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Aluminum Alloys and effect of adding copper to proprieties

(case Study)

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الآيـــــة

بسم الله الرحمن الرحيم

قال تعالي: (يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ)

صدق الله العظيم

المجادلة (11)

الإهـــــداء

إلى من كلله الله بالهيبة والوقار
إلى من علمني العطاء بدون انتظار
إلى من أحمل أسمه بكل افتخار
أرجو من الله أن يمد في عمرك لترى ثماراً قد حان قطافها بعد طول انتظار
والدي العزيز
إلى معنى الحب وإلى معنى الحنان والتفاني إلى من كان دعائها سر نجاحي
إلى حكمتي وعلمي
إلى أدبيوحلمي
إلى طريقيالمستقيم
إلى طريق الهداية
إلى ينبوع الصبر والتفاؤل والأمل
إلى كل من في الوجود بعد الله ورسوله أمي الغالية
إلى سندي وقوتي وملاذي بعد الله
إلى من آثروني على نفسهم
إلى من علموني علم الحياة
إلى من أظهروا لي ما هو أجمل من الحياة إخوتي
إلى من كانوا ملاذي وملجئي
إلى من تذوقت معهم أجمل اللحظات

إلى من جعلهم الله أخوتي بالله

الشكر والعرفان

إلى من وقف على المنابر وأعطى من حصيلة فكره لينير دربنا
إلى الشموع التي ذابت في كبرياء
لتنير كل خطوة في دربنا
لتذلل كل عائق أمامنا
فكانوا رسلاً للعلم والأخلاق
إلى الأساتذة الكرام في كلية الهندسة
شكراً لكم جميعاً
ونتوجه بالشكر الجزيل إلى:
مازن شمس الدينالطاهر

ملخص الدراسة:

تتلخص هذه الدراسة في التعرف على سبائك الألمنيوم بصفة عامة. وسبائك الألمنيوم– نحاس بصفة خاصة.ودراسة اضافة النحاس إلى الألومنيوم والخصائص التي تتغير في السبائك.

تتم عملية الصهر باستخدام فرن كهربي وعملية السبك تمت باستخدام القوالب الرملية وتم التأكد من نسب الخلط قبل عملية الصهر ومن ثمتمت عملية خراطة للعينات وتم اجراء اختبار الصلادة واختبار الشد.

تم التوصل إلى أن الصلادة تزيد بزيادة نسبة النحاس في سبيكة الألمونيوم وأن مقاومة السبيكة للصدم تقل مع زيادة نسبة النحاس.

Abstract

This study summarized in the identification of aluminum alloys in general and aluminum-copper alloys specific. And study effect of adding a pure copper to aluminum alloys.

The melting process has done by using electrical furnace and plumber process using sand molds and chemical analysis was done before melting process. Then use turning machine and move to hardness and tensile strength tests.

It was concluded that the hardness increase with proportion of copper in aluminum alloy. But tensile strength decrease with proportion of copper in aluminum alloy.

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Chapter one

Introduction

1.1 Introduction:

Aluminum one of the most existed metal on nature (earth surface). About 8% of earth surface and known until now about 250 varieties canprovide aluminum. And can economically be used and separated from its row form,and used in military and civilian application. And with alloys they can be second only to steels in use as structural metals.

About 3 of 5 of aluminum production use to aluminum alloys as good properties provided.

1.2 Problem and important of the research:

Knowing and study adding copper to aluminum and test mechanical and physical properties.

1.3 Propose of the research:

Study properties of aluminum alloys as general. Then aluminum-copper alloys. And what properties that should be existed in every alloys.

1.4 Scope of research:

Practical study to change of mixer percentage in aluminum-copper alloys and change of mechanical properties. According to copper percentage change. And we will examine two aluminum- copper alloys:

1. Copper ad by 5%: Al95%-Cu5%.
2. Copper ad by 10%: Al90%-Cu10%.

1.5 Research methodology:

Theoretical study of alloys variety and aluminum alloys precisely.Forming two samples of aluminum- copper alloys. First with 5% copper and the second with 10% copper. Prepaid the samples throw turning machine to perfect and desired shape then measuring hardness and Tensile strength. And compartment between tested values and standard values. And find the problem of the differences.

Chapter two

Theoretical framework and previous studies

2.1Aluminum: General Characteristics:

The unique combinations of properties provided by aluminum and its alloys make aluminum one of the most versatile, economical, and attractive metallic materials for a broad range of uses—from soft, highly ductile wrapping foil to the most demanding engineering applications. Aluminum alloys are second only to steels in use as structural metals.

Aluminum has a density of only 2.7 g/cm3, approximately one-third as much as steel (7.83 g/cm3). One cubic foot of steel weighs about 490 lb; a cubic foot of aluminum, only about 170 lb. Such light weight, coupled with the high strength of some aluminum alloys (exceeding that of structural steel), permits design and construction of strong, lightweight structures that are particularly advantageous for anything that moves space vehicles and aircraft as well as all types of land- and water-borne vehicles.

Aluminum resists the kind of progressive oxidization that causes steel to rust away. The exposed surface of aluminum combines with oxygen to form an inert aluminum oxide film only a few ten-millionths of an inch thick, which blocks further oxidation. And, unlike iron rust, the aluminum oxide film does not flake off to expose a fresh surface to further oxidation. If the protective layer of aluminum is scratched, it will instantly reseal itself.

Appropriately alloyed and treated, aluminum can resist corrosion by water, salt, and other environmental factors, and by a wide range of other chemical and physical agents. The corrosion characteristics of aluminum alloys are examined in the section “Effects of Alloying on Corrosion Behavior”.

2.2 Alloy Categories:

It is convenient to divide aluminum alloys into two major categories: wrought compositions and cast compositions. A further differentiation for each category is based on the primary mechanism of property development. Many alloys respond to thermal treatment based on phase solubility. These treatments include solution heat treatment, quenching, and precipitation, or age, hardening. For either casting or wrought alloys, such alloys are described as heat treatable.

A large number of other wrought compositions rely instead on work hardening through mechanical reduction, usually in combination with various annealing procedures for property development. These alloys are referred to as work hardening. Some casting alloys are essentially not heat treatable and are used only in as-cast or in thermally modified conditions unrelated to solution or precipitation effects.

Cast and wrought alloy nomenclatures have been developed. The Aluminum Association system is most widely recognized in the United States. Their alloy identification system employs different nomenclatures for wrought and cast alloys, but divides alloys into families for simplification.

For wrought alloys a four-digit system is used to produce a list of wrought composition families as follows:

- 1xxx: Controlled unalloyed (pure) composition, used primarily in the electrical and chemical industries
- 2xxx: Alloys in which copper is the principal alloying element, although other elements, notably magnesium, may be specified. 2xxx series alloys are widely used in aircraft where their high strength (yield strengths as high as 455 MPa, or 66 ksi) is valued.
- 3xxx: Alloys in which manganese is the principal alloying element, used as general-purpose alloys for architectural applications and various products
- 4xxx: Alloys in which silicon is the principal alloying element, used in welding rods and brazing sheet
- 5xxx: Alloys in which magnesium is the principal alloying element, used in boat hulls, gangplanks, and other products exposed to marine environments
- 6xxx: Alloys in which magnesium and silicon are the principal alloying elements, commonly used for architectural extrusions and automotive components
- 7xxx: Alloys in which zinc is the principal alloying element (although other elements, such as copper, magnesium, chromium, and zirconium, may be specified), used in aircraft structural components and other high-strength applications. The 7xxx series are the strongest aluminum alloys, with yield strengths ≥500 MPa (≥73 ksi) possible.

- 8xxx: Alloys characterizing miscellaneous compositions. The 8xxx series alloys may contain appreciable amounts of tin, lithium, and/or iron.

- 9xxx: Reserved for future use.

2.3 Aluminum Alloy Designation System:

2.3.1Wrought Aluminum Alloy Designation System:

The Aluminum Association Wrought Alloy Designation System consists of four numerical digits, sometimes including alphabetic prefixes or suffixes, but normally just the four numbers:

- The first digit defines the major alloying class of the series starting with that number.
- The second defines variations in the original basic alloy: that digit is always a zero (0) for the original composition, a one (1) for the first variation, a two (2) for the second variation, and so forth. Variations are typically defined by differences in one or more alloying elements of 0.15 to 0.50% or more, depending on the level of the added element.
- The third and fourth digits designate the specific alloy within the series; there is no special significance to the values of those digits, nor are they necessarily used in sequence.
- Members of the 1000 series family are commercially pure aluminum or special purity versions and as such do not typically have any alloying elements intentionally added; however, they do contain minor impurities that are not removed unless the intended application requires it.
- The 8000 series family is an “other elements” series comprising alloys with rather unusual major alloying elements such as iron and nickel.
- The 9000 series is unassigned.

Table (2.1): main alloying elements in wrought alloys designation system:

Alloy	**Main alloying element**
1xxx	Mostly pure aluminum; no additions
2xxx	Copper
3xxx	Manganese
4xxx	Silicon
5xxx	Magnesium
6xxx	Magnesium and silicon
7xxx	Zinc
8xxx	Other elements (e.g. iron or tin)
9xxx	Unassigned

- 1xxx series alloys are pure aluminum and its variations; compositions of 99.0% or more aluminum are by definition in this series.

Within the 1xxx series, the last two of the four digits in the designation indicate the minimum aluminum percentage. These digits are the same as the two digits to the right of the decimal point in the minimum aluminum percentage specified for the designation when expressed to the nearest 0.01%. As with the rest of the alloy series, the second digit indicates modifications in impurity limits or intentionally added elements.

- Compositions of the 1xxx series do not respond to any solution heat treatment but may be strengthened modestly by strain hardening.

2.3.2 Cast Aluminum Alloys Designation System:

- The first digit indicates the alloy group. For 2xx.x through 8xx.x alloys, the alloy group is determined by the alloying element present in the greatest mean percentage, except in cases in which the composition being registered qualifies as a modification of a previously registered alloy. The 6xx.x series is shown last and for cast alloys is designated as the unused series.

- The second and third digits identify the specific aluminum alloy or, for the aluminum 1xx.x series, indicate purity. If the greatest mean percentage is common to more than one alloying element, the alloy group is determined by the element that comes first in sequence. For the 1xx.x group, the second two of the four digits in the designation indicate the minimum aluminum percentage. These digits are the same as the two digits to the right of the decimal point in the minimum aluminum percentage when expressed to the nearest 0.01%.

- The fourth digit indicates the product form: xxx.0 indicates castings, and xxx.1, for the most part, indicates ingot having limits for alloying elements the same as or very similar to those for the alloy in the form of castings. A fourth digit of xxx.2 may be used to indicate that the ingot has composition limits that differ from but fall within the xxx.1 limits; this typically represents the use of tighter limits on certain impurities to achieve specific properties in the finished cast product produced from that ingot.

Table (2.2): Strength ranges of various wrought aluminum alloys:

Aluminum Association series	Type of alloy composition	Strengthening method	Tensile strength range	
			` MPa	ksi
1xxx	Al	Cold work	70–175	10–25
2xxx	Al-Cu-Mg (1–2.5% Cu)	Heat treat	170–310	25–45
2xxx	Al-Cu-Mg-Si (3–6% Cu)	Heat treat	380–520	55–75
3xxx	Al-Mn-Mg	Cold work	140–280	20–40
4xxx	Al-Si	Cold work (some heat treat)	105–350	15–50
5xxx	Al-Mg (1–2.5% Mg)	Cold work	140–280	20–40
5xxx	Al-Mg-Mn (3–6% Mg)	Cold work	280–380	40–55
6xxx	Al-Mg-Si	Heat treat	150–380	22–55
7xxx	Al-Zn-Mg	Heat treat	380–520	55–75
7xxx	Al-Zn-Mg-Cu	Heat treat	520–620	75–90
8xxx	Al-Li-Cu-Mg	Heat treat	280–560	40–80

Table (2.3): Strength ranges of various cast aluminum alloys:

Alloy system (AA designation)	Tensile strength range	
	MPa	Ksi
Heat treatable sand cast alloys (various tempers)		
Al-Cu (201–206)	353–467	51–68
Al-Cu-Ni-Mg (242)	186–221	27–32
Al-Cu-Si (295)	110–221	16–32
Al-Si-Cu (319)	186–248	27–36
Al-Si-Cu-Mg (355, 5% Si, 1.25% Cu, 0.5% Mg)	159–269	23–39
Al-Si-Mg (356, 357)	159–345	23–50
Al-Si-Cu-Mg (390, 17% Si, 4.5% Cu, 0.6% Mg)	179–276	26–40
Al-Zn (712, 713)	241	35
Non-heat treatable die cast alloys		
Al-Si (413, 443, F temper)	228–296	33–43
Al-Mg (513, 515, 518, F temper)	276–310	40–45
Non-heat treatable permanent mold cast alloys		
Al-Sn (850, 851, 852, T5 temper)	138–221	20–32

Table (2.4): Nominal chemical composition of wrought aluminum alloys:

Alloy	Silicon	Copper	Manganese	Magnesium	Chromium	Nickel	Zinc	Titanium
1050	…..	…..	99.50% min aluminum		…..	…..	…..	…..
1060	…..	…..	99.60% min aluminum		…..	…..	…..	…..
1100	…..	0.12	99.0% min aluminum		…..	…..	…..	…..
1145	…..	…..	99.45% min aluminum		…..	…..	…..	…..
1175	…..	…..	99.75% min aluminum		…..	…..	…..	…..
1200	…..	…..	99.00% min aluminum		…..	…..	…..	…..
1230	…..	…..	99.30% min aluminum		…..	…..	…..	…..
1235	…..	…..	99.35% min aluminum		…..	…..	…..	…..
1345	…..	…..	99.45% min aluminum		…..	…..	…..	…..
1350(a)	…..	…..	99.50% min aluminum		…..	…..	…..	…..
2011(b)	…..	5.5	…..	…..	…..	…..	…..	…..
2014	0.8	4.4	0.8	0.50	…..	…..	…..	…..
2017	0.50	4.0	0.7	0.6	…..	…..	…..	…..
2018	…..	4.0	…..	0.7	…..	2.0	…..	…..

2024	…..	4.4	0.6	1.5	…..	…..	…..	…..
2025	0.8	4.4	0.8	…..	…..	…..	…..	…..
2036	…..	2.6	0.25	0.45	…..	…..	…..	…..
2117	…..	2.6	…..	0.35	…..	…..	…..	…..
2124	…..	4.4	0.6	1.5	…..	…..	…..	…..
2218	…..	4.0	…..	1.5	…..	2.0	…..	…..
2219(c)	…..	6.3	0.30	…..	…..	…..	…..	0.06
2319(c)	…..	6.3	0.30	…..	…..	…..	…..	0.15
2618(d)	0.18	2.3	…..	1.6	…..	1.0	…..	0.07
3003	…..	0.12	1.2	…..	…..	…..	…..	…..
3004	…..	…..	1.2	1.0	…..	…..	…..	…..
3005	…..	…..	1.2	. 0.40	…..	…..	…..	…..
3105	…..	…..	0.6	0.50	…..	…..	…..	…..
4032	12.2	0.9	…..	1.0	…..	0.9	…..	…..
4043	5.2	…..	…..	…..	…..	…..	…..	…..
4045	10.0	…..	…..	…..	…..	…..	…..	…..
4047	12.0	…..	…..	…..	…..	…..	…..	…..
4145	10.0	4.0	…..	…..	…..	…..	…..	…..
4343	7.5	…..	…..	…..	…..	…..	…..	…..
4643	4.1	…..	…..	0.20	…..	…..	…..	…..
5005	…..	…..	…..	0.8	…..	…..	…..	…..
5050	…..	…..	…..	1.4	…..	…..	…..	…..
5052	…..	…..	…..	2.5	0.25	…..	…..	…..
5056	…..	…..	0.12	5.0	0.12	…..	…..	…..
5083	…..	…..	0.7	4.4	0.15	…..	…..	…..
5086	…..	…..	0.45	4.0	0.15	…..	…..	…..
5154	…..	…..	…..	3.5	0.25	…..	…..	…..
5183	…..	…..	0.08	4.8	0.15	…..	…..	…..
5252	…..	…..	…..	2.5	…..	…..	…..	…..
5254	…..	…..	…..	3. 5	0.25	…..	…..	…..
5356	…..	…..	0.12	5.0	0.12	…..	…..	0.13
5454	…..	…..	0.08	2.7	0.12	…..	…..	…..
5456	…..	…..	0.08	5.1	0.12	…..	…..	…..
5457	…..	…..	0.30	1.0	…..	…..	…..	…..
5554	…..	…..	0.08	2.7	0.12	…..	…..	0.12
5556	…..	…..	0.08	5.1	0.12	…..	…..	0.12
5652	…..	…..	…..	2.5	0.25	…..	…..	
5654	…..	…..	…..	3.5	0.25	…..	…..	0.10
5657	…..	…..	…..	0.8	…..	…..	…..	…..
6003	0.7	…..	…..	1.2	…..	…..	…..	…..
6005	0.8	…..	…..	0.50	…..	…..	…..	…..
6053	0.7	…..	…..	1.2	0.25	…..	…..	…..
6061	0.6	0.28	…..	1.0	0.20	…..	…..	…..
6063	0.40	…..	…..	0.7	…..	…..	…..	…..
6066	1.4	1.0	0.8	1.1	…..	…..	…..	…..

6070	1.4	0.28	0.7	0.8	…..	…..	…..	…..
6101	0.50	…..	…..	0.6	…..	…..	…..	…..
6105	0.8	…..	…..	0.6	…..	…..	…..	…..
6151	0.9	…..	…..	0.6	0.25	…..	…..	…..
6162	0.6	…..	…..	0.9	…..	…..	…..	…..
6201	0.7	…..	…..	0.8	…..	…..	…..	…..
6253	0.7	…..	…..	1.2	0.25	…..	2.0	…..
6262(e)	0.6	0.28	…..	1.0	0.09	…..	…..	…..
6351	1.0	…..	0.6	0.6	…..	…..	…..	…..
6463	0.40	…..	…..	0.7	…..	…..	…..	…..
6951	0.35	0.28	…..	0.6	…..	…..	…..	…..
7005(f)	…..	…..	0.45	1.4	0.13	…..	4.5	0.04
7008	…..		…..	1.0	0.18	…..	5.0	…..
7049	…..	1.6	…..	2.4	0.16	…..	7.7	…..
7050(g)	…..	2.3	…..	2.2	…..	…..	6.2	…..
7072	…..	…..	…..	…..	…..	…..	1.0	…..
7075	…..	1.6	…..	2.5	0.23	…..	5.6	…..
7108(h)	…..	…..	…..	1.0		…..	5.0	…..
7175	…..	1.6	…..	2.5	0.23	…..	5.6	…..
7178	…..	2.0	…..	2.8	0.23	…..	6.8	…..
7475	…..	1.6	…..	2.2	0.22	…..	5.7	…..
8017(i)	…..	0.15	…..	0.03	…..	…..	…..	…..
8030(j)	…..	0.22	…..	…..	…..	…..	…..	…..
8176(i)	0.09	…..	…..	…..	…..	…..	…..	…..
8177(k)	…..	…..	…..	0.08	…..	…..	…..	…..

Listed herein are designations and chemical composition limits for some wrought unalloyed aluminum and for wrought aluminum alloys registered with the Aluminum Association. This does not include all alloys registered with the Aluminum Association. A complete list of registered designations is contained in the Registration Record of International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys.

These lists are maintained by the Technical Committee on Product Standards of The Aluminum Association. (a) Formerly designated EC. (b) Lead and bismuth, 0.40 each. (c) Vanadium, 0.10; zirconium 0.18. (d) Iron,

1.1. (e) Lead and Bismuth, 0.55 each. (f) Zirconium, 0.14. (g) Zirconium, 0.12. (h) Zirconium, 0.18. (i) Iron, 0.7. (j) Boron, 0.02. (k) Iron, 0.35.

Alloy	Percent of alloying elements; aluminum and normal impurities constitute remainder									
	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Nickel	Zinc	Titanium	notes
201.0			4.6	0.35	0.35				0.25	(a)
204.0			4.6		0.25					
A206.0			4.6	0.35	0.25				0.22	
208.0	3.0		4.0							
213.0	2.0	1.2	7.0					2.5		
222.0			10.0		0.25					
224.0			5.0	0.35						(b)
240.0			8.0	0.5	6.0		0.5			
242.0			4.0		1.5		2.0			
A242.0			4.1		1.4	0.20	2.0		0.14	
295.0	1.1		4.5							
308.0	5.5		4.5							
319.0	6.0		3.5							
328.0	8.0		1.5	0.40	0.40					
332.0	9.5		3.0		1.0					
333.0	9.0		3.5		0.28					
336.0	12.0		1.0		1.0		2.5			
354.0	9.0		1.8		0.5					
355.0	5.0		1.25		0.5					
C355.0	5.0		1.25		0.5					(c)
356.0	7.0				0.32					
A356.0	7.0				0.35					(c)
357.0	7.0				0.52					
A357.0	7.0				0.55				0.12	(c, d)
359.0	9.0				0.6					
360.0	9.5				0.5					
A360.0	9.5				0.5					(c)
380.0	8.5		3.5							
A380.0	8.5		3.5							(c)
383.0	10.5		2.5							
384.0	11.2		3.8							
B390.0	17.0		4.5		0.55					
413.0	12.0									
A413.0	12.0									
443.0	5.2									
B443.0	5.2									(c)
C443.0	5.2	(e)								
A444.0	7.0									
512.0	1.8				4.0					
513.0					4.0			1.8		
514.0					4.0					
518.0					8.0					
520.0					10.0					
535.0				.18	6.8				0.18	(f)
705.0				0.5	1.6	0.30		3.0		
707.0				0.50	2.1	0.30		4.2		
710.0			0.50		0.7			6.5		
711.0		1.0	0.50		0.35			6.5		

712.0					0.58	0.50		6.0	0.20		
713.0			0.7		0.35			7.5			
771.0					0.9	0.40		7.0	0.15		
850.0			1.0				1.0			(g)	
851.0	2.5		1.0				0.50			(g)	
852.0			2.0		0.75		1.2			(g)	

Table (2.5): Nominal chemical compositions of aluminum alloy castings:

Values are nominal (i.e., average of range of limits for elements for which a range is specified). (a) Also contains 0.7% silver. (b) Also contains 0.10% vanadium and 0.18% zirconium. (c) For this alloy, impurity limits are significantly lower than for the similar alloy listed just above. (d) Also contains 0.055% beryllium. (e) May contain higher iron (up to 2.0% total) than 443.0 and A443.0. (f) Also contains 0.005% beryllium and 0.005% boron. (g) Also contains 6.2% tin.

2.4Wrought alloys heat-treatable (precipitation-hardenable):

Aluminum alloys include the 2xxx, 6xxx, 7xxx, and some of the 8xxx alloys. The various combinations of alloying additions and strengthening mechanisms used for wrought aluminum alloys are shown in Table 1. The strength ranges achievable with various classes of wrought and cast alloys are given in Tables 2 and 3.

2.4.1 Effects of Alloying on Corrosion Behavior:

Normal surface film formed in air at ambient temperature is only about5 nm (50 Å) thick. If damaged, this thin film re-forms immediately inmost environments and continues to protect the aluminum from corrosion.

When the film is removed or damaged under conditions such that self-repair cannot occur, corrosion takes place.

The corrosion resistance of an aluminum alloy depends on both metallurgical and environmental variables. Metallurgical variables that affect corrosion are composition (as described below), heat treatment (proper temper selection), and mechanical working. These determine the microstructure, which decides whether localized corrosion occurs and the method of attack.

Because many variables influence corrosion, the suitability of aluminum cannot be considered solely on the basis of a specific product or environment. A detailed knowledge of traces of impurities, conditions of operation, design of a piece of equipment, and alloy microstructure is essential. Experience gained from previously successful service applications is most valuable.

- 1xx.x Controlled unalloyed (pure) compositions.
- 2xx.x: Alloys in which copper the principal is alloying element.
- 3xx.x: Alloys in which silicon is the principal alloying element. The other alloying elements such as copper and magnesium are specified. The 3xx.x series comprises nearly 90% of all shaped castings produced.
- 4xx.x: Alloys in which silicon is the principal alloying element.
- 5xx.x: Alloys in which magnesium is the principal alloying element.
- 6xx.x: Unused.
- 7xx.x: Alloys in which zinc is the principal alloying element. Other alloying elements such as copper and magnesium may be specified.
- 8xx.x: Alloys in which tin the principal is alloying element.

2.5 Aluminum Alloy Temper Designation System:

2.5.1Basic Temper Designation:

The temper designation is always presented immediately after the alloy designation with a hyphen “-” between the designation and the tempering. (2014-T6).

The first character in the temper designation is a capital letter indicating the general class of treatment.

2.5.2 General class of treatment designations:

1. **(F) As fabricated**: Applies to wrought or cast products made by shaping processes in which there is no special control over thermal conditions or strain-hardening processes employed to achieve specific properties. For wrought alloys there are no mechanical property limits associated with this temper, although for cast alloys there generally are.
2. **(O)Annealed**: Applies to wrought products that are annealed to obtain the lower strength temper, usually to increase subsequent workability. The O applies to cast products that are annealed to improve ductility and dimensional stability and may be followed by a digit other thanzero.
3. **(H)Strain hardened:** Applies to products that have their strength increased by strain hardening. They may or may not have supplementary thermal treatments to produce some reduction in strength. The H is always followed by two or more digits.
4. **(W)Solution heat treated:** Applies only to alloys that age spontaneously after solution heat treating. This designation is specific only when digits are used in combination with W to indicate the period of natural aging, for example, W 1⁄2 hr.
5. **(T)Thermally treated to produce stable tempers other than F, O, or H:** Applies to products that are thermally treated, with or without supplementary strain hardening, to produce stable tempers. The T is always followed by one or more digits.

2.5.3 Subdivisions of the Basic (H)Tempers:

The temper designation system is based on sequences of basic treatments used to produce different tempers and their variations. Subdivisions of the basic tempers, discussed next, are indicated by one or more digits (descriptor digits) following the letter:

- **(H1**) strain hardened only: Applies to products that have been strain hardened to obtain a desired level of strength without a supplementary thermal treatment. The number following H1 indicates degree of strain hardening.
- **(H2**) strain hardened and partially annealed: Applies to products that have been strain hardened more than the desired final amount, and their strength is reduced to the desired level by partial annealing. The number added to H2 indicates the degree of strain hardening remaining after partial annealing
- **(H3**) strain hardened and stabilized: Applies to products that have been strain hardened and then stabilized either by a low temperature treatment, or as a result of heat introduced during fabrication of the product. Thermal Stabilization usually improves ductility .The H3 temper is used only for those alloys that will gradually age soften at room temperature if they are not stabilized. The number added to H3 indicates the degree of strain hardening remaining after stabilization.
- **(H4**) strain hardened and lacquered or painted: Applies to products that have been strain hardened and that have been subjected to heat during subsequent painting or lacquering operations. The number added to H4 indicates the amount of strain hardening left after painting or lacquering.

2.5.4Subdivisions of the Basic (T)Temper:

The first numbers following the letter T designation indicates the specific combination of basic operations:

1. **(T1) cooled from elevated temperature shaping process and naturally aged to a substantially stable condition: Applies to products:**
    (a) Products that are not cold worked after cooling from an elevated temperature shaping process.
    (b) The effect of cold work in flattening or straightening may not be recognized in mechanical property limits.

2. **(T2) cooled from an elevated temperature shaping process, cold worked, and naturally aged to a substantially stable condition: Applies to products:**
   - (a) Products that are cold worked to improve strength after cooling from an elevated temperature shaping process.
   - (b) The effect of cold work in flattening or straightening is recognized in mechanical property limits.
3. **(T3) solution heat treated, cold worked, and naturally aged to a substantially stable condition: Applies to products:**
   - a. (a)Products that are cold worked to improve strength after solution heat treatment.
   - b. (b) The effect of cold work in flattening or straightening is recognized in mechanical property limits.
4. **(T4) solution heat treated and naturally aged to a substantially stable condition: Applies to products:**
   - (a) Products that are not cold worked after solution heat treatment.
   - b. (b)The effect of cold work in flattening or straightening may not be recognized in mechanical property limits.
5. **(T5) cooled from an elevated temperature shaping process, then artificially aged: Applies to products:**
   - (a) Products that are not cold worked after cooling from elevated temperature shaping process.
   - (b) Effect of cold work in flattening or straightening may not be recognized in mechanical property limits.
6. **(T6) solution treated, then artificially aged: Applies to products:**
   - (a) Products that are not cold worked after solution treatment.
   - (b) Theeffect of cold work in flattening or straightening may not be recognized in mechanical property limits.
7. **(T7) solution heat treated and over aged/stabilized Applies to:**
   - (a) Wrought products that are artificially aged after solution heat treating to increase their strength beyond the maximum value

achievable to provide control of some significant property or characteristic.

(b) Cast products that are artificially aged after solution treatment to provide stability in dimensions and in strength.

- **(T8) solution heat treated, cold worked, then artificially aged: Applies to products:**
  (a) That are cold worked to improve strength
  (b) The effect of cold work in flattening and straightening is recognized in mechanical property limits.
- **(T9) solution heat treated, artificially aged, and then cold worked: Applies to products that are cold worked to improve strength.**
- **(T10) cooled from an elevated temperature shaping process, cold worked, then artificially aged: Applies to products**:
  (a) That are cold worked to improve strength.
  (b) The effect of cold work in flattening or straightening is recognized in mechanical property limits.

In all of the T-type temper definitions just described, solution heat treatment is achieved by:

1. Heating cast or wrought shaped products to a suitable temperature
2. Holding them at that temperature long enough to allow constituents to enter into solid solution.
3. Cooling them rapidly enough to hold the constituents in solution to take advantage of subsequent precipitation and the associated strengthening (precipitation hardening).

2.5.5Adding Additional Digits (T) Temper:

Additional digits, the first of which shall not be zero, may be added to designations T1 through T10 to indicate a variation in treatment that significantly alters the product characteristics that are or would be obtained using the basic treatment. The specific additional digits shown in Table 7 have been assigned for stress-relieved tempers of wrought products. The special T-temper designations.

Table(2.6):Tempersforstress-relievedproducts**:**

Temper	Application
Stress relieved by stretching	
TX51	- Applies to plate and rolled or cold-finished rod or bar, die or ring forgings, and rolled rings when stretched the indicated amounts after solution heat treatment or after cooling from an elevated temperature shaping process. The products receive no further straightening after stretching. - Plate, 11⁄2–3% permanent set. - Rolled or cold-finished rod and bar, 1–3% permanent set - Die or ring forgings and rolled rings, 1–5% permanent set
TX510	- Applies to extruded rod, bar, profiles (shapes), and tube and to draw tube when stretched the indicated amounts after solution heat treatment or after cooling from an elevated temperature shaping process. These products receive no further straightening after stretching. - Extruded rod, bar, profiles (shapes), and tube, 1–3% permanent set. - Drawn tube, 1⁄2–3% permanent set.
TX511	- Applies to extruded rod, bar, profiles (shapes), and tube and to draw tube when stretched the indicated amounts after solution heat treatment or after cooling from an elevated temperature shaping process. These products may receive minor straightening after stretching to comply with standard tolerances. - Extruded rod, bar, profiles (shapes), and tube, 1–3% permanent set - Drawn tube, 1.5–3% permanent set.
Stress relieved by compressing	
TX52	- Applies to products that are stress relieved by compressing after solution heat treatment or cooling from an elevated temperature shaping process to produce a permanent set of 1–5%.
Stress relieved by combined stretching and compressing	
TX54	Applies to die forgings that are stress relieved by restricting cold in the finish die.

2.5.6Assigned (O) Temper Variations:

The following temper designation has been assigned for wrought products that are high-temperature annealed to accentuate ultrasonic response and to provide dimensional stability.

(O1) thermally treatedat approximately the same time and temperature required for solution heat treatment and slow cooled to room temperature: Applicable to products that are to be machined prior to solution heat treatment by the user. Mechanical property limits are not applicable.

Note: As the O temper is not part of the strain-hardened (H) series, variations of O temper shall not apply to products that are strain hardened after annealing and in which the effect of strain hardening is recognized in the mechanical properties or other characteristics.

Table (2.7) Tempers for testing response to heat treatment:

Temper	Application
T42	- Solution heat treated from annealed or F temper and naturally aged to a substantially stable condition.
T62	- Solution heat treated from annealed or F temper and artificially aged.
T7X2	- Solution heat treated from annealed or F temper and artificially over aged to meet the mechanical properties and corrosion resistance limits of the T7X temper.

2.6 characteristics and Applications by Alloy Class:

2.6.1Wrought Alloys:

2.6.1.1 Pure Aluminum1xxx:

The major characteristics:

1. Strain hardenable.
2. Exceptionally high formability, corrosion resistance, and electrical conductivity.
3. Typical ultimate tensile strength range: 70 to 185 MPa (10–27 ksi).
4. Readily joined by welding, brazing, and soldering.

The 1xxx series represents the commercially pure (CP) aluminum, ranging from the baseline 1100 (99.00% min Al) to relatively purer 1050/1350(99.50% minAl) and 1175 (99.75 % min Al).

The 1xxx series of alloys are strain hardenable but would not be used where strength is a prime consideration.

Applications is:

1. The primary uses of the 1xxx series would be applications in which the combination of extremely high corrosion resistance and formability are required (e.g., foil and strip for packaging, chemical equipment, tank caror truck bodies, spun hollowware, and elaborate sheet metal work).

2. Electrical applications are one major use of the 1xxx series, primarily 1350, which has relatively tight controls on those impurities that might lower electrical conductivity. As a result, an electrical conductivity of 62% of the International Annealed Copper Standard (IACS) is guaranteed for this material, which, combined with the natural light weight of aluminum, means a significant weight and, therefore, cost advantage over copper in electrical applications.

2.6.1.2 Aluminum-Copper Alloys2xxx:

The major characteristics:

1. Heat treatable.
2. High strength, at room and elevated temperatures.
3. Ultimate tensile strength range: 190 - 430 MPa (27–62 ksi).
4. Usually joined mechanically, but some alloys are wieldable.

The 2xxx series of alloys are heat treatable and possess in individual alloys good combinations of high strength (especially at elevated temperatures), toughness, and, in specific cases, weldability. They are not as resistant to atmospheric corrosion as several other series and so usually are painted or clad for added protection.

Applications is:

1. The higher-strength 2xxx alloys are widely used for aircraft (2024) and truck body (2014) applications, where they generally are used in bolted or riveted construction. Specific members of the series (e.g., 2219 and 2048) are readily joined by gas metal arc welding (GMAW) or gas tungsten arc welding (GTAW) and so are used for aerospace applications where that method is the preferred joining method.
2. Alloy 2195 is a new lithium-bearing aluminum alloy providing very high modulus of elasticity along with higher strength and comparable weldability to 2219 for space applications.

2.6.1.3 Aluminum-Manganese Alloys 3xxx:

The major characteristics:

1. Heat treatable.
2. High formability and corrosion resistance with medium strength.
3. Typical ultimate tensile strength range: 110 to 285 MPa (16–41 ksi).
4. Readily joined by all commercial procedures.

The 3xxx series of alloys are strain hardenable, have excellent corrosion resistance, and readily welded, brazed, and soldered.

Applications is:

1. Alloy 3003 is widely used in cooking utensils and chemical equipment because of its superiority in handling many food sand chemicals, and in builders' hardware because of its superior corrosion resistance. Alloy 3105 is a principal for roofing and siding.
2. 3003 and other members of the 3xxx series are widely used in sheet and tubular form for heat exchangers in vehicles and power plants. Because of the ease and flexibility of joining.

2.6.1.4Aluminum-Silicon Alloys4xxx:

The major characteristics:

1. Heat treatable.
2. Good flow characteristics, medium strength.
3. Typical ultimate tensile strength range: 175 to 380 MPa (25–55 ksi).
4. Easily joined, especially by brazing and soldering.

The 3xxx series of alloys are strain hardenable, have excellent corrosion resistance, and readily welded, brazed, and soldered.

Applications is:

There are two major uses of the 4xxx series, both generated by the excellent flow characteristics provided by relatively high silicon contents. The first is for forgings: the workhorse alloy is 4032, a medium high-strength, heat treatable alloy used principally in applications such as forged aircraft pistons. The second major application is a weld filler alloy; here the workhorse is 4043, used for GMAWand GTAW 6xxx alloys for structural and automotive applications.

2.6.1.5 Aluminum-Magnesium Alloys5xxx:

The major characteristics:

1. Strain hardenable.
2. Excellent corrosion resistance, toughness, weldability; moderate strength.
3. Building and construction, automotive, cryogenic, and marine applications.
4. Representative alloys: 5052, 5083, and 5754.
5. Typical ultimate tensile strength range: 125 to 350 MPa (18–51 ksi).

Aluminum-magnesium alloys of the 5xxx series are strain hardenable and have moderately high strength, excellent corrosion resistance even in saltwater, and very high toughness even at cryogenic temperatures to near absolute zero. They are readily welded by a variety of techniques, even at thicknesses up to 20 cm (8 in).

Applications is:

1. 5xxx alloys find wide application in building and construction; highway structures, including bridges, storage tanks, pressure vessels; cryogenic tankage and systems for temperatures as low as –270°C (-455°F) or near absolute zero, and marine applications.
2. Alloys 5052, 5086, and 5083 are the workhorses from the structural standpoint, with increasingly higher strength associated with the increasingly higher magnesium content.

3. 5754 for automotive body panel and frame applications. 5252, 5457, and 5657 for bright trim applications, including automotive trim.
4. 5083-H113/H321machined plate for hulls, hull stiffeners, decking, and superstructure.
5. 5083, 5383, and 5454, as sheet and plate with all-welded construction.

2.6.1.6 Aluminum-Magnesium-Silicon Alloys6xxx:

The major characteristics:

1. Heat treatable.
2. High corrosion resistance, excellent extrudability; moderate strength.
3. Typical ultimate tensile strength range: 125 to 400 MPa (18–58 ksi).
4. Readily welded by GMAW and GTAW methods.

The 6xxx alloys are heat treatable and have moderately high strength coupled with excellent corrosion resistance. Unique feature is their greatextrudability, making it possible to produce in single shapes relatively complex architectural forms, as well as to design shapes that put the majority of the metal where it will most efficiently carry the highest tensile and compressive stresses. This feature is a particularly important advantage for architectural and structural members where stiffness criticality is important.

Applications is:

1. Alloy 6063 is perhaps the most widely used because of its extrudability; it is not only the first choice for many architectural and structural members, but it has been the choice for the Audi automotive space frame members.
2. Higher-strength alloy 6061 extrusions and plate find broad use in welded structural members such as truck and marine frames, railroad cars, and pipelines.
3. 6066-T6, with high strength for forgings; 6070 for the highest strength available in 6xxx extrusions; and 6101and 6201 for high-strength electrical bus and electrical conductor wire, respectively.

2.6.1.7 Aluminum-Zinc Alloys7xxx:

The major characteristics:

1. Heat treatable.
2. Very high strength; special high-toughness versions.
3. Typical ultimate tensile strength range: 220 to 610 MPa (32–88 ksi).
4. Mechanically joined.

The 7xxx alloys are heat treatable and, among the aluminum-zinc-magnesium-copper versions in particular, provide the highest strengths of all aluminum alloys.

Several alloys in the series that are produced especially for their high toughness, notably 7150, 7175, and 7475; for these alloys, controlled impurity levels, particularly of iron and silicon, maximize the combination of strength and fracture toughness.

The atmospheric corrosion resistance is not high as that of the 5xxx and 6xxx alloys, thus, in such service, they usually are coated or, for sheet and plate, used in an alclad version.

Special tempers have been developed to improve their resistance to exfoliation and SCC, the T76 and T73 types, respectively.

Applications is:

1. The widest application of the 7xxx alloys historically has been in the aircraft industry where critical design concepts have provided the impetus for the high-toughness alloy development
2. Applications of 7xxx alloys include critical aircraft wing structures of integrally stiffened aluminum extrusions
3. Premium forged aircraft part of alloy 7175-T736.

2.6.1.8Alloys with Aluminum plus Other Elements 8xxx:

The major characteristics:

1. Heat treatable.
2. High conductivity, strength, and hardness.
3. Ultimate tensile strength range: 120 to 240 (17–35 ksi).

The 8xxx series is used for those alloys with lesser-used alloying elements such as iron, nickel, and lithium. Each is used for the particular characteristics it provides the alloys.

Applications is:

1. Iron and nickel provide strength with little loss in electrical conductivity and so are used in a series of alloys represented by 8017 for conductors.
2. Lithium in alloy 8090 provides exceptionally high strength and modulus,
3. And so this alloy is used for aerospace applications in which increases in stiffness combined with high strength reduces component weight.
4. Forged helicopter component of aluminum-lithium alloy 8090-T852.

2.6.2 Cast Alloys:

In comparison with wrought alloys, casting alloys contain larger proportions of alloying elements such as silicon and copper, which results in a largely heterogeneous cast structure This second phase material warrants careful study, since any coarse, sharp, and brittle constituent can create harmful internal notches and nucleate cracks when the component is later put under load. The fatigue properties are very sensitive to large heterogeneities.

2.6.2.1 Aluminum-Copper Alloys2xx.x:

The major characteristics:

1. Heat treatable sand and permanent mold castings.
2. High strength at room and elevated temperatures; some hightoughnessAlloys.
3. Approximate ultimate tensile strength range: 130 - 450 MPa (20–65ksi).

Applications is:

1. The strongest of the common casting alloys is heat treated 201.0 which has found important application in the aerospace industry.
2. The castability of the alloy is somewhat limited by a tendency microporosity and hot tearing so that it is best suited to investment casting. Its high toughness makes it particularly suitable for highly stressed components in machine tool construction, in electrical engineering. and in aircraft construction
3. The alloy 203.0, which to date is the aluminum casting alloy with the highest strength at approximately 200 °C (400 °F).
4. An example of an application for 2xx.x alloys is an aircraft component that is made in alloys of high-strength alloy 201.0-T6.

2.6.2.3 Aluminum-Silicon Plus Copper or Magnesium Alloys 3xx.x:

The major characteristics:

1. Heat treatable sand, permanent mold castings and die castings.
2. Excellent fluidity, high-strength, and some high-toughness alloys.
3. Approximate ultimate tensile strength range: 130- 275 MPa (20–40ksi).
4. Readily welded.

The 3xx.x series of castings is one of the most widely used because of the flexibility provided by the high silicon content and its contribution to fluidity, plus their response to heat treatment, which provides a variety of high-strength options.

The 3xx.x series may be cast by variety of techniques ranging from relatively simple sand or die casting to very intricate permanent mold, investment castings, and the newerthixo-casting and squeeze casting technologies.

Applications is:

1. 319.0 And 356.0/A356.0 for sand and permanent mold casting.
2. 360.0, 380.0/A380.0, and 390.0 for die casting.
3. 357.0/A357.0 for many types of casting, including, especially, the relatively newly commercialized squeeze/forge cast technologies.

4. Alloy 332.0 also is one of the most frequently used aluminum casting alloys because it can be made almost exclusively from recycled scrap.
5. Thixo-formed A356.0-T6 inner turbo frame for the Airbus aircrafts.
6. the gearbox casing for a passenger car in alloy pressure die cast 380.0
7. Complex 3xx.x castings made by the investment casting processes, providing the ability to obtain exceptionally intricate detail and fine quality.
8. A356.0 cast wheels, which are widely used in the U.S. automotive industry.

2.6.2.4 Aluminum-Silicon Alloys 4xx.x:

The major characteristics:

1. Non-heat-treatable sand, permanent mold, and die castings.
2. Excellent fluidity, good for intricate castings.
3. Representative alloys: 413.0, 443.0.
4. Approximate ultimate tensile strength range: 120 to 175 MPa (17–25ksi)

These alloys have found applications in relatively complex cast parts for typewriter and computer housings and dental equipment, and also for fairly critical components in marine and architectural applications.

Applications is:

Alloy B413.0 is notable for its very good castability and excellent weldability, which are due to its eutectic composition and low melting point of 700 °C (1292 °F). It combines moderate strength with high elongation before rupture and good corrosion resistance. The alloy is particularly suitable for intricate, thin-walled, leak-proof, fatigue-resistant castings.

2.6.2. 5Aluminum-Magnesium Alloys5xx.x:

The major characteristics:

1. Non-heat-treatable sand, permanent mold, and die castings.
2. Tougher to cast; provides good finishing characteristics.
3. Excellent corrosion resistance, machinability, and surface appearance.
4. Representative alloys:512.0,514.0, 518.0, 535.0.
5. Approximate ultimate tensile strength range: 120 - 175 MPa (17–25ksi).

The common feature of this group of alloys is good resistance to corrosion.

Applications is:

1. Alloys 512.0 and 514.0 have medium strength and good elongation and are suitable for components exposed to seawater or to other similar corrosive environments. Their castability is inferior to that of the aluminum-silicon alloys because of its magnesium content and, consequently, long freezing range.
2. For die castings where decorative anodizing is particularly important, alloy 520.0 is quite suitable.

2.6.2.6 Aluminum-Zinc Alloys7xx.x:

The major characteristics:

1. Heat treatable sand and permanent mold castings (harder to cast).
2. Excellent machinability and appearance.
3. Representative alloys705.0, 712.0.
4. Approximate ultimate tensile strength range: 210-380MPa (30–55 ksi).

Applications is:

Because of the increased difficulty in casting 7xx.x alloys they tend to be used only where the excellent finishing characteristics and machinability are important. Representative applications include furniture garden tools, office machines, and farming and mining equipment.

2.6.2.7 Aluminum-Tin Alloys8xx.x:

The major characteristics:

1. Heat treatable sand and permanent mold castings (harder to cast).
2. Excellent machinability.
3. Bearings and bushings of all types.
4. Representative alloys705.0, 712.0.
5. Approximate ultimate tensile strength range105 to 210MPa (15–30ksi).

Applications is:

As with the 7xx.x alloys, 8xx.x alloys are relatively hard to cast and tend to be used only where their combination of superior surface finish and relative hardness are important. The prime example is for parts requiring extensive machining and for bushings and bearings.

2.7 Aluminum – Copper Alloys:

- Copper has been the most common alloying element almost since the beginning of the aluminum industry, and a variety of alloys in which copper is the major addition were developed. Most of these alloys fall within one of the **following groups:**
- Cast alloys with 5% Cu, often with small amounts of silicon and magnesium.
- Cast alloys with 7-8% Cu, which often contain large amounts of iron and silicon and appreciable amounts of manganese, chromium, zinc, tin, etc.
- Cast alloys with 10-14% Cu. These alloys may contain small amounts of magnesium (0.10-0.30% Mg), iron up to 1.5%, up to 5% Si and smaller amounts of nickel, manganese, chromium.
- Wrought alloys with 5-6% Cu and often small amounts of manganese, silicon, cadmium, bismuth, tin, lithium, vanadium and zirconium. Alloys of this type containing lead, bismuth, and cadmium have superior machinability.

Durals, whose basic composition is 4-4.5% Cu, 0.5-1.5% Mg, 0.5-1.0%Mn, sometimes with silicon additions.

Copper alloys containing nickel, which can be subdivided in two groups:

The Y alloy type, whose basic composition is 4% Cu, 2% Ni, 1.5% Mg; and the Hyduminiums, which usually have lower copper contents and in which iron replaces 30me of the nickel.

In most of the alloys in this group aluminum is the primary constituent and in the cast alloys the basic structure consists of cored dendrites of aluminum solid solution, with a variety of constituents at the grain boundaries or interdendritic spaces, forming a brittle, more or less continuous network of eutectics.

Wrought products consist of a matrix of aluminum solid solution with the other constituents dispersed within it. Constituents formed in the alloys can be divided in two groups: in the soluble ones are the constituents containing only one or more of copper, lithium, magnesium, silicon, zinc; in the insoluble ones are the constituents containing at least one of the more or less insoluble iron, manganese, nickel, etc.

The type of soluble constituents formed depends not only on the amount of soluble elements available but also on their ratio. Available copper depends on the iron, manganese and nickel contents; the copper combined with them is not available.

Copper forms (CuFe)Al6 and Cu2FeAl7, with iron, (CuFeMn)Al6 and Cu2Mn3Al20 with manganese, Cu4NiAl, and several not too well known compounds with nickel and iron. The amount of silicon available to some extent controls the copper compounds formed. Silicon above 1% favors the FeSiAl5, over the iron-copper compounds and (CuFeMn)3Si2Al15, over the (CuFeMn)Al6 and Cu2Mn3Al20 compounds.

Similarly, but to a lesser extent, available silicon is affected by iron and manganese contents. With the Cu:Mg ratio below 2 and the Mg:Si ratio well above 1.7 the CuMg4Al6 compound is formed, especially if appreciable zinc is present. When Cu:Mg> 2 and Mg:Si> 1.7, CuMgAl2 is formed. If the Mg:Si ratio is approximately 1.7, Mg2Si and CuAl2 are in equilibrium. With the Mg:Si ratio 1 or less, Cu2Mg8Si6Al5, is formed, usually together with CuAl2. When the copper exceeds 5%, commercial heat treatment cannot dissolve it and the network of eutectics does not break up. Thus, in the 10-15% Cu alloys there is little difference in structure between the as-cast and heat treated alloys.

Magnesium is usually combined with silicon and copper. Only if appreciable amounts of lead, bismuth or tin are present, Mg2Sn, Mg2Pb, Mg2Bi3 can be formed.

The effect of alloying elements on density and thermal expansion is additive; thus, densities range from 2 700 to 2 850 kg/m3, with the lower values for the high-magnesium, high-silicon and low-copper alloys, the higher for the high-copper, high-nickel, high-manganese and high-iron contents.

Expansion coefficients are of the order of 21-24 x 10-6 1/K for the 300-4000 K range and 23-26 x 10-6 1/K for the 300-700 K range, with the higher values for the high-magnesium, low-copper and low-silicon alloys, the lower ones for the higher silicon and higher copper contents. At subzero temperatures the coefficient decreases practically in the same way as that of pure aluminum. However, release of casting stresses or precipitation and solution of copper and magnesium produce changes in length of up to 0.2%, which may affect the dimensional accuracy of parts exposed to high temperature. Subzero treatment of castings to reduce warpage has been recommended.

Specific heat of the commercial alloys is practically the same as for the binary aluminum-copper. Thermal conductivity is little affected by alloying elements other than copper: for the commercial alloys with 4-12% Cu, < 4% other elements, it is approximately 70% of that of pure aluminum at room temperature, some 75-80% at 600 K and 30-35% at 200 K.

Electric conductivity is very sensitive to copper in solution, and to a much lesser extent to magnesium and zinc, but is little affected by alloying elements out of solution. In an alloy with 5% Cu in solution the conductivity is approximately half that of pure aluminum (30-33% IACS), but in the annealed state an alloy with 12% Cu and up to 5% other elements has a conductivity of 37-42% IACS, only 25-30% lower than that of pure aluminum.

The mechanical properties of the alloys vary over an extremely wide range, from those of the sand cast 8% Cu alloys, which are among the lowest in aluminum alloys, to those of durals or wrought 5% Cu alloys, which may reach values of up to 650 MPa.

Higher purity, special compositions, fabricating techniques or heat treatments may produce higher properties. Porosity, poor feeding of castings, excessive amounts of impurities, segregation and poor quality control in fabrication may reduce the properties well below the determined limits. Surface defects reduce the properties of castings more than internal ones. Restrain or elastic strain during testing have no effect on properties. Ultrasonic vibration may reduce or increase them; and irradiation at cryogenic temperatures may slightly increase strength. Dynamic loading may produce strength and ductility values higher or lower, depending on the speed, but not at high temperature. Temperatures below room temperature increase strength and hardness, with some loss of ductility and a decrease in anisotropy.

Correspondingly, exposure to temperatures above room temperature eventually results in a decrease in strength and hardness with a decided increase in elongation. Heat treatment has a substantial effect: if the alloys are quenched from high temperature and only naturally aged, exposure to temperatures in the range up to 500-600 K may produce a temporary increase in hardness and strength due to artificial aging. Eventually this increase disappears, the faster the higher the temperature, and the normal decline sets in, as in alloys already aged to peak hardness. Prolonged heating (for up to 2 years) results in appreciable softening at all temperatures. For intermediate exposure times this softening is less if the materials are thermo-mechanically treated. In short-time tests fast heating to test temperature increases the strength.

Impact resistance is low, as for all aluminum alloys: in the Charpy test values range from a minimum of 2-3 x 104N/m for cast alloys with 7% Cu to a maximum of 30-40 x 104N/m for wrought products in the naturally aged temper. Notch sensitivity is usually low, especially in the wrought alloys, or in the cast alloys heat treated to maximum ductility. The plane strain fracture toughness ranges from 85 to 100% of the yield strength, depending on a variety of factors. Both impact resistance and notch toughness increase with increasing temperature, but the decrease with subzero temperatures is limited. In the softer alloys at 70 K the difference is within error of testing; only for the higher-strength alloys is the decrease appreciable.

Shear strength is of the order of 70-75% of tensile strength, even at high temperature; bearing strength is approximately 1.5 of tensile; compressive yield strength is 10-15% higher or lower than ultimate tensile strength.

Most alloying elements raise the modulus of elasticity of aluminum, but the increase is not substantial: for the aluminum-copper alloys the modulus of elasticity at room temperature is of the order of 70-75 GPa and practically the same in tension and in compression. It changes regularly with temperature from a value of 76-78 GPa at 70 K to a value of the order of 60 GPa at 500 K. The change during aging is negligible for practical purposes. The Poisson ratio is slightly lower and of the order of 0.32-0.34, and so is the compressibility. The Poisson ratio increases with increasing temperature.

Many of the cast alloys and of the aluminum-copper-nickel alloys are used for high-temperature applications, where creep resistance is important. Resistance is the same whether the load is tensile or compressive.

Wear resistance is favored by high hardness and the presence of hard constituents. Alloys with 10-15% Cu or treated to maximum hardness have very high wear resistance.

Silicon increases the strength in cast alloys, mainly by increasing the castability and thus the soundness of the castings, but with some loss of ductility and fatigue resistance, especially when it changes the iron-bearing compounds from $FeM2SiAl8$ or $Cu2FeAl7$, to $FeSiAl5$.

Magnesium increases the strength and hardness of the alloys, but, especially in castings, with a decided decrease in ductility and impact resistance.

Iron has some beneficial strengthening effect, especially at high temperature and at the lower contents (< 0.7% Fe).

Nickel has a strengthening effect, similar to that of manganese, although more limited because it only acts to reduce the embrittling effect of iron. Manganese and nickel together decrease the room-temperature properties because they combine in aluminum-manganese-nickel compounds and reduce the beneficial effects of each other. The main effect of-nickel is the increase in high-temperature strength, fatigue and creep resistance.

Titanium is added as grain refiner and it is very effective in reducing the grain size. If this results in a better dispersion of insoluble constituents, porosity and nonmetallic inclusions, a decided improvement in mechanical properties results.

Lithium has an effect very similar to that of magnesium: it increases strength, especially after heat treatment and at high temperatures, and there is a corresponding decrease in ductility. Zinc increases the strength but reduces ductility.

2.7.Copper Aluminum Alloys phase diagram:

This Al-Cu phase diagramshown below figure (2.1).Only goes up to a 60%, by weight, of Copper.And is “split” at around 54wt%Cu by a particular phase. This "split" means that the two parts of the diagram must be considered separately.

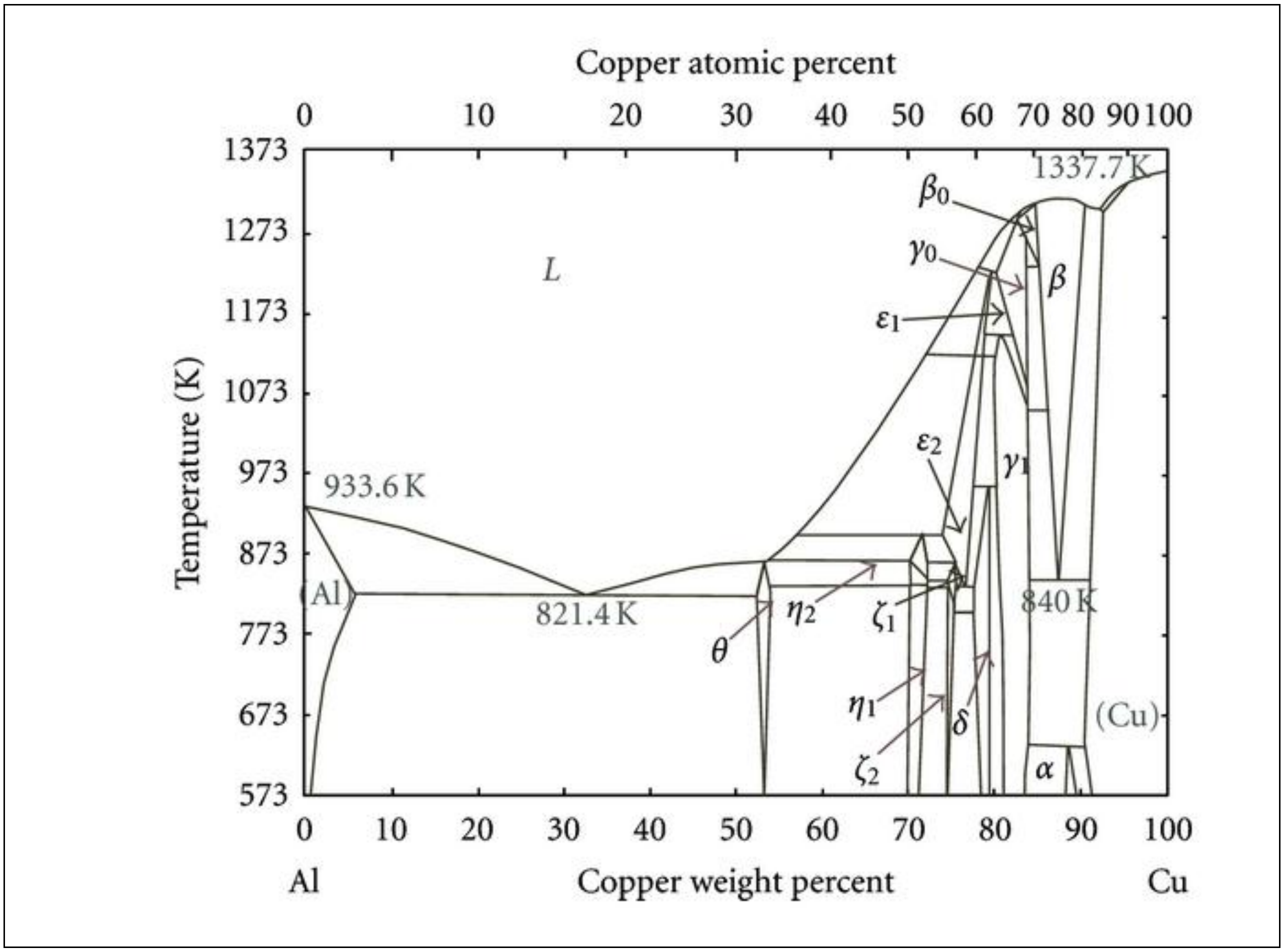

Figure (2.1): Al-Cu phase diagram.

The diagram up to the 54% point is very similar to the "standard" phase diagram.

Intermetallic phases are not named αor β, but are assigned other Greek letters (though there is no strict convention for this).

Here the phase on the right is named 2, but other than its name it is dealt with in exactly the sameway as a beta phase.

2.8Cu-Al Phase Diagram:

The eutectic composition is at 33%Cu/67%Al, and the Te is a. 550 K.

A 25%Cu/75%Al composition is known as a hypoeutectic alloy.

A 36%Cu/64%Al composition is correspondingly called hypereutectic.

All this information shown below in figure (2.2).

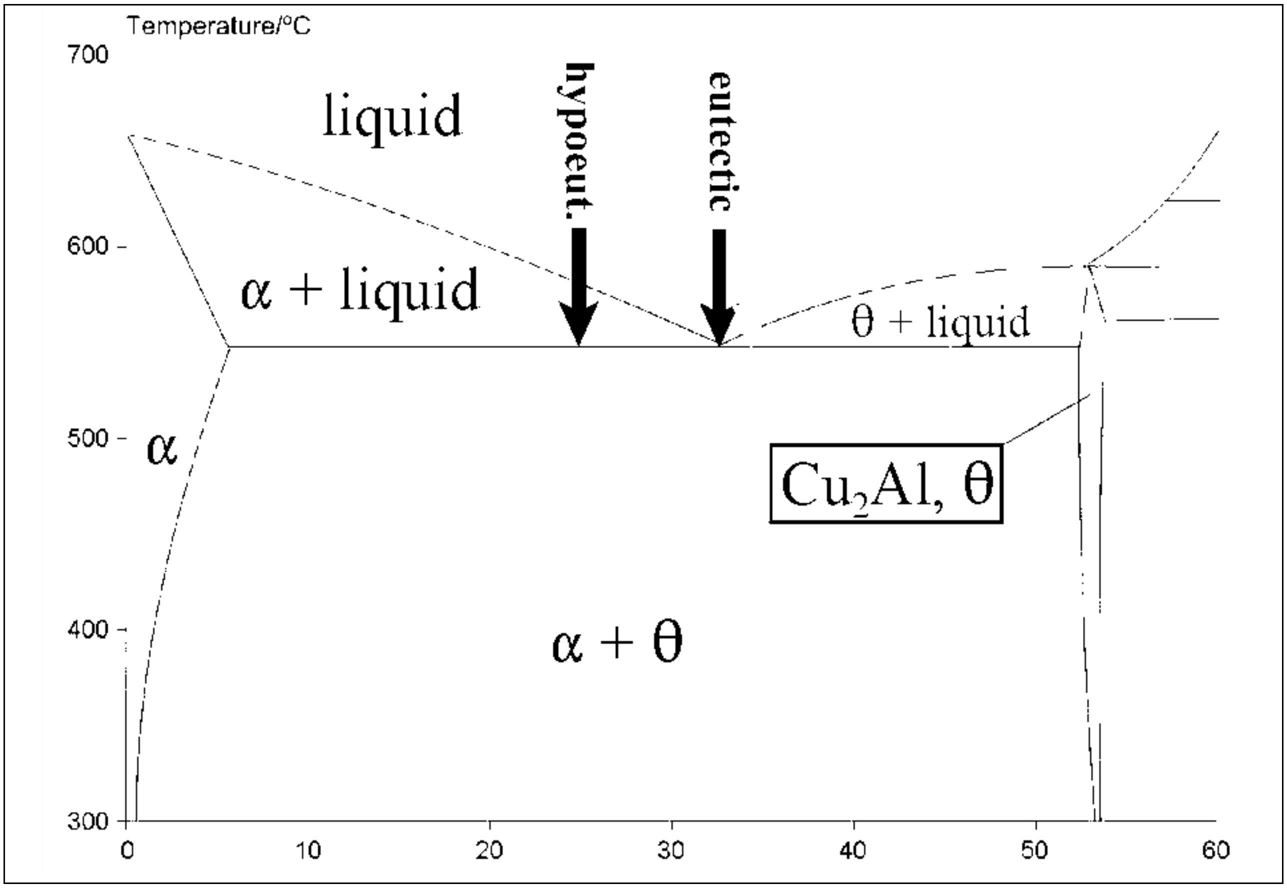

Figure (2.2): Al-Cu Phases diagram.

Chapter Three

Materials and Research Methodology

3.1 Materials:

1- Commercial aluminum 1*** with purity of 99.6 as shown in next table (3.1) below.

martial	Al%	Si%	Fe%	Cu%	Zn%	Mn%	Mg%
percentage	99.6	0. 1	0.06	0.05	0.09	0.01	0.05

2- Commercial copper. With purity of 99.69 as shown in next table (3.2) below.

martial	Cu%	Zn%	Pb%	Sn%	Fe%	Ag%	Al%	Be%
percentage	99.962	0.216	0.004	0.017	0.001	0.008	0.031	0.031

3.1.1Foundry sand molds:

Sand casting, also known as sand molded casting, is a metal casting process characterized by using sand as the mold material. The figure (3.1) below show the sand molds foundry for shapes.

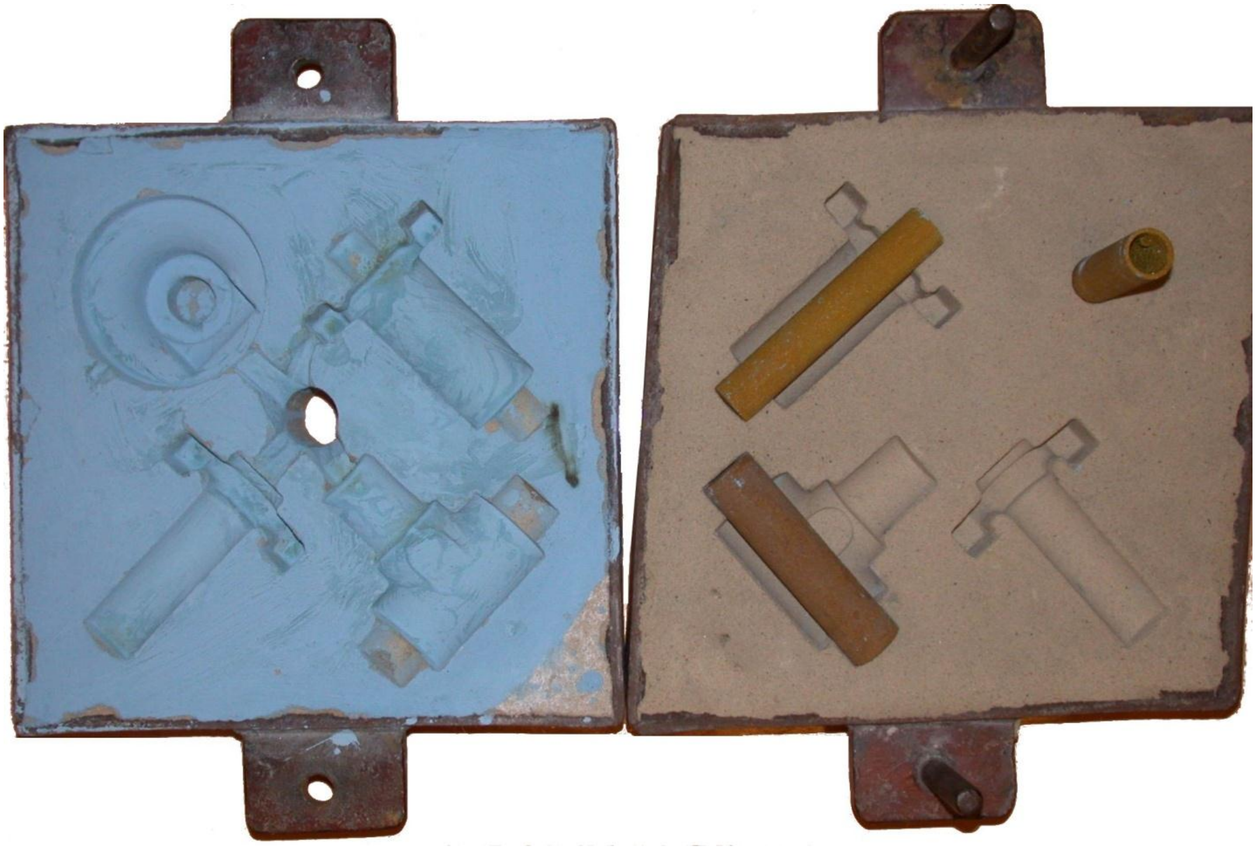

Figure (3.1): sand molds foundry for complex shapes

3.1.2Ceramic melting pot:

Size: 350 dia, 440 depth, Like any piece of Ceramic melting pot, this melting pot is a great heat conductor. And use for saving temperate of the alloy and casting. The figure (3.2) below show Ceramic melting pot shape and name.

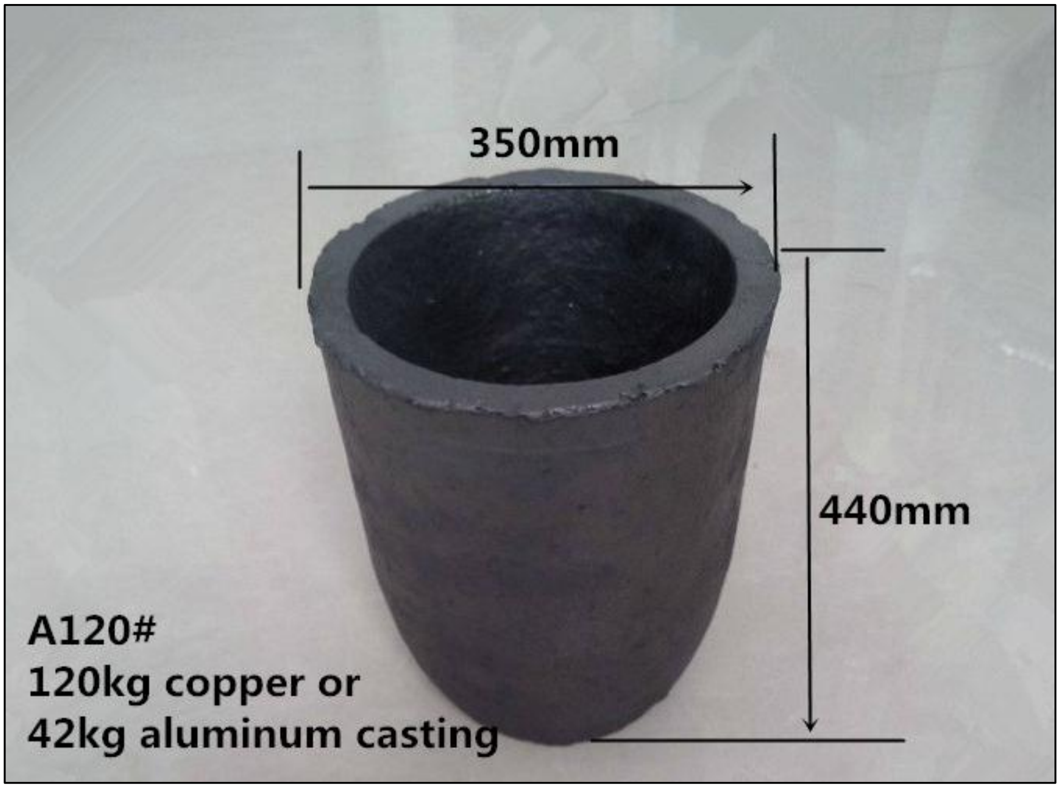

Figure (3.2): Ceramic melting pot shape and name.

3.1.3Alloy melting furnace:

We use melting furnace as thermal container to melting the metals that we have until entirely mixed and form new solution with new proprieties. The figure (3.3) below showmelting furnace.

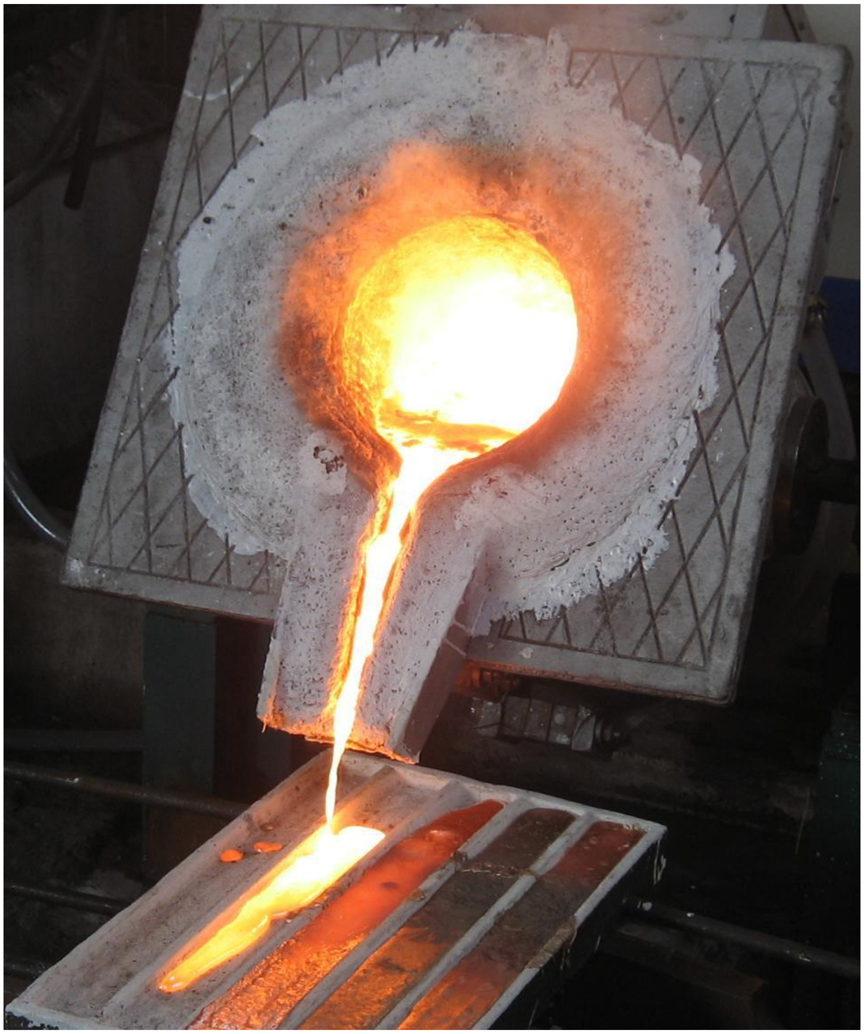

Figure (3.3) below show melting furnace.

3.1.4Lathe (turning machine):

We use turning machine to achieve perfect form for next stage (testing) . The figure (3.4) below show lathe (turning machine).

Figure (3.4): lathe (turning) machine.

3.1.5Portable digital durometer Brinell hardness:

We use Portable Digital durometer Brinell hardness to examine the hardness of our samples. The figure (3.5) below show Portable digital urometer Brinell hardness.

Figure (3.5): Portable Digital durometer Brinell hardness.

3.2 Practice:

First we prepaid materials as shown before in tables. Foundry sand molds for its availability than metal molds. And after that we use an electrical Alloy melting furnace to melt copper first then aluminum. And we moved the melt until they alloyed. Then we forming the models into the foundry sand molds and let them cooled. We never measure temperatures along the melting process. And melting temperature because of no availability of sensors and temperature testing methods.

After we insured the samples we moved to turnery process aiming to have perfect surface for mechanical tests.

Table (3.3): show the material weights and percentage in melting process:

Sample number	1	2
Aluminum weights	180	190
Copper weights	20	10
Total weights	200	200
Copper percentage	10%	5%

3.3Mechanical Tests:

3.3.1 Hardness test:

We used Brinell hardness test method. Which Proposed by Swedish engineer Johan August Brinell in 1900,The typical test uses a 10millimeters (0.39 in) diameter steel ball as an indenter with a 3,000 kgf (29.42 kN; 6,614 lbf) force. For softer materials, a smaller force is used; for harder materials, a tungsten carbide ball is substituted for the steel ball. The indentation is measured and hardness calculated as:

$$\text{HBN} = 0.102\frac{2F}{\pi D(D-\sqrt{D^2 - d^2})}$$

Where:

BHN = Brinell hardness number (kgf/mm2).
F = applied load in kilogram-force (kgf).
D = diameter of indenter (mm).
d = diameter of indentation (mm).

3.3.2 Tensile strength (T):

Tensile strength is the capacity of a material or structure to withstand loads tending to elongate, as opposed to compressive strength, which withstands loads tending to reduce size. In other words, tensile strength resists tension. Ultimate tensile strength is measured by the maximum stress that a material can withstand while being stretched or pulled before breaking. In the study of strength of materials, tensile strength, compressive strength, and shear strength can be analyzed independently. Figure (3.6) below show Tensile strength testing machine a universal testing machine (Hegewald & Peschke).

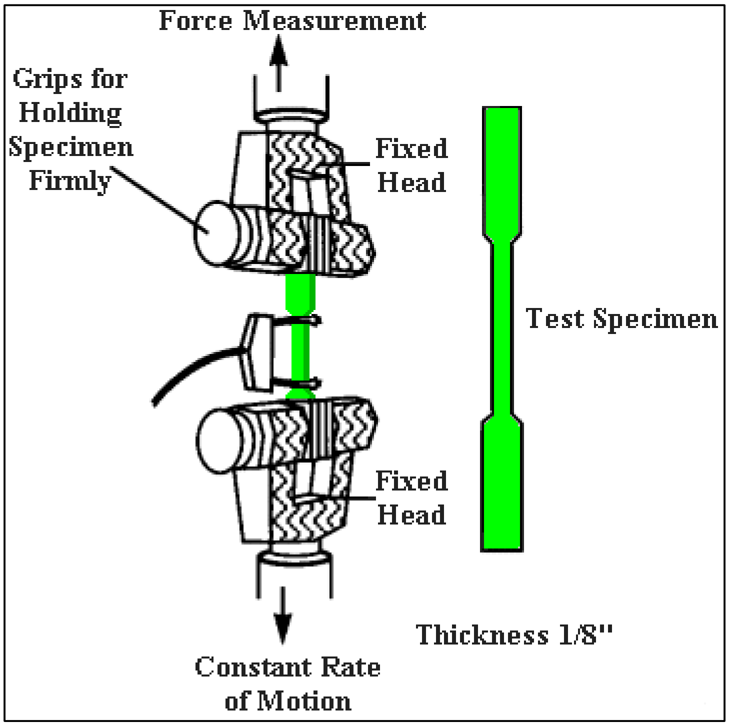

Figure (3.6): Tensile strength testing machine

Chapter Four

Results and conclusions

4.1 Materials testing:

4.2Importance of mechanical properties knowing:

1. Products Conformity to specifications.
2. Establish new scales for design.
3. Evaluating operation that run on materials “like heat treatment”.

4.2.1Destructive testing (DT):

1. Stress tests.
2. Crash tests.
3. Hardness tests.
4. Metallographic tests.

4.2.2Nondestructive testing (NDT):

1. Visual inspection.
2. Ultrasound inspection.
3. Magnetic powder inspection.
4. Industrial radiography inspection.

4.3 Brinell hardness test:

Tungsten carbide ball is substituted for the steel ball. The indentation is measured and hardness calculated as:

$$\text{HBN} = 0.102\frac{2F}{\pi D(D-\sqrt{D^2 - d^2})}$$

Where:

BHN = Brinell hardness number (kgf/mm2)
F = applied load in kilogram-force (kgf)
D = diameter of indenter (mm)
d = diameter of indentation (mm)

4.4 Tensile strength test methodology:

Typically, the testing involves taking a small sample with a fixed cross-sectional area, and then pulling it with a tonometer at a constant strain (change in gauge length divided by initial gauge length) rate until the sample breaks as shown as figure (4.1).

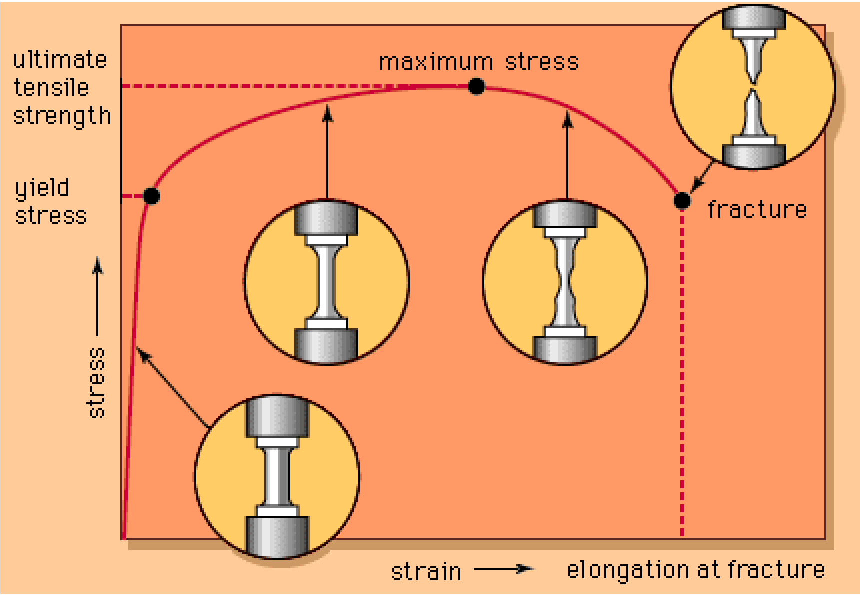

Figure (4.1): Tensile strength

4.5 Practice result:

Brinell hardness numbers for aluminum and copper is:

Aluminum 15 HB, Copper 35 HB.

And in alloys that we formed and have this values:

4.5.1 Sample (1):

Table (4.1) chemical formation for the first alloy.

Martial	Al%	Cu%	Si%	Ti%	Ni%	Mn%
Percentage	88%	10%	0.23	0.441	0.48	0.837

Brinell hardness number: Firstresult is:97.2 HB.

Secondresult is: 98.1 HB.

Thirdresult is: 98.5 HB.

Tensile strength value is: 80.4 N/mm^2

4.5.2 Sample (2):

Table (4.2) chemical formation for the second alloy:

martial	Al%	Cu%	Si%	Ti%	Ni%	Mn%
percentage	94%	5%	0.13	0.231	0.28	0.337

Brinell hardness number: First result is 70.6 HB.

Secondresult is: 70.1 HB.

Thirdresult is: 70.3 HB.

Tensile strength value is 121 N/mm^2

4.6 Comparison:

There is deference in our Result values and standard values that we take (1).

Table (4.3) Comparison for the first sample (Cu10%):

	Test1	Test2	Test3	Standard values
Tensile strength N/mm^2	80.4	-	-	86.57 N/mm^2
Brinell hardness HB	97.2	98.1	98.5	144 HB

Table (5.4) Comparison for the second sample (Cu5%):

	Test1	Test2	Test3	Standard values
Tensile strength N/mm^2	121	-	-	125.2 N/mm^2
Brinell hardness HB	70.6	70.1	70.3	86 HB

This chart (4.1) below represents the variance in samples test result with the change in copper (Cu) percentage in the aluminum –copper alloy.

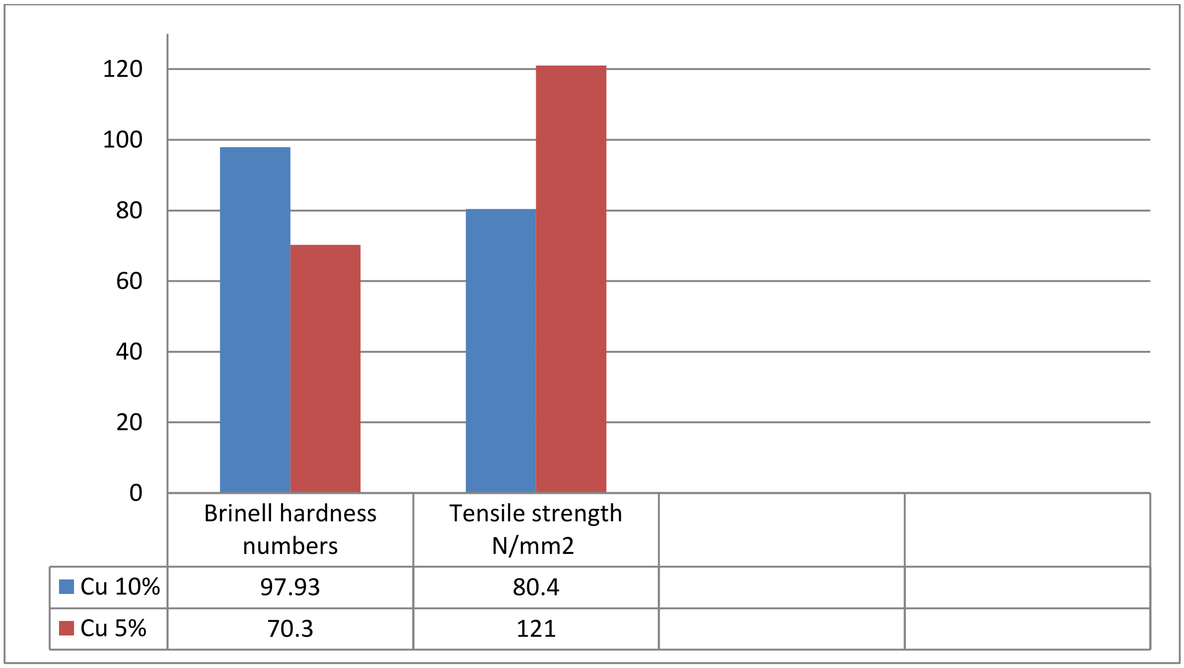

Chart (4.1).

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[1] Research Journal of Engineering Sciences _ ISSN 2278 – 9472 Vol. 3(3), 1-5, March (2014) page 2

This chart (4.2) below show the standard value for Brinell hardness number. Test against the practical test result of the first sample which contain 10% copper. The test have been taken three times.

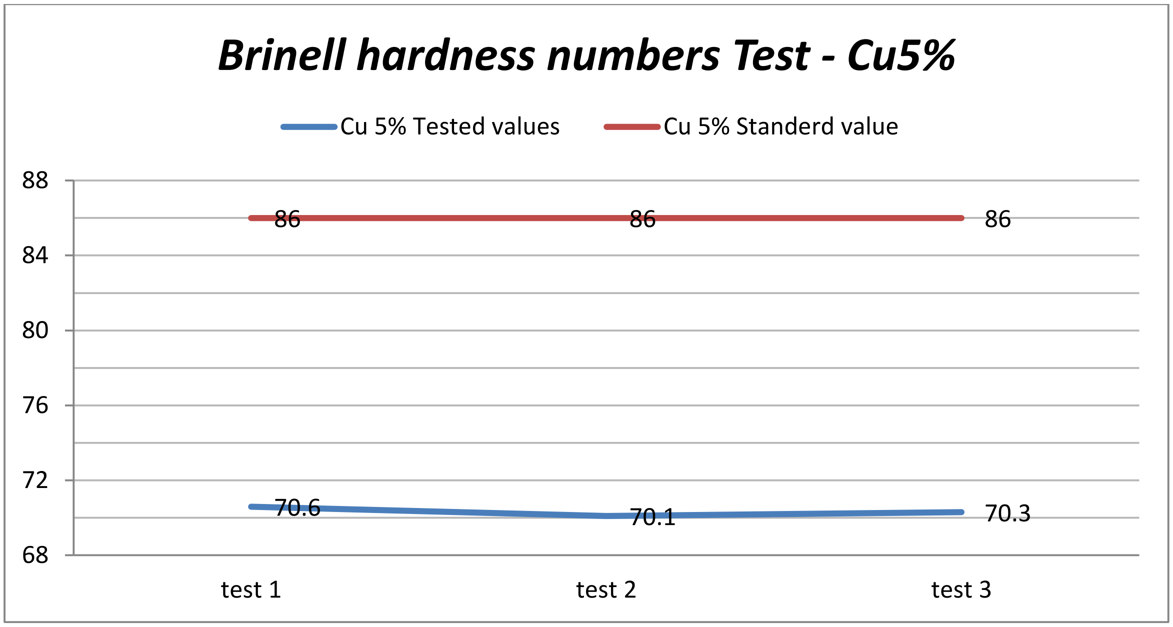

Chart (4.2).

This chart (4.3) below show the standard value for Brinell hardness number. Test against the practical test result of the second sample which contain 5% copper. The test have been taken three times.

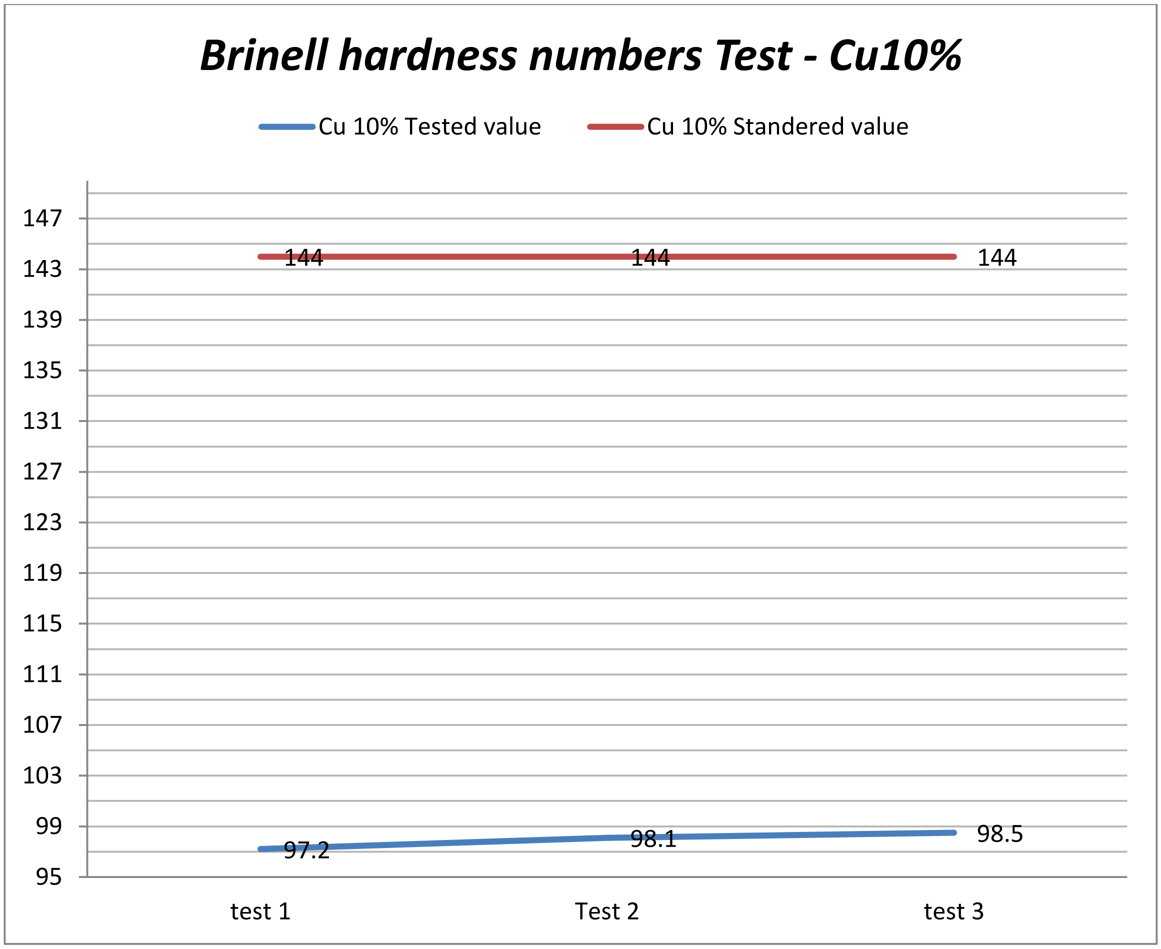

Chart (4.3)

Chapter Five

Results and Recommendations

5.1 Results:

After testing samples we find that average value of hardness of first sample (Cu10%) is 97.93HB. and for the second sample (Cu 5%) is 70.3 HB.

The value of hardness number rise with rising percentage of copper in the alloy.And impact resistance decline with rising percentage of copper adding to alloy.

Tensile strength decline with rising copper percentage of copper adding to alloy

There are deference in result values according to:

Melting process between aluminum and copper and formation of the alloys. Deference in alloys and Impurities value to each alloy.

5.2discussion:

The research study aluminum alloys as general and their condition. Digits and their properties and applications. Then heat treatment methods and digits. After thatwe study Aluminum-copper alloys. And do our practice in two aluminum- cooper alloys samples. Apply our operation (inspection- turning – Hardness test and Tensile strength-strain test). And calculated the value ofBrinell hardness numbers and Tensile strength value.

We find that adding copper to aluminum will increase hardness.

5.3Recommendations:

1. Notto use foundry sand molds in small diameters to avoid gas bubbles formation.
2. Using Heat treatment for cast alloys after cool down to increase impact resistance. And especially for alloys that have high rate of copper.
3. The copper shouldn’t be more than 10% unless there is heat treatment available.
4. Use sensors to measure temperature alongside melting operation.

5.4 References:

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