness of from 4.0 to 8.0 inches. In another embodiment, the new 7xxx aluminum alloy product has a thickness of from 4.0 to 6.0 inches.

[0031] In one embodiment, a new 7xxx aluminum alloy product is a rolled product (e.g., a plate product). In another embodiment, a new 7xxx aluminum alloy product is an extruded product. In yet another embodiment, a new 7xxx aluminum alloy product is a forged product (e.g., a hand forged product, a die forged product).

[0032] As mentioned above, the new 7xxx aluminum alloy products may realize an improved combination of properties. In one embodiment, a new 7xxx aluminum alloy product realizes a typical tensile yield strength (L) of at least 63 ksi as per ASTM E8 and B557. In another embodiment, a new 7xxx aluminum alloy product realizes a typical tensile yield strength (L) of at least 64 ksi. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical tensile yield strength (L) of at least 65 ksi. In another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (L) of at least 66 ksi. In yet another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (L) of at least 67 ksi. In another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (L) of at least 68 ksi. In yet another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (L) of at least 69 ksi. In another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (L) of at least 70 ksi. In yet another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (L) of at least 71 ksi. In another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (L) of at least 72 ksi. In yet another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (L) of at least 73 ksi.

[0033] In one embodiment, a new 7xxx aluminum alloy product realizes a typical tensile yield strength (ST) of at least 57 ksi as per ASTM E8 and B557. In another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (ST) of at least 58 ksi. In yet another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (ST) of at least 59 ksi. In another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (ST) of at least 60 ksi. In yet another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (ST) of at least 61 ksi. In another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (ST) of at least 62 ksi. In yet another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (ST) of at least 63 ksi. In another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (ST) of at least 64 ksi. In yet another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (ST) of at least 65 ksi. In another embodiment, a 7xxx aluminum alloy product may realize a typical tensile yield strength (ST) of at least 66 ksi.

[0034] In one embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (L-T) of at least 25 ksi-sqrt-inch as per ASTM E8 and E399-12. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC}

plane-stain fracture toughness (L-T) of at least 27 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 28 ksi-sqrt-inch. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 29 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 30 ksi-sqrt-inch. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 31 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 32 ksi-sqrt-inch. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 33 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 34 ksi-sqrt-inch. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 35 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 36 ksi-sqrt-inch. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 37 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 38 ksi-sqrt-inch. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 39 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 40 ksi-sqrt-inch. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 41 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 42 ksi-sqrt-inch. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 43 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 44 ksi-sqrt-inch. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-stain fracture toughness (L-T) of at least 45 ksi-sqrt-inch.

[0035] In one embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 20 ksi-sqrt-inch as per ASTM E8 and E399-12. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 22 ksi-sqrt-inch. In another embodiment, a new

7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 24 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 26 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 28 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 30 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 32 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 34 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 36 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 38 ksi-sqrt-inch. In another embodiment, a new 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 40 ksi-sqrt-inch.

[0036] In one embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (L) of at least 8% as per ASTM E8 and B557. In another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (L) of at least 9%. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (L) of at least 10%. In another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (L) of at least 11%. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (L) of at least 12%. In another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (L) of at least 13%. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (L) of at least 14%. In another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (L) of at least 15%. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (L) of at least 16%.

[0037] In one embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (ST) of at least 3% as per ASTM E8 and B557. In another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (ST) of at least 4%. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (ST) of at least 5%. In another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (ST) of at least 6%. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (ST) of at least 7%. In another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (ST) of at least 8%. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (ST) of at least 9%. In another embodiment, a new 7xxx aluminum alloy product realizes a typical elongation (ST) of at least 10%.

[0038] In one embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 25 ksi-sqrt-in. In another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 27 ksi-sqrt-in. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 29 ksi-sqrt-in. In another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 31 ksi-sqrt-in. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 33 ksi-sqrt-in. In another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 35 ksi-sqrt-in. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 37 ksi-sqrt-in. In another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 39 ksi-sqrt-in. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 41 ksi-sqrt-in. In another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 43 ksi-sqrt-in. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 45 ksi-sqrt-in. In another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 47 ksi-sqrt-in. In yet another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 49 ksi-sqrt-in. In another embodiment, a new 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max-dev}$) of at least 50 ksi-sqrt-in.

[0039] In one embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 80 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 100 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 120 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 140 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 160 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 180 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 200 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 220 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 240 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 260 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 280 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 300 days.

[0040] In one embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 90 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 120 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 150 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 180 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 210 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 240 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 270 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 300 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 330 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 360 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 390 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 420 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 450 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 480 days. In another embodiment, a new 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 500 days.

[0041] As noted above, the new thick 7xxx aluminum alloy products may be suitable for parts in various aerospace applications. In one embodiment, the alloy product is an aerospace structural component. The aircraft structural component may be any of an upper wing panel (skin), an upper wing stringer, an upper wing cover with integral stringers, a spar, a spar cap, a spar web, a rib, rib feet or a rib web, stiffening elements, frames, a landing gear component (e.g., a cylinders, beams), drag braces, bulkheads, flap track assemblies, fuselage and windshield frames, gear ribs, side stays, fittings, a fuselage component (e.g., a fuselage skin), and space components (e.g., for rockets and other vehicles that may exit the earth). In one embodiment, the alloy product is an armor component (e.g., of a motorized vehicle). In one embodiment, the alloy product is used in the oil and gas industry (e.g., as pipes, structural components). In one embodiment, the alloy product is a thick mold block / mold plate product (e.g., for injection molding). In one embodiment, the alloy product is an automotive product.

[0042] The new thick 7xxx aluminum alloy products may be made into wrought products by casting an aluminum alloy having any of the aforementioned compositions into an ingot or billet, followed by homogenizing of the ingot or billet. The homogenized ingot or billet may worked by rolling, extruding, or forging to final gauge, generally by hot working, optionally with some cold working. The final gauge product may be solution heat treated, and then quenched, and then stress relieved (e.g., by stretching or compression) and then artificially aged.

[0043] Aside from traditional wrought products, the new 7xxx aluminum alloys may be made into shape castings or by additive manufacturing into additively manufactured products. The additively manufactured products may be used as-is, or may be subsequently processed, e.g., processed via mechanical, thermal, or thermomechanical treatment.

Definitions

[0044] As used herein, "typical longitudinal (L) tensile yield strength" or TYS(L) is determined in accordance with ASTM B557-10 and by measuring the tensile yield strength (TYS) in the longitudinal direction (L) at the T/4 location from at least three different lots of material, and with at least duplicate specimens being tested for each lot, for a total of at least 6 different measured specimen values, with the typical TYS(L) being the average of the at least 6 different measured specimen values. Typical elongation (L) is measured during longitudinal tensile testing.

[0045] As used herein, "typical longitudinal (ST) tensile yield strength" or TYS(ST) is determined in accordance with ASTM B557-10 and by measuring the tensile yield strength (TYS) in the short transverse direction (ST) from at least three different lots of material, and with at least duplicate specimens being tested for each lot, for a total of at least 6 different measured specimen values, with the typical TYS(ST) being the average of the at least 6 different measured specimen values. Short transverse tensile specimens are taken so that the midpoint of the gage section coincides with the plate mid-thickness plane. Typical elongation (ST) is measured during short transverse tensile testing.

[0046] As used herein, "typical plane strain fracture toughness (K_{IC}) (L-T)" is determined in accordance with ASTM E399-12, by measuring the plane strain fracture toughness in the L-T direction at the T/4 location from at least three different lots of material using a C(T) specimen, where "W" is 4.0 inches, and where "B" is 2.0 inches for products having a thickness of at least 2.0 inches and where "B" is 1.5 inches for products having a thickness less than 2.0 inches, with at least duplicate specimens being tested for each lot, for a total of at least 6 different measured specimen values, and with the typical plane strain fracture toughness (K_{IC}) (L-T) being the average of the at least 6 different valid K_{IC} measured specimen values.

[0047] As used herein, "typical plane strain fracture toughness (K_{IC}) (S-L)" is determined in accordance with ASTM E399-12, by measuring the plane strain fracture toughness in the S-L direction at the T/2 location from at least three different lots of material using a C(T) specimen, where "W" and "B" are per the below table, with at least duplicate specimens being tested for each lot, for a total of at least 6 different measured specimen values, and with the typical plane strain fracture toughness (K_{IC}) (S-L) being the average of the at least 6 different valid K_{IC} measured specimen values.

S-L specimen parameters

Product Thickness	"W"	"B"
≥ 5.0 inches	4.0 inches	2.0 inches
< 5.0 inches to ≥ 3.8 inches	3.0 inches	1.5 inches
< 3.8 inches to ≥ 3.2 inches	2.5 inches	1.25 inches
< 3.2 inches to ≥ 2.6 inches	2.0 inches	1.0 inches
< 2.6 inches to ≥ 2.0 inches	1.5 inches	0.75 inches

Product Thickness	"W"	"B"
< 2.0 inches to ≥ 1.5 inches	1.0 inches	0.5 inches

[0048] The typical L-S crack deviation resistance properties ($K_{max\text{-}dev}$) are to be determined per the procedure described in commonly-owned U.S. Patent Application Publication No. 2017/0088920, paragraph 0058, *except*: (a) the "W" dimension of the specimen shall be 2.0 inches (5.08 cm), (b) the specimen shall be centered at T/2 (as opposed to the notch tip), and (c) the test specimens may be tested in lab air as opposed to high humidity air.

[0049] As used herein, "EAC resistance" is tested per ASTM G49 and per the conditions defined below. At least three short transverse (ST) samples are taken from mid-thickness of the final product and between W/4 and 3W/4 of the final product. The extracted samples are then machined into tensile specimens per ASTM E8 and matching the dimensions of FIG. 3 (the dimensions of FIG. 3 are in inches). If the final product thickness is at least 2.25 inches, then the length of the tensile specimen is 2.00 inches, as shown in FIG. 3. If the final product thickness is from 1.50 inches to less than 2.25 inches, the length of the specimen must be at least 1.25 inches and should be as close to 2.00 inches as possible. Prior to testing the tensile specimens are to be cleaned / degreased by washing in acetone. The tensile specimens are then strained in the short-transverse direction at 85% or 60% of their ST tensile yield strength (strength being measured at room temperature). The stressing frame used is a constant strain type per ASTM G49, section 7.2.2 (*see, e.g.,* FIG. 4a of ASTM G49). The strained specimens are then placed into a controlled cabinet having air at 85% relative humidity (without additions to the air, such as chlorides) and a temperature of 70°C. At least three specimens must be tested. The "typical EAC resistance" is the lowest failure date of the at least three specimens. For instance, if specimen A fails at 76 days, but specimens B and C fail at 140 and 180 days, respectively, the "typical EAC resistance" is 76 days. A failure is when the specimen breaks into two halves, either along the gauge length or at one of the specimen shoulders adjoining the gauge length. Shoulder failures are statistically equivalent to gauge length failures. Thread failures are not included when determining typical EAC resistance. A thread failure is when a crack occurs in a threaded end of a specimen as opposed to in the gauge length. Thread failures are generally not detectable until the specimen is removed from the stressing frame.

[0050] The term "square root" may be abbreviated herein as "sqrt."

Date Reçue/Date Received 2021-08-05

[0051] Throughout the specification and claims, the following terms take the meanings explicitly associated herein, unless the context clearly dictates otherwise. The phrases "in one embodiment" and "in some embodiments" as used herein do not necessarily refer to the same embodiment(s), though they may. Furthermore, the phrases "in another embodiment" and "in some other embodiments" as used herein do not necessarily refer to a different embodiment, although they may. Thus, as described below, various embodiments of the invention may be readily combined, without departing from the scope or spirit of the invention.

[0052] In addition, as used herein, the term "or" is an inclusive "or" operator, and is equivalent to the term "and/or," unless the context clearly dictates otherwise. The term "based on" is not exclusive and allows for being based on additional factors not described, unless the context clearly dictates otherwise. In addition, throughout the specification, the meaning of "a," "an," and "the" include plural references, unless the context clearly dictates otherwise. The meaning of "in" includes "in" and "on", unless the context clearly dictates otherwise.

[0053] While a number of embodiments of the present invention have been described, it is understood that these embodiments are illustrative only, and not restrictive, and that many modifications may become apparent to those of ordinary skill in the art. Further still, unless the context clearly requires otherwise, the various steps may be carried out in any desired order, and any applicable steps may be added and/or eliminated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0054] FIG. 1 is a graph showing EAC resistance properties of Example 1 alloys at 85% of its TYS-ST.

[0055] FIG. 2 is a graph showing EAC resistance properties of Example 1 alloys at 60% of its TYS-ST.

[0056] FIG. 3 is an illustration of a tensile specimen for testing EAC resistance properties.

[0057] FIG. 4 is a graph showing EAC resistance properties of Example 3 alloys at 85% of its TYS-ST.

[0058] FIG. 5 is a graph showing EAC resistance properties of Example 3 alloys at 60% of its TYS-ST.

[0059] FIG. 6 is a graph showing EAC resistance properties of Example 4 alloys at 85% of its TYS-ST.

[0060] FIG. 7 is a graph showing EAC resistance properties of Example 4 alloys at 60% of its TYS-ST.

DETAILED DESCRIPTION

Example 1

[0061] Various 7xxx aluminum alloys were cast as six inch (15.24 cm) thick ingots (nominal). The actual compositions of the cast ingots are shown in Table 1, below. 7085-LS is a lab scale version of a conventional aluminum alloy, registered with the Aluminum Association as aluminum alloy 7085. The registered version of the 7085 alloy requires, among other things, 0.08 - 0.15 wt. % Zr, not greater than 0.04 wt. % Mn and not greater than 0.04 wt. % Cr, as shown by the document "International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys", The Aluminum Association (2009), page 12. Commonly-owned U.S. Patent No. 6,972,110 (among others) also relates to the 7085 alloy. Alloys 1-7 are new alloys having lower amounts of zinc (Zn) and/or also having manganese (Mn).

Table 1 - Composition of Example 1 Alloys (wt. %) - Lab Scale Materials

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr
1	0.02	0.04	1.68	0.23	1.55	--	7.42	0.03	0.11
2	0.02	0.05	1.59	0.35	1.47	--	6.48	0.03	0.11
3	0.02	0.04	1.62	0.35	1.39	0.12	6.43	0.02	0.11
4	0.03	0.04	1.74	0.34	1.34	--	7.44	0.03	0.10
5	0.02	0.04	1.67	0.36	1.33	0.15	7.52	0.02	0.11
6	0.02	0.04	1.92	0.36	1.53	--	6.41	0.02	0.11
7	0.02	0.04	1.69	0.35	1.71	--	6.43	0.02	0.11
7085-LS	0.02	0.04	1.67	--	1.51	--	7.64	0.02	0.11

The balance of each alloy was aluminum and unavoidable impurities (≤ 0.03 wt. % each, ≤ 0.10 wt. % total). After casting, the ingots were stress-relieved, sawed into multiple sections, scalped, homogenized, and then hot rolled to plate having a final gauge of about 1.75 inches (4.445 cm). The alloy plates were then solution heat treated and then hot water quenched in 190°F water (87.8°C) to simulate cooling conditions at T/2 (mid-thickness) for 5 inch plate relative to cold water (ambient) quenching. The plates were then stretched about 2.25% and then artificially aged. Table 2, below, provides the aging conditions for the various alloys. Samples of alloys 4, 6 and 7 were aged using two different aging practices. The 7085 plates were aged to a T7451-type or a T7651-type temper (*see*, ANSI H35.1, AMS-4329A).

Table 2 – Aging Practice for Various Alloys

Alloy	Aging Practice
Alloy 1	6h/250F + 14-15h/310F + Air Cool + 24h/250F
Alloy 2	6h/250F + 10-11h/320F + Air Cool + 24h/250F
Alloy 3	6h/250F + 7h/320F + Air Cool + 24h/250F
Alloy 4-1	6h/250F + 6-7h/320F + Air Cool + 24h/250F
Alloy 4-2	6h/250F + 10h/320F + Air Cool + 24h/250F
Alloy 5	6h/250F + 4-5h/320F + Air Cool + 24h/250F
Alloy 6-1	6h/250F + 12-13h/320F + Air Cool + 24h/250F
Alloy 6-2	6h/250F + 13-14h/320F + Air Cool + 24h/250F
Alloy 7-1	6h/250F + 14-15h/320F + Air Cool + 24h/250F
Alloy 7-2	6h/250F + 16-17h/320F + Air Cool + 24h/250F

[0062] Various properties of the aluminum alloy plates were then tested. Specifically, the strength and elongation properties were tested in accordance with ASTM E8 and B557 at the T/2 location of the material. Plane strain fracture toughness properties were tested in the L-T direction and in accordance with ASTM E399 using a C(T) specimen taken from the T/2 location of the material, where the "B" dimension of the specimen was 0.25 inch (6.35 mm) and the "W" dimension of the specimen was 2.5 inches (63.5 mm). The typical L-S crack deviation resistance properties ($K_{max-dev}$) were determined per the procedure described in commonly-owned U.S. Patent Application Publication No. 2017/0088920, paragraph 0058, except, for this Example 1, the “W” dimension of the specimen was 1.3 inches (33.02 mm). The test is started using a K_{max} of approximately 20 ksi√in.

Date Reçue/Date Received 2021-08-05

[0063] The test results are shown in Table 3, below. The shown strength and elongation values are averages of duplicate specimens. The fracture toughness values are taken from a single specimen. The crack deviation values are averages of triplicate specimens.

Table 3 - Measured Properties

Alloy	TYS-L (ksi)	UTS-L (ksi)	elong-L (%)	TYS-ST (ksi)	UTS-ST (ksi)	Elong-ST (%)	$K_{max-dev}$ (ksi-sqrt-in.)	K_Q L-T (ksi-sqrt-in.)
1	71.2	77.9	13.5	64.5	75.9	9.4	29.4	32.0
2	67.3	75.3	15.0	60.5	72.8	10.2	40.9	39.7
3	66.4	74.5	14.5	61.9	73.4	10.2	45.3	42.5
4-1	70.9	77.2	14.0	63.7	75.0	10.2	31.6	34.9
4-2	65.8	73.2	13.3	59.8	71.2	10.2	N/A	N/A
5	68.2	75.6	14.0	61.1	72.8	10.9	41.4	41.0
6-1	68.9	77.2	14.0	61.8	74.4	10.2	32.4	37.9
6-2	67.0	75.7	12.5	60.2	72.8	10.9	N/A	N/A
7-1	69.0	77.5	14.0	62.2	74.8	9.4	34.6	38.3
7-2	65.7	75.0	14.1	60.0	73.1	10.9	N/A	N/A
7085(LS) (T7451)	69.6	76.6	15.5	64.3	74.7	9.4	33.5	36.2
7085(LS) (T7651)	74.1	79.9	14.0	67.2	77.3	9.4	27.0	36.2

[0064] The EAC resistance of the materials were also tested, the results of which are shown in Tables 4a-4b, below. Days in test are included for materials that have not yet failed (T = still in test at the stated number of days).

Table 4a - EAC Properties – First Test

Alloy	Stress (% TYS-ST)	Stress (ksi)	Stress (Mpa)	70 °C / 85 % RH			
				Days in test	Days to failure		
					rep 1	rep 2	rep 3
2	60	36.3	250	697	592	N/A	T
	85	51.4	354	--	291	199	178
4-1	60	38.2	263	--	N/A	N/A	38
	85	54.1	373	--	N/A	35	N/A
6-1	60	37.1	256	697	604	T	T
	85	52.5	362	--	221	312	337
7-1	60	37.4	258	697	T	T	611
	85	52.9	365	--	N/A	220	N/A
7085(LS)-T7451	60	38.2	263	--	119	46	53
	85	54.1	373	--	46	53	44

Table 4b - EAC Properties – Second Test

Alloy	Stress (% TYS-ST)	Stress (ksi)	Stress (Mpa)	70 °C / 85 % RH			
				Days in test	Days to failure		
					rep 1	rep 2	rep 3
1	60	38.7	267	--	192	282	N/A
	85	54.8	378	--	84	106	147
3	60	37.2	256	533	T	T	480
	85	52.7	363	--	198	N/A	333
4-2	60	35.8	247	--	66	105	156
	85	50.7	350	--	51	53	63
5 (Test 1)	60	36.9	254	--	144	189	169
	85	52.2	360	--	79	66	87
5 (Test 2)	60	36.6	252	--	130	206	291
	85	51.8	357	--	120	137	127
6-2	60	36.1	249	533	T	T	T
	85	51.2	353	--	326	518	326
7-2	60	36	248	533	T	T	T
	85	51	352	533	T	T	441
7085(LS) -T7651	60	40.3	278	--	73	123	109
	85	57	393	--	39	45	51
7085(LS) -T7451	60	38.5	265	--	120	106	129
	85	54.5	376	--	60	53	60

"N/A" means specimen data not applicable due to thread failure.

[0065] As shown, the new alloys with manganese and having zinc, magnesium, and copper within the scope of the formula $2.362 \leq Mg+0.429*Cu+0.067*Zn \leq 3.062$ realize an improved combination of properties, including EAC resistance properties, over the conventional 7085 materials. This data also suggests that using a Zn/Mg (wt. % ratio) of not greater than 5.25:1 in combination with the use of manganese may lead to an improved combination of properties.

[0066] As a comparison, mechanical properties and EAC resistance of plant produced 7050 and 7085 materials in the T7451 and T7651 tempers were also measured, the results of which are provided in Tables 5a-5b, below.

Table 5a - Plant Mechanical Property Data

Alloy-Temper	Gauge (in)	TYS-L (ksi)	UTS-L (ksi)	elong-L (%)	TYS-ST (ksi)	UTS-ST (ksi)	elong-ST (%)	Kmax-dev (ksi-sqrt-in.)	KQ L-T (ksi-sqrt-in.)
7085-T7651	4.331	73.8	76.6	12.1	67.4	77.0	5.95	N/A	N/A
7085-T7451	4.3	71.2	74.8	15.1	66.0	76.0	7.85	N/A	N/A
7050-T7651	5.42	68.2	76.0	12.5	60.9	72.4	8	27.5	33.4
7050-T7451	3.92	68.9	77.2	12.45	62.9	74.4	5.8	N/A	N/A

Table 5b - Plant EAC Data

Alloy / Temper	Gauge (in.)	Stress (% TYS-ST)	Stress (ksi)	Stress (Mpa)	70 °C / 85 % RH					
					Days in test	Days to failure				
						rep 1	rep 2	rep 3	rep 4	rep 5
7085-T7651	4.331	60	40.5	279	--	68	N/A	42	N/A	39
		85**	57.4	396	--	35	26	57	43	N/A
7085-T7451	4.3	60	39.6	273	--	92	71	46	53	92
		85	56.1	387	--	57	42	56	N/A	46
7050-T7651	5.42	50	30.45	210	614	T	T	T	T	T
		85	51.765	357	--	203	401	260	246	147
7050-T7451	3.92	60	37.7	260	--	292	180	540	393	330
		85	53.4	368	--	292	292	386	162	469

** Three additional replicates of this material failed in 18, 14 and 26 days.

As shown in Tables 5a-5b, the EAC resistance of the conventional 7085 materials are consistent with the results of the lab-scale materials.

[0067] FIGS. 1-2 illustrate the tensile strength versus EAC results. As shown, alloys falling within the scope of the composition ranges defined herein realize an improved combination of EAC resistance and strength. The plant produced materials include the label PP. The lab scale materials include the label LS. The plant produced materials have a dark border on the data markers.

Example 2

[0068] Additional testing was completed on Alloys 2, 3, 6 and 7 of Example 1. Specifically, samples of Alloys 2, 3, 6, and 7 were artificially aged to different conditions, after which mechanical and corrosion properties were tested. The aging conditions and results are shown in Tables 6-8, below.

Table 6 - Aging Practices for Example 2 Alloys

Alloy	Aging Practice
Alloy 2	6h/250F + 7-8h/320F + Air Cool + 24h/250F
Alloy 3	6h/250F + 2h/320F + Air Cool + 24h/250F
Alloy 6	6h/250F + 10-11h/320F + Air Cool + 24h/250F
Alloy 7	6h/250F + 12h/320F + Air Cool + 24h/250F

Table 7 - Measured Properties - Example 2

Alloy	TYS-L (ksi)	UTS-L (ksi)	elong-L (%)	TYS-ST (ksi)	UTS-ST (ksi)	Elong-ST (%)	$K_{max-dev}$ (ksi-sqrt-in.)	K_Q L-T (ksi-sqrt-in.)
2	68.5	76.3	11.7	61.6	73.7	9.4	32.3	37.3
3	69.8	77.4	12.5	62.4	74.5	11.7	31.7	43.7
6	68	76	12.5	60	73	9.4	31.8	36.4
7	69	78	12.5	62	75	9.4	31.8	37.3

Table 8 - EAC Properties – Example 2

Alloy	Stress (% TYS-ST)	Stress (ksi)	Stress (Mpa)	70 °C / 85 % RH			
				Days in test	Days to failure		
					rep 1	rep 2	rep 3
2	60	37	255	449	T	424	412
	85	52.4	361	449	T	197	190
3	60	37.4	258	449	T	288	291
	85	53	365	449	T	137	N/A
6	60	36.2	250	449	T	T	T
	85	51.3	354	449	T	T	T
7	60	37.4	258	449	T	T	70
	85	53	365	--	242	344	340

[0069] As shown, Alloys 2, 3, 6 and 7 achieve an improved combination of mechanical and corrosion properties over the conventional 7085-T7451 alloy.

Example 3 - Additional Lab Scale Testing

[0070] Various 7xxx aluminum alloys were cast as six inch (15.24 cm) thick ingots (nominal). The actual compositions of the cast ingots are shown in Table 9, below. Conventional alloys 7085 and 7050 were also produced.

Table 9 - Composition of Example 3 Alloys (wt. %) - Lab Scale Materials

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr
7085	0.02	0.03	1.64	--	1.52	--	7.59	0.02	0.11
7050	0.05	0.08	2.22	--	2.09	--	6.10	0.02	0.11
8	0.02	0.03	1.69	0.36	1.29	--	6.55	0.02	0.11
9	0.03	0.03	1.89	0.35	1.30	--	6.49	0.02	0.11
10	0.02	0.03	2.10	0.36	1.31	--	6.57	0.02	0.11
11	0.02	0.03	2.06	0.34	1.55	--	5.98	0.02	0.12

The balance of each alloy was aluminum and unavoidable impurities (≤ 0.03 wt. % each, ≤ 0.10 wt. % total). The ingots were then hot rolled to a final gauge of 1.75 inches, and then solution heat treated, and then hot water quenched to simulate cooling conditions at T/2 (mid-thickness) for approximately 8-inch thick plate. The plates were then stretched about 2.25% and then artificially aged, after which mechanical and corrosion properties were tested. The aging conditions and results are shown in Tables 10-13, below.

[0071] For this Example 3, the same testing standards as Example 1 were used for strength, fracture toughness, EAC resistance and L-S crack deviation resistance ($K_{max-dev}$). The shown strength and elongation values are averages of duplicate specimens. The fracture toughness values are taken from a single specimen. The crack deviation values are averages of triplicate specimens.

Table 10 - Aging Practices for Example 2 Alloys

Alloy	Aging Practice 1	Aging Practice 2
7085	Both T7451	
7050	Both T7651	
8	6h/250F + 6.2h/320F + Air Cool + 24h/250F	6h/250F + 8.8h/320F + Air Cool + 24h/250F
9	6h/250F + 6.8h/320F + Air Cool + 24h/250F	6h/250F + 9.8h/320F + Air Cool + 24h/250F
10	6h/250F + 6.8h/320F + Air Cool + 24h/250F	6h/250F + 9.8h/320F + Air Cool + 24h/250F
11	6h/250F + 7.3h/320F + Air Cool + 24h/250F	6h/250F + 11.1h/320F + Air Cool + 24h/250F

Table 11 - Mechanical Properties of Example 3 Alloys - Aging Practice 1

Alloy	TYS-L (ksi)	UTS-L (ksi)	Elong-L (%)	TYS-ST (ksi)	UTS-ST (ksi)	Elong-ST (%)	Kmax-dev (ksi-sqrt-in)	KQ L-T (ksi-sqrt-in)
7085	68.7	76.0	14.1	62.3	73.3	9.4	28.1	35.3
7050	61.6	72.3	11.7	56.3	70.4	9.4	26.6	30.7
8	71.1	77.6	12.5	63.4	74.4	10.9	28.9	36.0
9	70.2	77.1	12.5	62.0	73.6	10.9	25.9	35.2
10	71.9	78.5	12.5	63.1	74.6	8.6	27.7	35.7

Alloy	TYS-L (ksi)	UTS-L (ksi)	Elong-L (%)	TYS-ST (ksi)	UTS-ST (ksi)	Elong-ST (%)	Kmax-dev (ksi-sqrt-in)	KQ L-T (ksi-sqrt-in)
11	71.0	78.6	11.7	62.5	74.2	7.8	25.4	32.7

Table 12 - Mechanical Properties of Example 3 Alloys - Aging Practice 2

Alloy	TYS-L (ksi)	UTS-L (ksi)	Elong-L (%)	TYS-ST (ksi)	UTS-ST (ksi)	Elong-ST (%)	Kmax-dev (ksi-sqrt-in)	KQ L-T (ksi-sqrt-in)
7085	68.5	75.9	14.1	62.0	73.4	10.9	31.9	36.1
7050	61.2	72.2	12.5	56.2	70.3	10.2	29.0	28.2
8	66.9	74.4	13.3	59.0	71.2	10.9	30.4	40.7
9	66.7	74.4	14.9	59.2	71.4	10.2	30.8	38.2
10	66.2	74.3	13.3	59.0	71.4	10.2	32.6	40.0
11	67.6	76.2	14.1	60.4	71.8	7.1	29.6	36.0

Table 13 - EAC Properties – Example 3

Alloy - Aging	Stress (% TYS -ST)	Stress (ksi)	Stress (Mpa)	70°C / 85 % RH			
				Days in test	Days to failure		
					rep1	rep2	rep3
7085-T7451	60	37.4	258	--	175	187	301
	85	53	365	--	79	98	N/A
7085-T7451	60	37.2	256	--	N/A	N/A	173
	85	52.7	363	--	N/A	79	N/A
7050-T7651	60	33.8	233	301	T	T	T
	85	47.9	330	301	T	T	T
7050-T7651	60	33.7	232	301	T	T	T
	85	47.8	330	301	T	T	T
Alloy 8 - Aging 1	60	38	262	--	N/A	56	159
	85	53.9	372	--	N/A	N/A	68
Alloy 8 - Aging 2	60	35.4	244	301	T	259	243
	85	50.2	346	--	N/A	146	121
Alloy 9 - Aging 1	60	37.2	256	--	64	N/A	153
	85	52.7	363	--	N/A	N/A	301
Alloy 9 - Aging 2	60	35.5	245	301	273	T	180
	85	50.3	347	--	231	198	180
Alloy 10 - Aging 1	60	37.9	261	--	100	135	N/A
	85	53.6	370	--	65	100	79
Alloy 10 - Aging 2	60	35.4	244	--	292	301	T
	85	50.2	346	--	N/A	148	166
Alloy 11 - Aging 1	60	37.5	259	301	T	T	T
	85	53.1	366	301	T	T	T
Alloy 11 - Aging 2	60	36.2	250	301	T	T	T
	85	51.3	354	301	T	T	T

[0072] As shown by the above data, alloy 7085 simulating around 8 inch thick plate realizes longer days to failure than alloy 7085 shown in Table 4a and 4b that simulated around 5 inch thick plate. As also shown, alloy 11 realizes no EAC failures after 300 days, but with significantly higher strength and fracture toughness than that of alloy 7050. Alloy 11 realizes significantly better EAC resistance properties than alloy 7085 and with similar strength and fracture toughness properties. Alloys 8-10 have slightly lower properties, but may realize properties similar to alloy 11 if alloys 8-10 had at least 1.35 wt. % Mg and/or a lower weight ratio of zinc-to-magnesium (e.g., a ratio of not greater than 4.75:1, (wt. % Zn)/(wt. % Mg)).

Example 4 - Plant Scale Testing

[0073] Twenty industrial size ingots were cast, nine conventional 7085 ingots, two 7050 ingots, and nine experimental alloy ingots (three per alloy). The compositions of the experimental alloy ingots are provided in Table 14, below.

Table 14 - Composition of Plant Scale Ingot - Invention Alloys

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr
12	0.02	0.04	1.68	0.27	1.53	--	6.62	0.02	0.11
13	0.02	0.04	1.87	0.25	1.52	--	6.43	0.02	0.11
14	0.02	0.04	1.64	0.25	1.65	--	6.37	0.02	0.11

The balance of each alloy was aluminum and unavoidable impurities (≤ 0.03 wt. % each, ≤ 0.10 wt. % total). The ingots were then hot rolled to various final gauges, and then solution heat treated and quenched in cold water. The plates were then stretched about 2.25-2.50% and then artificially aged. Table 15, below, provides the various conditions for the various alloys. Table 16 provides various artificial aging conditions listed in Table 15. The 7085 plates were aged to a T7451-type or a T7651-type temper (*see*, ANSI H35.1, AMS-4329A). The 7050 plates were also aged to a T7451-type or a T651-type temper.

Table 15 - Alloy Conditions

Alloy	Plate	Final Gauge (in.)	Artificial Aging / Temper
7085	1	6.45	T7651
7085	2	6.50	T7651
7085	3	4.00	T7451
7085	4	6.00	T7451
7085	5	6.00	T7451
7085	6	7.00	T7451
7085	7	7.00	T7451
7085	8	8.50	T7451

Alloy	Plate	Final Gauge (in.)	Artificial Aging / Temper
7085	9	8.50	T7451
7050	1	4.40	T7651
7050	2	3.94	T7651
12	1	3.94	A
12	2	3.94	B
12	3	6.70	A
12	4	6.70	B
12	5	7.87	A
12	6	7.87	B
13	1	3.94	C
13	2	3.94	D
13	3	6.70	C
13	4	6.70	D
13	5	7.87	C
13	6	7.87	D
14	1	3.94	C
14	2	3.94	D
14	3	6.70	C
14	4	6.70	D
14	5	7.87	C
14	6	7.87	D

Table 16 - Artificial Aging Practices for Table 15

Condition	Aging Practice
A	6h/250°F + 8h/320F + Air Cool + 24h/250F
B	6h/250F + 12.5h/320F + Air Cool + 24h/250F
C	6h/250F + 9h/320F + Air Cool + 24h/250F
D	6h/250F + 14h/320F + Air Cool + 24h/250F

[0074] For this Example 4, the same ASTM testing standards as Example 1 were used for strength, fracture toughness and EAC resistance. The typical L-S crack deviation resistance properties ($K_{max-dev}$) were determined per the procedure described in commonly-owned U.S. Patent Application Publication No. 2017/0088920, paragraph 0058, as modified above per the

Definitions section, above. The shown strength, elongation and fracture toughness values are averages of duplicate specimens. The crack deviation values are averages of triplicate specimens. The test results are shown in Tables 17-19, below.

Table 17 - Mechanical Properties of Example 4 - Conventional Alloys

Alloy	TYS-L (ksi)	UTS-L (ksi)	Elong-L (%)	TYS-ST (ksi)	UTS-ST (ksi)	Elong-ST (%)	K_{IC} L-T (ksi-sqrt-in)	K_{IC} S-L (ksi-sqrt-in)
7085-1	74.1	77.3	9.5	68.0	75.8	5.1	31.0	23.4
7085-2	73.4	76.3	10.1	67.2	75.2	5.1	30.7	26.7
7085-3	69.7	74.3	16.2	63.4	73.9	9.0	46.4	32.7
7085-4	71.5	75.7	12.6	65.4	73.7	6.3	33.9	30.1
7085-5	70.2	74.0	14.0	63.7	72.4	6.0	32.6	28.9
7085-6	69.0	73.8	12.7	62.5	71.1	6.0	32.7	31.6
7085-7	69.4	73.3	12.5	62.4	71.1	6.3	32.4	29.1
7085-8	67.4	73.0	11.6	60.2	69.5	5.9	31.3	28.8
7050-1	67.9	75.9	12	61.9	73	5.7	N/A	26.6
7050-2	67.65	75.25	10.5	62.7	73.8	4.7	33.6	N/A

Table 18 - Mechanical Properties of Example 4 - Experimental Alloys

Alloy-Specimen	TYS-L (ksi)	UTS-L (ksi)	Elong-L (%)	TYS-ST (ksi)	UTS-ST (ksi)	Elong-ST (%)	Kmax-dev (ksi-sqrt-in)	K_{IC} L-T (ksi-sqrt-in)	K_{IC} S-L (ksi-sqrt-in)
12-1	71.3	75.3	15.0	64.5	75.4	6.8	33.3	41.4(*)	34.8
12-2	67.8	73.2	15.5	61.5	72.8	7.1	39.0	45.1	37.0
12-3	70.7	75.0	12.3	63.9	72.9	5.5	30.1	33.6	31.5
12-4	66.3	72.0	13.0	60.3	70.3	6.8	34.3	37.8	35.6
12-5	70.1	74.5	10.5	62.7	71.8	5.0	28.4	31.1	30.5
12-6	65.3	71.3	12.0	58.6	68.8	7.3	33.6	35.3	36.5
13-1	71.8	76.0	14.0	64.5	75.4	7.1	33.1	39.4(*)	34.9
13-2	68.9	75.3	13.0	61.0	72.8	7.1	42.3	44.8(*)	38.1
13-3	70.8	75.1	12.0	63.9	72.8	5.0	28.5	32.7	30.4
13-4	67.1	72.9	12.5	60.8	70.8	6.3	32.6	36.0	33.3
13-5	69.9	74.8	10.8	63.0	72.2	5.3	29.4	30.4	28.5
13-6	65.5	71.8	11.0	58.9	69.1	6.8	33.8	34.1	34.2
14-1	71.8	76.1	14.5	64.5	75.3	7.1	35.1	38.9(*)	34.7
14-2	67.5	73.4	15.0	60.8	72.5	7.1	37.2	44.2(*)	37.4
14-3	71.4	75.7	11.8	64.2	73.1	5.5	32.2	31.9	30.5
14-4	67.8	73.5	12.5	61.4	71.0	6.3	35.4	35.8	33.1
14-5	70.6	75.1	10.5	63.2	72.1	5.0	26.4	29.8	29.8

Alloy-Specimen	TYS-L (ksi)	UTS-L (ksi)	Elong-L (%)	TYS-ST (ksi)	UTS-ST (ksi)	Elong-ST (%)	Kmax-dev (ksi-sqrt-in)	K_{IC} L-T (ksi-sqrt-in)	K_{IC} S-L (ksi-sqrt-in)
14-6	66.7	72.7	11.8	60.2	70.0	5.0	30.2	32.8	32.3

* = Test result was technically invalid per ASTM E399-17, and is thus a K_Q value, as a result of P_{max}/P_Q being greater than 1.1. However, per ASTM B645-10, test result is usable for lot release given that B has been maximized at the specified test location.

Table 19 - EAC Properties – Example 4

Alloy	Stress (% TYS-ST)	Stress (ksi)	Stress (Mpa)	70°C / 85 % RH					
				Days in test	Days to failure				
					rep 1	rep 2	rep 3	rep 4	rep 5
7085-1	60	40.8	281	--	78	87	N/A	87	87
7085-1	85	57.8	399	--	58	51	51	51	51
7085-2	60	40.3	278	--	N/A	N/A	68	69	53
7085-2	85	57.1	394	--	N/A	38	56	N/A	46
7085-3	60	38.0	262	87	39	20	60	T	60
7085-3	85	53.9	372	87	39	15	T	25	25
7085-4	60	39.2	270	--	171	164	129	94	157
7085-4	85	55.5	383	--	N/A	91	N/A	87	91
7085-5	60	39.2	270	--	120	198	92	105	105
7085-5	85	55.5	383	--	56	N/A	56	120	58
7085-6	60	37.9	261	327	81	T	T	T	91
7085-6	85	53.7	370	327	N/A	T	55	67	67
7085-7	60	37.5	259	--	162	88	81	N/A	113
7085-7	85	53.1	366	327	70	T	57	57	70
7050-1	60	37.1	256	369	T	T	T	T	225
7050-1	85	52.6	363	--	176	225	186	368	176
7050-2	60	37.6	259	124	T	T	T	T	T
7050-2	85	53.3	368	124	T	T	T	T	T
12-1	60	38.7	267	124	T	69	T	T	111
12-1	85	54.8	378	124	43	T	36	41	83
12-2	60	36.9	254	124	T	T	T	97	T
12-2	85	52.3	361	124	69	80	T	69	69
13-1	60	38.7	267	--	62	90	62	83	115
13-1	85	54.8	378	--	41	48	52	64	52
13-2	60	36.6	252	124	T	T	T	T	T
13-2	85	51.9	358	124	T	T	T	97	97
14-1	60	38.7	267	124	T	T	T	T	T
14-1	85	54.8	378	124	29	T	48	34	T
14-2	60	36.5	252	124	T	T	T	T	T
14-2	85	51.7	356	124	90	T	83	T	69
12-3	60	38.3	264	115	T	T	T	T	T
12-3	85	54.3	374	115	T	T	T	T	T

Alloy	Stress (% TYS-ST)	Stress (ksi)	Stress (Mpa)	70°C / 85 % RH					
				Days in test	Days to failure				
					rep 1	rep 2	rep 3	rep 4	rep 5
12-4	60	36.2	250	115	T	T	T	T	T
12-4	85	51.2	353	115	T	T	T	T	T
13-3	60	38.3	264	115	T	T	T	T	T
13-3	85	54.3	374	115	T	T	T	T	T
13-4	60	36.5	252	115	T	T	T	T	T
13-4	85	51.7	356	115	T	T	T	T	T
14-3	60	38.5	265	115	T	T	T	T	T
14-3	85	54.6	376	115	T	T	T	T	T
14-4	60	36.8	254	115	T	T	T	T	T
14-4	85	52.2	360	115	T	T	T	T	T
12-5	60	37.6	259	117	T	T	T	T	T
12-5	85	53.3	368	117	T	T	T	T	T
12-6	60	35.2	243	117	T	T	T	T	T
12-6	85	49.8	343	117	T	T	T	T	T
13-5	60	37.8	261	117	T	T	T	T	T
13-5	85	53.5	369	117	T	T	T	T	T
13-6	60	35.3	243	117	T	T	T	T	T
13-6	85	50.1	345	117	T	T	T	T	T
14-5	60	37.9	261	117	T	T	T	T	T
14-5	85	53.7	370	117	T	T	T	T	T
14-6	60	36.1	249	117	T	T	T	T	T
14-6	85	51.1	352	117	T	T	T	T	T

[0075] As shown by the above data, alloys 12-14 show significantly improved EAC resistance over 7085 at equivalent gauge for at least one of the aging conditions. In addition, alloys 12-14 exhibit significantly better strength and fracture toughness relative to 7050 in similar gauges and a comparable strength and fracture toughness relative to 7085. As shown in Example 3, EAC resistance increases with increasing gauge for given aging practices.

[0076] While various embodiments of the present disclosure have been described in detail, it is apparent that modifications and adaptations of those embodiments will occur to those skilled in the art. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present disclosure.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A wrought 7xxx aluminum alloy product comprising:

0.15 to 0.50 wt. % Mn;

5.5-7.3 wt. % Zn;

0.95-2.2 wt. % Mg;

1.5-2.4 wt. % Cu;

up to 1.0 wt. % of grain structure control materials, wherein the grain structure control materials comprise at least one of Zr, Cr, Sc, and Hf; and

up to 0.15 wt. % Ti;

the balance being aluminum and unavoidable impurities;

wherein the wrought 7xxx aluminum alloy product has a thickness of from 1.5 to 12 inches; and

wherein the wrought 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 80 days.

2. The wrought 7xxx aluminum alloy product of claim1, wherein the wrought 7xxx aluminum alloy product includes at least 0.20 wt. % Mn, or at least 0.22 wt. % Mn, or at least 0.25 wt. % Mn.

3. The wrought 7xxx aluminum alloy product of claim 1 or 2, wherein the wrought 7xxx aluminum alloy product includes not greater than 0.45 wt. % Mn, or not greater than 0.40 wt. % Mn, or not greater than 0.35 wt. % Mn, or not greater than 0.325 wt. % Mn, or not greater than 0.30 wt. % Mn.

4. The wrought 7xxx aluminum alloy product of any one of claims 1-3, wherein the wrought 7xxx aluminum alloy product includes not greater than 7.2 wt. % Zn, or not greater than 7.1 wt. % Zn, or not greater than 7.0 wt. % Zn, or not greater than 6.9 wt. % Zn, or not greater than 6.8 wt. % Zn, or not greater than 6.7 wt. % Zn.

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5. The wrought 7xxx aluminum alloy product of any one of claims 1-4, wherein the wrought 7xxx aluminum alloy product includes at least 5.75 wt. % Zn, or at least 6.0 wt. % Zn, or at least 6.25 wt. % Zn, or at least 6.375 wt. % Zn, or at least 6.5 wt. % Zn.

6. The wrought 7xxx aluminum alloy product of any one of claims 1-5, wherein the wrought 7xxx aluminum alloy product includes not greater than 2.3 wt. % Cu, or not greater than 2.2 wt. % Cu, or not greater than 2.1 wt. % Cu, or not greater than 2.0 wt. % Cu.

7. The wrought 7xxx aluminum alloy product of any one of claims 1-6, wherein the wrought 7xxx aluminum alloy product includes at least 1.55 wt. % Cu, or at least 1.60 wt. % Cu, or at least 1.65 wt. % Cu, or at least 1.70 wt. % Cu, or at least 1.75 wt. % Cu, or at least 1.80 wt. % Cu.

8. The wrought 7xxx aluminum alloy product of any one of claims 1-7, wherein the wrought 7xxx aluminum alloy product includes at least 1.05 wt. % Mg, or at least 1.15 wt. % Mg, or at least 1.25 wt. % Mg, or at least 1.35 wt. % Mg, or at least 1.40 wt. % Mg, or at least 1.45 wt. % Mg, or at least 1.50 wt. % Mg, or at least 1.55 wt. % Mg, or at least 1.60 wt. % Mg, or at least 1.65 wt. % Mg, or at least 1.70 wt. % Mg.

9. The wrought 7xxx aluminum alloy product of any one of claims 1-8, wherein the wrought 7xxx aluminum alloy product includes not greater than 2.15 wt. % Mg, or not greater than 2.10 wt. % Mg, or not greater than 2.05 wt. % Mg, or not greater than 2.00 wt. % Mg, or not greater than 1.95 wt. % Mg, or greater than 1.90 wt. % Mg.

10. The wrought 7xxx aluminum alloy product of any one of claims 1-3, wherein the wrought 7xxx aluminum alloy product includes from 5.5 - 7.2 wt. % Zn, 1.7 - 2.2 wt. % Mg and 1.5 - 2.4 wt. % Cu.

11. The wrought 7xxx aluminum alloy product of any one of claims 1-3, wherein the wrought 7xxx aluminum alloy product includes from 5.5 - 7.2 wt. % Zn, 1.35 - 1.7 wt. % Mg and 1.5 - 2.1 wt. % Cu.

12. The wrought 7xxx aluminum alloy product of any one of claims 1-3, wherein the wrought 7xxx aluminum alloy product includes from 5.5 - 7.2 wt. % Zn, 1.7 - 2.2 wt. % Mg and 1.5 - 1.8 wt. % Cu.

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13. The wrought 7xxx aluminum alloy product of any one of claims 1-3, wherein the wrought 7xxx aluminum alloy product includes from 5.5 - 7.2 wt. % Zn, 1.7 - 2.2 wt. % Mg and 1.8 - 2.0 wt. % Cu.

14. The wrought 7xxx aluminum alloy product of any one of claims 1-3, wherein the wrought 7xxx aluminum alloy product includes from 5.5 - 7.2 wt. % Zn, 1.7 - 2.2 wt. % Mg and 2.0 - 2.4 wt. % Cu.

15. The wrought 7xxx aluminum alloy product of any one of claims 1-14, wherein the wrought 7xxx aluminum alloy product includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 2.9 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.0 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.1 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.2 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.3 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.35 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.4 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.45 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.5 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.55 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.6 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.65 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\geq$ 3.7 wt. %.

16. The wrought 7xxx aluminum alloy product of any one of claims 1-15, wherein the wrought 7xxx aluminum alloy product includes a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.5 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.4 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.3 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.2 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.1 wt. %, or a total amount of copper and magnesium such that (wt. % Cu + wt. % Mg) $\leq$ 4.0 wt. %.

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17. The wrought 7xxx aluminum alloy product of any one of claims 1-16, wherein the amounts of zinc, magnesium and copper within the 7xxx aluminum alloy product (in wt. %) satisfy the relationship 2.362 ≤ Mg+0.429*Cu+0.067*Zn ≤ 3.062, or the amounts of zinc, magnesium and copper within the 7xxx aluminum alloy product (in wt. %) satisfy the relationship 2.502 ≤ Mg+0.429*Cu+0.067*Zn ≤ 2.912, or the amounts of zinc, magnesium and copper within the 7xxx aluminum alloy product (in wt. %) satisfy the relationship 2.662 ≤ Mg+0.429*Cu+0.067*Zn ≤ 3.062, or the amounts of zinc, magnesium and copper within the 7xxx aluminum alloy product satisfy (in wt. %) the relationship 2.662 ≤ Mg+0.429*Cu+0.067*Zn ≤ 2.912.

18. The wrought 7xxx aluminum alloy product of any one of claims 1-17, wherein the amounts of zinc and magnesium are such that a weight ratio of zinc-to-magnesium is not greater than 5.25:1, or not greater than 5.00:1, or not greater than 4.75:1, or not greater than 4.60:1, or not greater than 4.50:1, or not greater than 4.40:1, or not greater than 4.35:1, or not greater than 4.30:1, or not greater than 4.25:1, or not greater than 4.20:1, or not greater than 4.15:1, or not greater than 4.10:1, or not greater than 4.05:1, or not greater than 4.00:1, or not greater than 3.95:1, or not greater than 3.90:1.

19. The wrought 7xxx aluminum alloy product of any one of claims 1-18, wherein the amounts of zinc and magnesium are such that a weight ratio of zinc-to-magnesium is at least 3.00:1, or at least 3.25:1, or at least 3.33:1, or at least 3.45:1, or at least 3.55:1, or at least 3.60:1.

20. A wrought 7xxx aluminum alloy product comprising:

0.25 to 0.40 wt. % Mn;

6.0-7.0 wt. % Zn;

1.35-2.05 wt. % Mg;

1.5-2.2 wt. % Cu;

wherein (wt. % Cu + wt. % Mg) ≥ 3.2 wt. %;

wherein the amounts of zinc, magnesium and copper within the 7xxx aluminum alloy product (in wt. %) satisfy the relationship 2.362 ≤ Mg+0.429*Cu+0.067*Zn ≤ 3.062;

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wherein the amounts of zinc and magnesium are such that a weight ratio of zinc-to-magnesium is not greater than 5.25:1;

up to 1.0 wt. % of grain structure control materials, wherein the grain structure control materials comprise at least one of Zr, Cr, Sc, and Hf; and

up to 0.15 wt. % Ti;

the balance being aluminum and unavoidable impurities;

wherein the wrought 7xxx aluminum alloy product has a thickness of from 1.5 to 12 inches.

21. The wrought 7xxx aluminum alloy product of claim 20, comprising 0.25 - 0.35 wt. % Mn.

22. The wrought 7xxx alloy product of claim 21, wherein the amounts of zinc, magnesium and copper within the 7xxx aluminum alloy product (in wt. %) satisfy the relationship $2.662 \leq Mg+0.429*Cu+0.067*Zn \leq 2.912$.

23. The wrought 7xxx aluminum alloy product of any one of claims 20-22, wherein the 7xxx aluminum alloy product realizes a typical tensile yield strength (L) of at least 63 ksi, or at least 64 ksi, or at least 65 ksi, or at least 66 ksi, or at least 67 ksi, or at least 68 ksi, or at least 69 ksi, or at least 70 ksi, or at least 71 ksi, or at least 72 ksi, or at least 73 ksi.

24. The wrought 7xxx aluminum alloy product of any one of claims 20-23, wherein the 7xxx aluminum alloy product realizes a typical tensile yield strength (ST) of at least 57 ksi, or at least 58 ksi, or at least 59 ksi, or at least 60 ksi, or at least 61 ksi, or at least 62 ksi, or at least 63 ksi, or at least 64 ksi, or at least 65 ksi, or at least 66 ksi.

25. The wrought 7xxx aluminum alloy product of any one of claims 20-24, wherein the 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (L-T) of at least 25 ksi-sqrt-inch, or at least 26 ksi-sqrt-inch, or or at least 27 ksi-sqrt-inch, or at least 28 ksi-sqrt-inch, or at least 29 ksi-sqrt-inch, or at least 30 ksi-sqrt-inch, or at least 31 ksi-sqrt-inch, or at least 32 ksi-sqrt-inch, or at least 33 ksi-sqrt-inch, or at least 34 ksi-sqrt-inch, or at least 35 ksi-sqrt-inch, or at least 36 ksi-sqrt-inch, or at least 37 ksi-sqrt-inch, or at least 38 ksi-sqrt-inch, or at least 39 ksi-sqrt-inch, or at least 40 ksi-sqrt-inch,

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or at least 41 ksi-sqrt-inch, or at least 42 ksi-sqrt-inch, or at least 43 ksi-sqrt-inch, or at least 44 ksi-sqrt-inch, or at least 45 ksi-sqrt-inch.

26. The wrought 7xxx aluminum alloy product of any one of claims 20-25, wherein the 7xxx aluminum alloy product realizes a typical K_{IC} plane-strain fracture toughness (S-L) of at least 20 ksi-sqrt-inch, or at least 22 ksi-sqrt-inch, or at least 24 ksi-sqrt-inch, or at least 26 ksi-sqrt-inch, or at least 28 ksi-sqrt-inch, or at least 30 ksi-sqrt-inch, or at least 32 ksi-sqrt-inch, or at least 34 ksi-sqrt-inch, or at least 38 ksi-sqrt-inch, or at least 38 ksi-sqrt-inch, or at least 40 ksi-sqrt-inch.

27. The wrought 7xxx aluminum alloy product of any one of claims 20-26, wherein the 7xxx aluminum alloy product realizes a typical elongation (L) of at least 8%, or at least 9%, or at least 10%, or at least 11%, or at least 12%, or at least 13%, or at least 14%, or at least 15%, or at least 16%.

28. The wrought 7xxx aluminum alloy product of any one of claims 20-27, wherein the 7xxx aluminum alloy product realizes a typical elongation (ST) of at least 3%, or at least 4%, or at least 5%, or at least 6%, or at least 7%, or at least 8%, or at least 9%, or at least 10%.

29. The wrought 7xxx aluminum alloy product of any one of claims 20-28, wherein the 7xxx aluminum alloy product realizes a typical L-S crack deviation resistance ($K_{max\text{-}dev}$) of at least 25 ksi-sqrt-in, or at least 27 ksi-sqrt-in, or at least 29 ksi-sqrt-in, or at least 31 ksi-sqrt-in, or at least 33 ksi-sqrt-in, or at least 35 ksi-sqrt-in, or at least 37 ksi-sqrt-in, or at least 39 ksi-sqrt-in, or at least 41 ksi-sqrt-in, or at least 43 ksi-sqrt-in, or at least 45 ksi-sqrt-in, or at least 47 ksi-sqrt-in, or at least 49 ksi-sqrt-in, or at least 50 ksi-sqrt-in.

30. The wrought 7xxx aluminum alloy product of any one of claims 20-29, wherein the 7xxx aluminum alloy product realizes a typical EAC resistance at 85% of TYS-ST of at least 80 days, or at least 100 days, or at least 120 days, or at least 140 days, or at least 160 days, or at least 180 days, or at least 200 days, or at least 220 days, or at least 240 days, or at least 260 days, or at least 280 days, or at least 300 days.

31. The wrought 7xxx aluminum alloy product of any one of claims 20-30, wherein the 7xxx aluminum alloy product realizes a typical EAC resistance at 60% of TYS-ST of at least 90 days, or at least 120 days, or at least 150 days, or at least 180 days, or at least 210 days, or at least 240 days, or at least 270 days, or at least 300 days, or at least 330

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days, or at least 360 days, or at least 390 days, or at least 420 days, or at least 450 days, or at least 480 days, or at least 500 days.

32. An aerospace structural component made from the wrought 7xxx aluminum alloy product of any one of claims 1-31.

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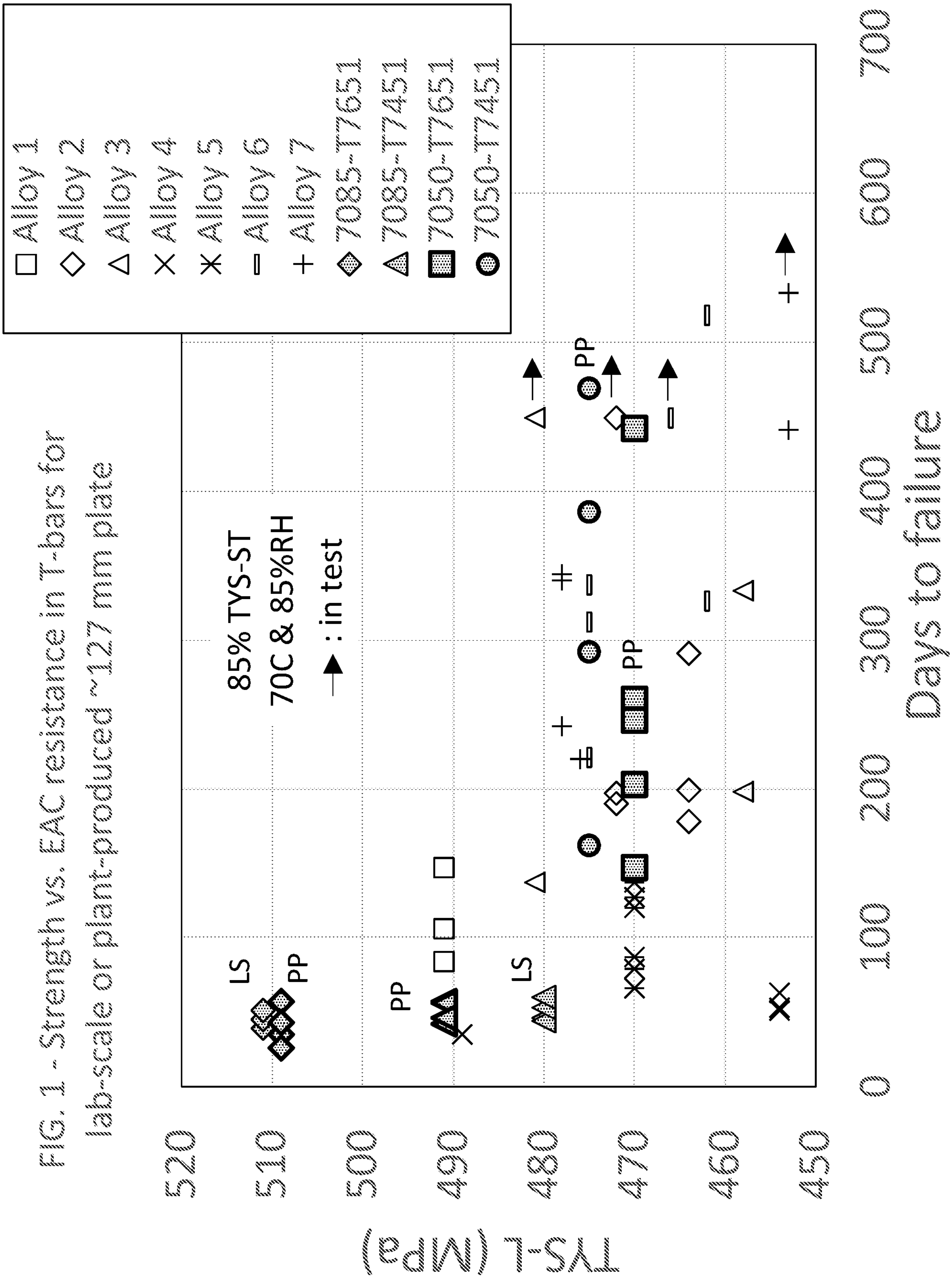

FIG. 1 - Strength vs. EAC resistance in T-bars for lab-scale or plant-produced ~127 mm plate

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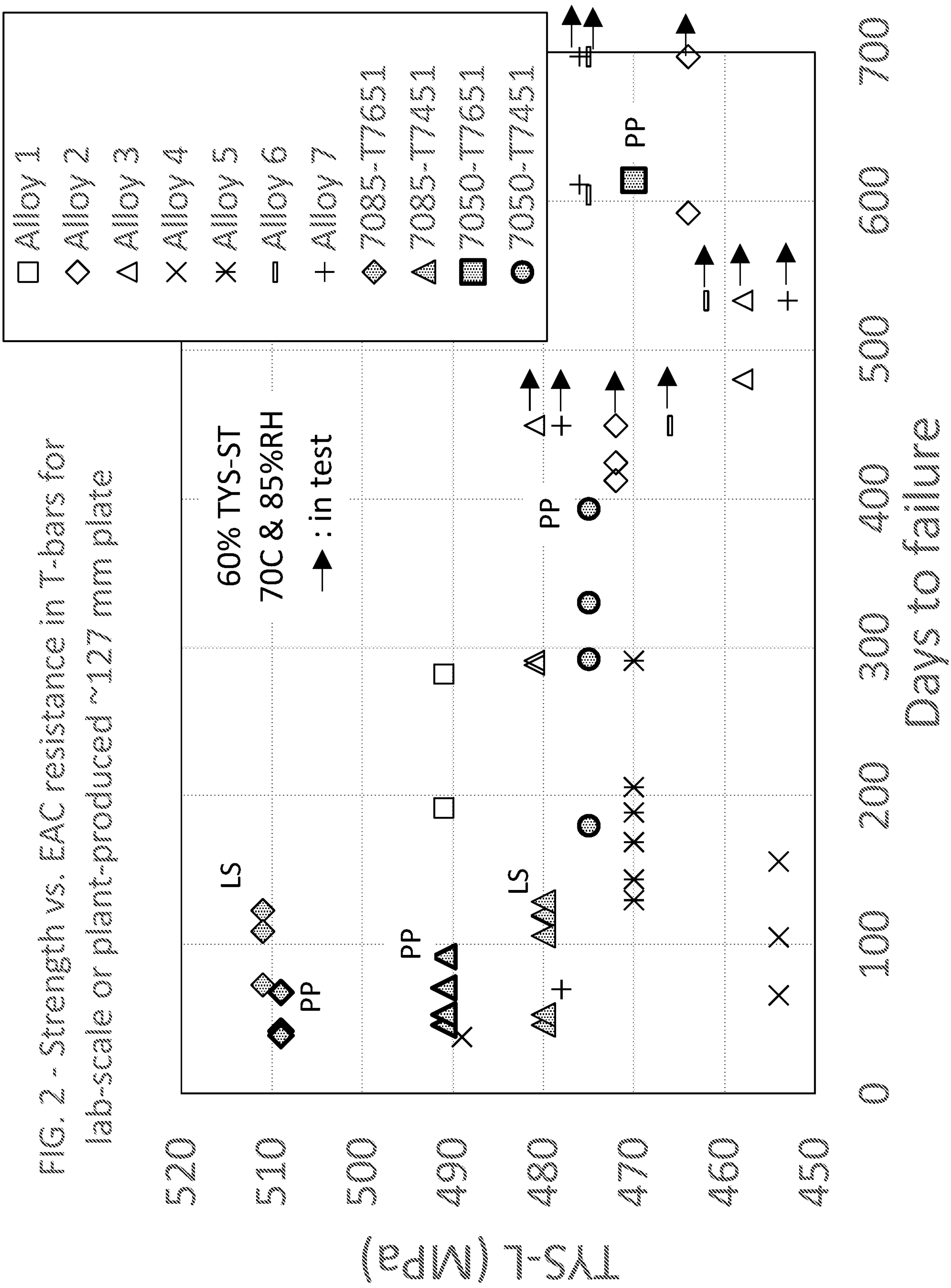


FIG. 2 - Strength vs. EAC resistance in T-bars for lab-scale or plant-produced ~127 mm plate

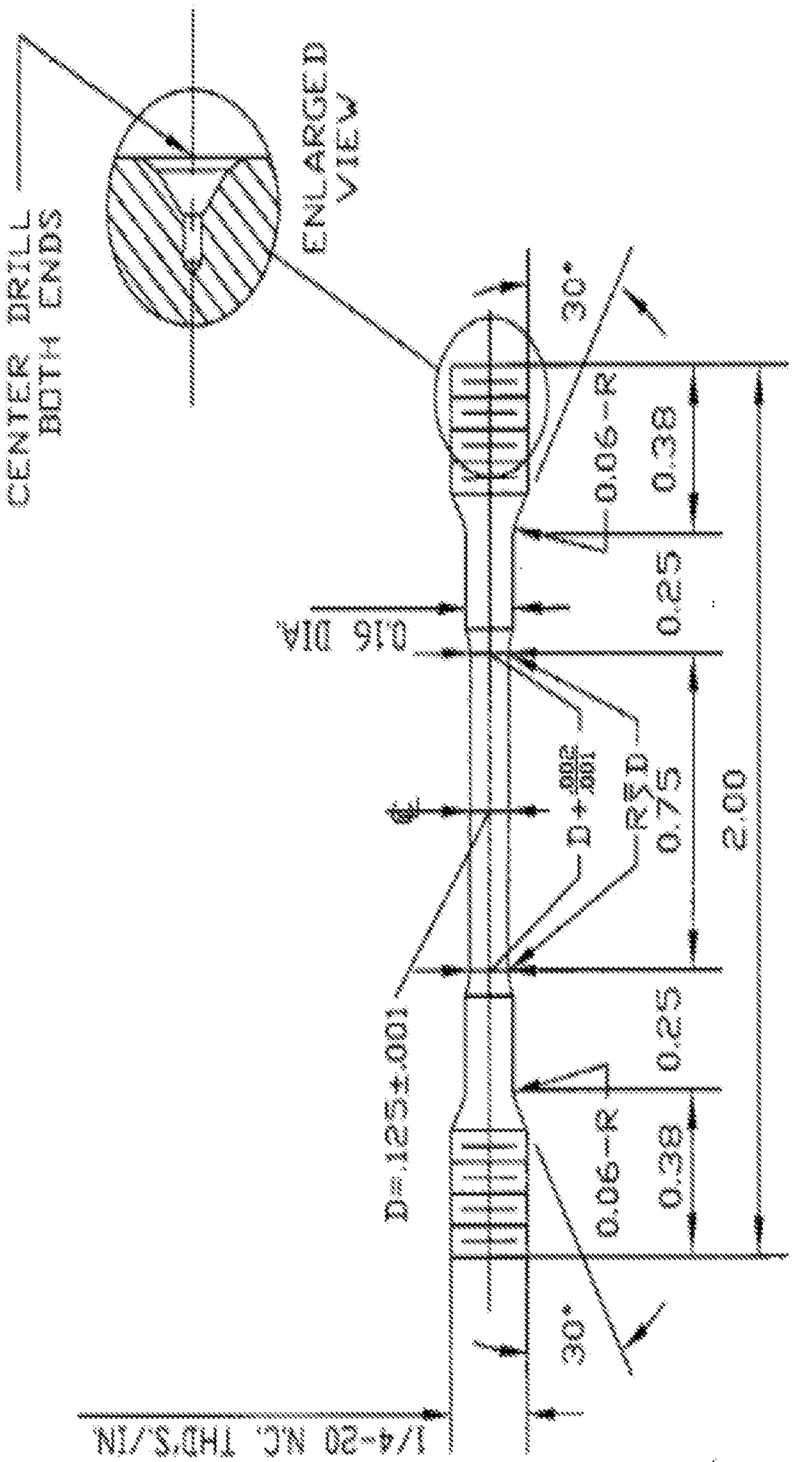

CENTER DRILL
BOTH ENDS
ENLARGED
VIEW
30°
0.06-R
0.38
0.25
0.16 DIA
0.75
2.00
0.25
0.06-R
0.38
D=.125±.001
30°
1/4-20 N.C. THD'S./IN

FIG. 3

FIG. 4 - Strength vs. EAC resistance in T-bars for lab-scale or plant-produced ~200 mm plate

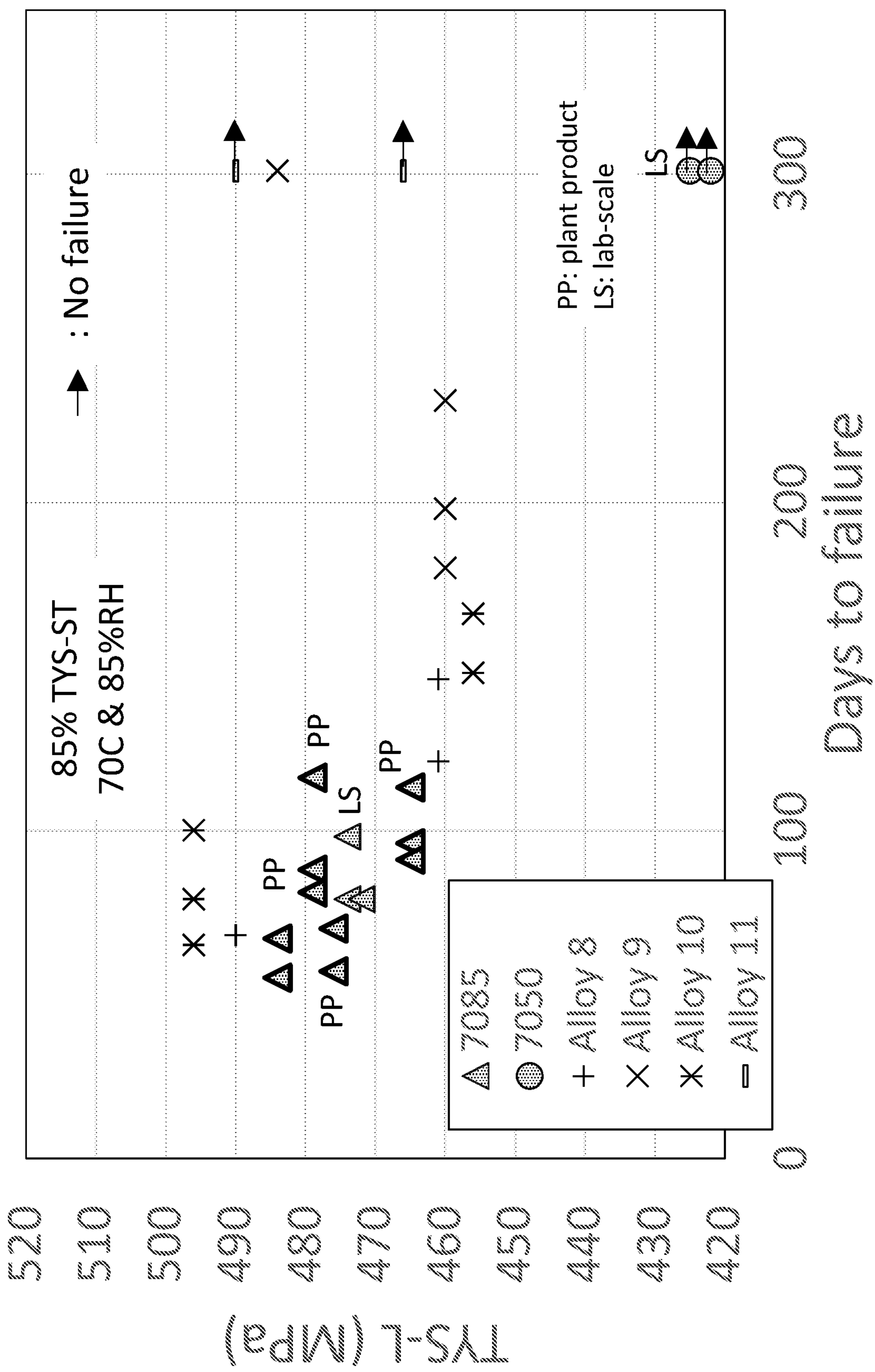


FIG. 5 - Strength vs. EAC resistance in T-bars for lab-scale or plant-produced ~200 mm plate

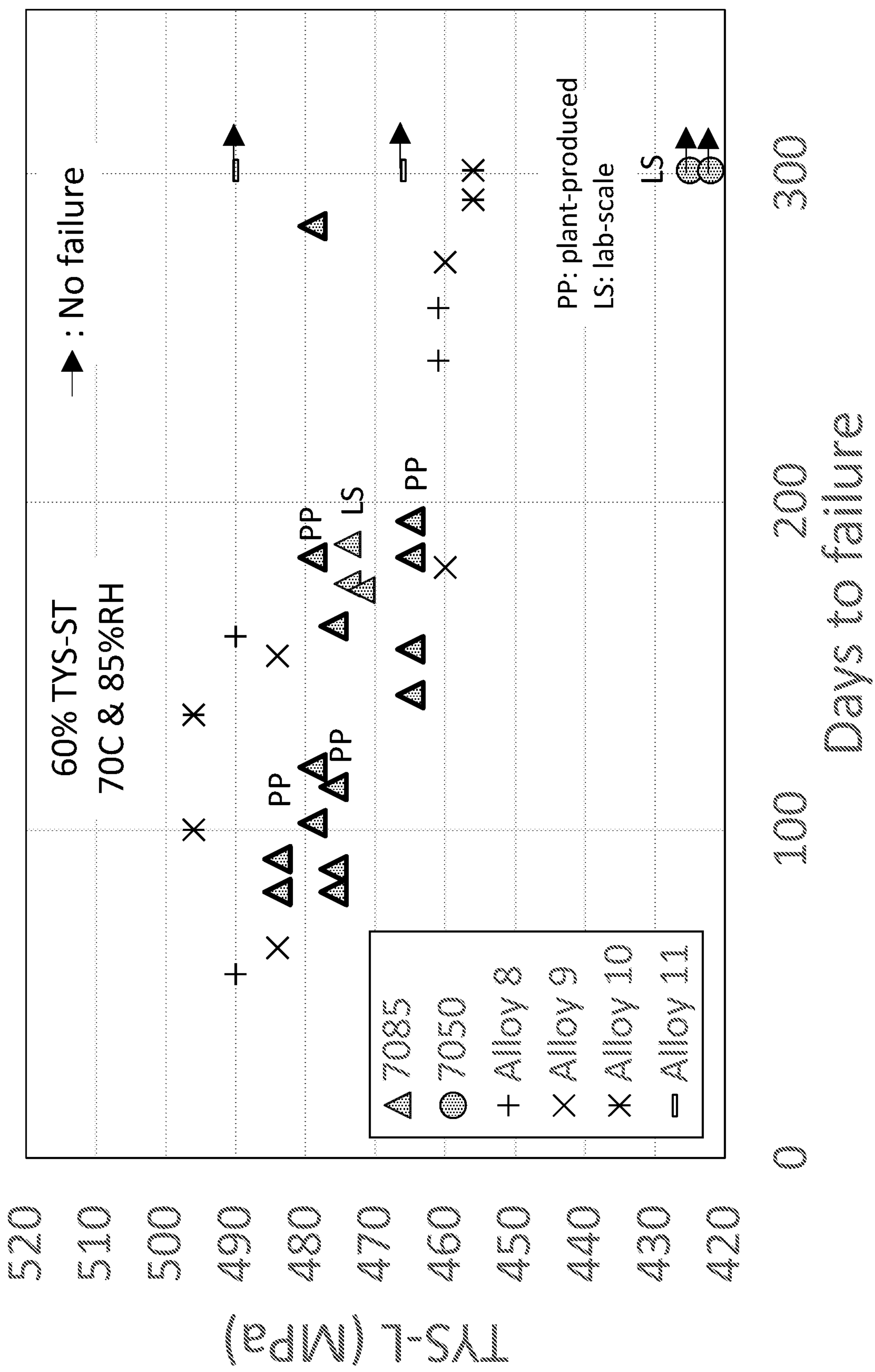


FIG. 6 - Strength vs. EAC resistance in T-bars for plant-produced ~100 mm plate

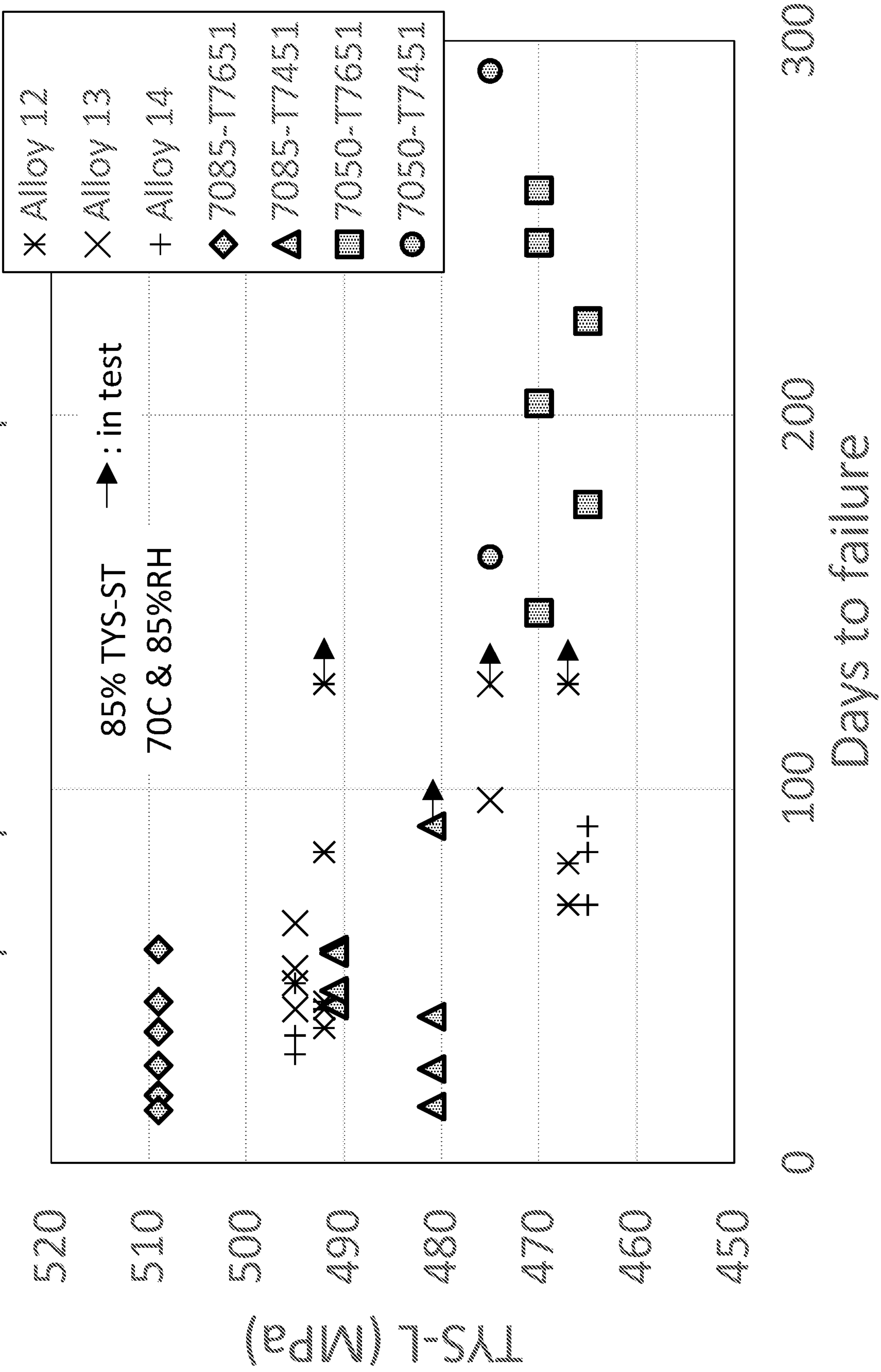
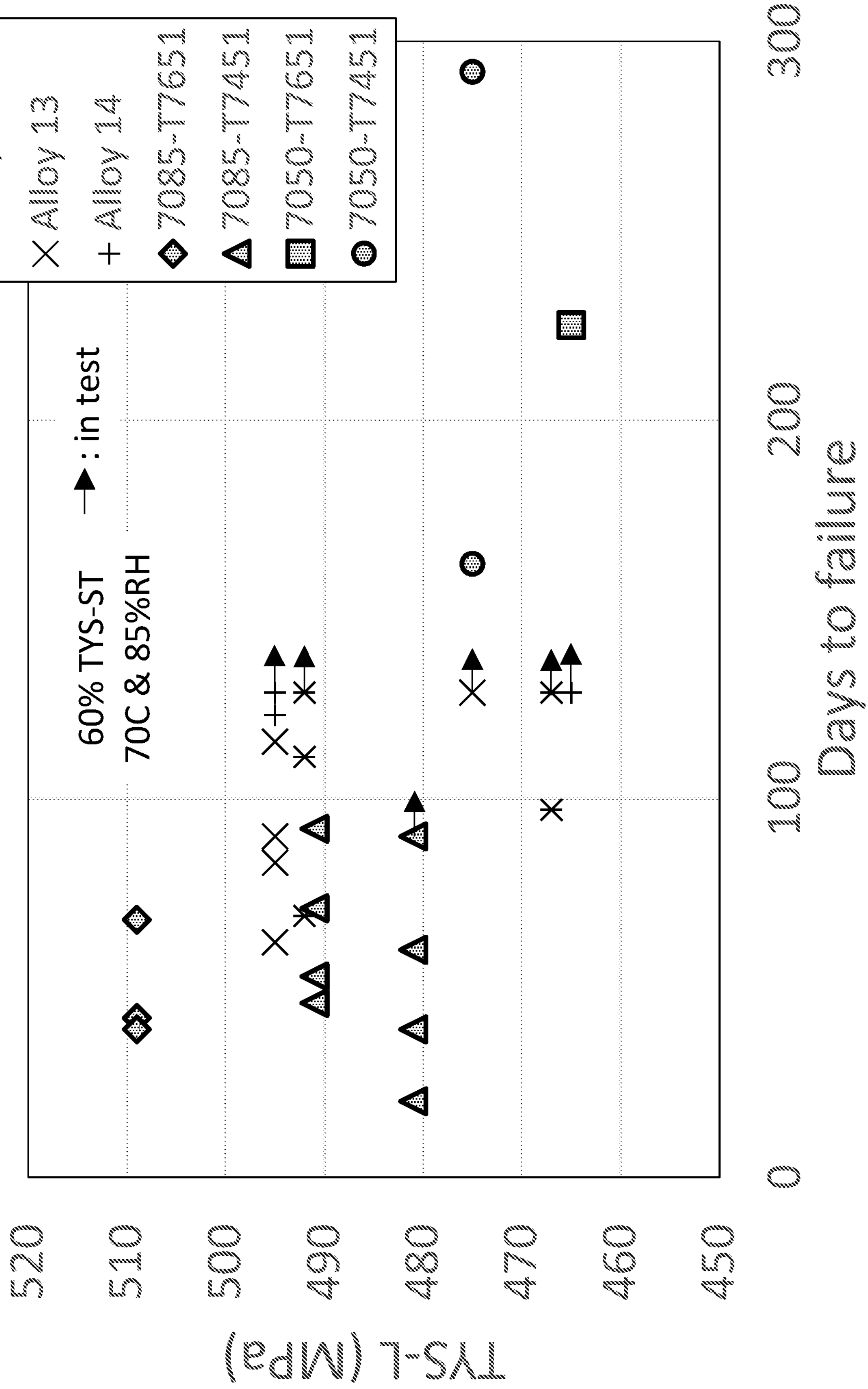
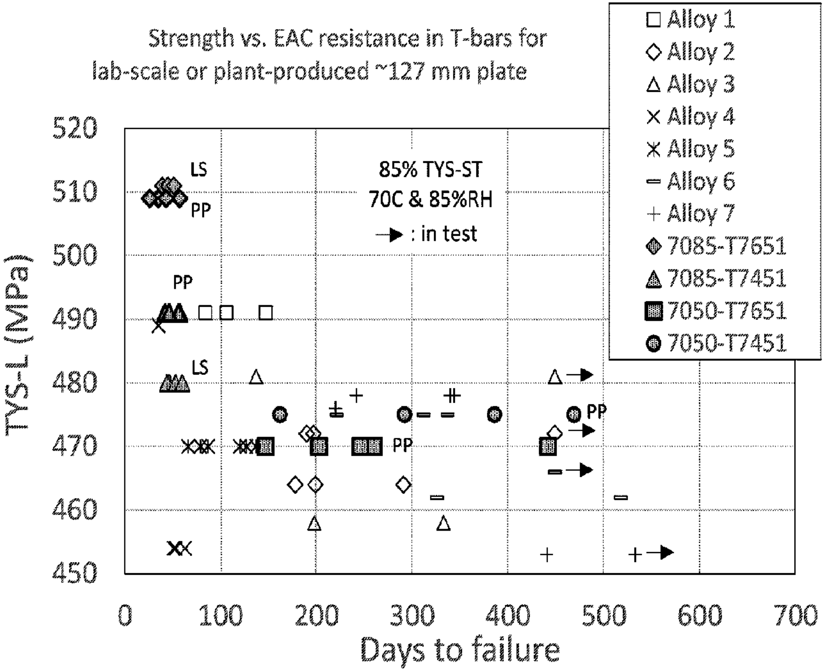


FIG. 7 - Strength vs. EAC resistance in T-bars for plant-produced ~100 mm plate





Strength vs. EAC resistance in T-bars for
lab-scale or plant-produced ~127 mm plate
85% TYS-ST
70C & 85%RH
: in test
LS
PP
PP
LS
PP
PP
520
510
500
490
480
470
460
450
TYS-L (MPa)
0
100
200
300
400
500
600
700
Days to failure
Alloy 1
Alloy 2
Alloy 3
Alloy 4
Alloy 5
Alloy 6
Alloy 7
7085-T7651
7085-T7451
7050-T7651
7050-T7451