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" Effect of Process Conditions on Mechanical Properties of Aluminum Alloys in Stir Casting "

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بسم الله الرحمن الرحيم

فَدَعَا رَبَّهُ أَنِّي مَغْلُوبٌ فَانْتَصِرْ (10) فَفَتَحْنَا أَبْوَابَ
السَّمَاءِ بِمَاءٍ مُنْهَمِرٍ (11) وَفَجَّرْنَا الْأَرْضَ عُيُونًا
فَالْتَقَى الْمَاءُ عَلَى أَمْرٍ قَدْ قُدِرَ (12)

صدق الله العلي العظيم

شكر وتقدير

الحمد لله رب العالمين والشكر له على فضله الذي أنعمه علينا...وعلى ما منحني من صبر وهمة لإكمال هذا البحث...

أتقدم بجزيل الشكر والامتنان إلى الاستاذ الفاضل

(استاذ حسين البيرماني)

على جهوده القيمة في توجيهي وإرشادي خلال مراحل إعداد البحث.

الإهداء

بكل الحب ...

إلى **الشمعتين اللتين انارتا لي درب نجاحـي والمدرسة التي علمتني الكثير ...**

امي وأبي

الى **الذين وقفوا معـي يتأملون نجاحـي ..**

اخوتـي

الى الذين علموني أن اهدي هذا الانجاز بعلمهم و عطائهم ...

أساتذتي الافاضل

الى من عشت معهم بأجمل الحكايات وأحلى الذكريات...

زملائي

الى روح من هم اكرم منا جميعاً ...

شهدائنا الابرار

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الملخص:

يدرس هذا البحث تأثير السباكة في (القالب الرملي) والسباكة في (القالب المعدني) والمعاملات الحرارية على الخواص الميكانيكية للألمنيوم النقي و سبيكة الالمنيوم- سيليكون بعد اجراء الاختبارات التالية: (اختبار البنية المجهرية ، واختبار الانضغاط ، واختبار الصلادة)

أظهرت النتائج أنه تم الحصول على افضل بنية مجهرية عن طريق الصب في القالب المعدني وبعد اجراء المعاملة الحرارية.

أما بالنسبة لنتائج اختبار الانضغاط فقد بينت ان مقاومة الانضغاط لسبيكة الالمنيوم- سيليكون وبعد اجراء المعاملة الحرارية لها هي الافضل وكلما ارتفعت نسبة السيليكون في السبيكة كلما كانت مقاومة الانضغاط افضل ، على العكس من الالمنيوم النقي حيث يكون ناعم وسهل الانحناء .

أما بالنسبة لاختبار الصلادة، فقد أظهرت النتائج أن أعلى قيم للصلادة يتم الحصول عليها عند صب سبيكة المنيوم- سيليكون في قالب معدني وبعد اجراء المعاملة الحرارية لها ، على العكس من الالمنيوم النقي الذي تكون صلادته تتأثر سلباً عند اجراء المعاملة الحرارية له.

Abstract:

This research examines the effect of casting (in sandy mold) and casting (in metallic mold) and thermal treatments on the mechanical properties of al-9si and pure aluminum. After conducting several tests, including (microstructure testing, compression testing, and hardness testing). The results showed that it is the best microstructure obtained by casting in the metal mold and after heat treatment.

As for the results of the compression test, it showed that the compressive strength is better in the heat-treated (Al-9Si) alloy, and the higher the percentage of silicon, the better the compression. On the contrary, pure aluminum is not resistant to the test because it is soft and easy to bend.

As for the hardness test, the results showed that the highest hardness values were obtained in casting with a metal mold, (Al-9si) alloy heat treated is positively affected by hardness, unlike pure aluminum, whose hardness is negatively affected when heat treatment is performed on it.

Chapter One: Introduction

1.1 Introduction

Aluminum alloys are widely used in different industries due to their lightweight, corrosion resistance, and excellent strength-to-weight ratio. These alloys are composed of aluminum as the primary element with the addition of other elements like copper, magnesium, zinc, and silicon. The proportion of these elements can vary depending upon the application requirements.[1]

Aluminum alloys are categorized into two groups: wrought alloys and casting alloys. Wrought alloys are further divided into 8 categories based on their major alloying element, while casting alloys are mainly composed of silicon, copper, and magnesium. [1]

The most common aluminum alloys include 6061, 7075, and 2024. 6061 is a wrought alloy and is known for its excellent corrosion resistance. 7075 is a high-strength alloy and is used in the manufacturing of aircraft parts. 2024 is also a high-strength alloy and is used in aerospace applications due to its good machinability.[2]

There are different methods for producing aluminum alloys. One method is casting, which involves pouring molten metal into a mold and allowing it to solidify. Another is extrusion, which involves heating the alloy and pushing it through a shaped die resulting in a uniform cross-section. [2]

The properties of aluminum alloys can vary based on the alloying elements and production methods. Generally, aluminum alloys have low density, excellent thermal and electrical conductivity, good machinability, and good corrosion resistance.[3]

In conclusion, aluminum alloys are a versatile material used in various industries due to their desirable properties. The selection of the suitable alloy depends upon the application requirements. With continuous research and development, it is possible to develop improved aluminum alloys in terms of strength, weight, and corrosion resistance.[3]

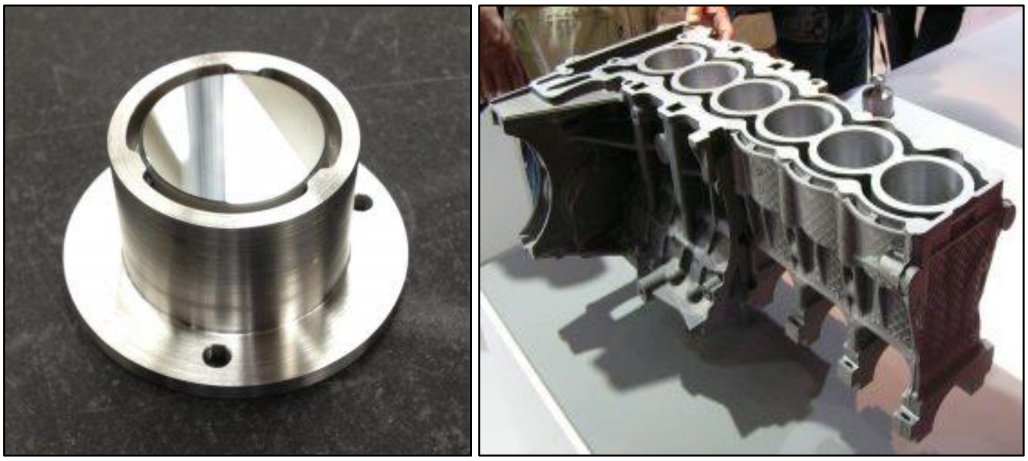

Figure (1-1) aluminum alloys

1.2.1 Al-Si alloy

Aluminum-silicon alloy or Al-Si alloys are alloys that are made by combining aluminum and silicon. The combination of these two elements results in a versatile material that has a wide range of uses in many industries such as automotive, aerospace, construction and food packaging, among others. This report aims to provide a comprehensive analysis of Al-Si alloys, including their properties, production methods, and application areas. [4]

1.2.2 Properties of Al-Si Alloys

Al-Si Alloys have a unique set of properties that make them ideal for various industrial applications. One of the primary properties is their high thermal conductivity, which makes them suitable for use in heat sinks and other heat management systems. Moreover, Al-Si Alloys have excellent mechanical properties such as high strength, ductility, and good wear resistance, which makes them ideal for use in the automotive industry.

Another unique feature of Al-Si alloys is their ability to be cast easily, which makes them an ideal choice for components that need to be manufactured in large quantities. For instance, the automotive industry uses Al-Si alloys to produce engine blocks, cylinder heads, and other parts that require high heat resistance.[5]

1.2.3 Production of Al-Si Alloys

There are two primary methods for producing Al-Si alloys: casting and wrought production. Casting involves the process of pouring molten Al-Si alloy into a mold, which takes the shape of the component required.

On the other hand, wrought production involves the shaping of Al-Si alloys by using rolling or forging processes. This method is used primarily for producing sheets, bars, and tubes. Moreover, the production of Al-Si alloys is cost-effective, which makes their use in various industries practical. [6]

1.2.4 Application of Al-Si Alloys

Al-Si alloys are widely used in many industries due to their unique set of properties. One of the primary application areas of Al-Si alloys is the automotive industry. Al-Si alloys are used to manufacture engine blocks that provide high heat resistance, which can withstand high temperatures. Additionally, they are used to make pistons that are light in weight, making them efficient in reducing engine fuel consumption.

Another significant application of Al-Si alloys is in the construction industry due to their high resistance to corrosion, which makes them ideal for use in harsh environments. Al-Si alloys can also be used in food packaging due to their ability to protect food from contamination. [7]

1.2.5 Conclusion :

Al-Si alloys have unique properties that make them ideal for several industrial applications. Al-Si alloys have excellent mechanical properties, high heat resistance, and excellent machinability that make them an ideal choice for the transportation, aerospace, construction, and food packaging industries. Further research and development in Al-Si alloys will result in new applications in other industries and will contribute to the development of novel manufacturing techniques. [7]

1.2.6 Aim and Objectives :

In this project research, Aluminum alloy (Al-9Si) was used to study the effect of heat treatments on the microstructure, Fagers hardness and compression test of the selected aluminum alloy.

1.2.7 Solidification:

Al-Si alloys solidify by a primary precipitation of dendrites; an illustration of primary aluminium dendrite (α-Al) structure embedded in Al-Si eutectic is shown in Figure 1. Inhypoeutectic Al-Si alloys primary aluminium solidifies dendritically and grows in <100> direction. Dendrites are often drawn having four secondary arms growing around the primary stem at each junction which is true for cubic structures [8]. The undercooling depends on the cooling rate, the concentration of the alloying element in the melt and the type of the alloying element. It is well established that the undercooling increases with increasing cooling rate and increasing concentration of the alloying element [9].

The solidification of the alloy continues with formation of Al-Si eutectic mixture. In eutectic solidification two phases of Al and Si precipitate simultaneously from the liquid at constant temperature [9, 10]. Figure 2 presents a phase diagram of the Al-Si system with a eutectic point. The eutectic point is at 12.6 wt. % Si and the eutectic temperature is 577 °C. Aluminium dissolves a maximum of 1.6 wt. % of Si while the solubility of Al in Si is almost zero [11].

Eutectic alloys provide a natural composite which gives good properties for the alloy. [9, 10]. Commercial aluminium alloys often contain other alloying elements such as Cu and Mg in addition to Si. The eutectics of these alloys may be more complex than those observed when looking at the binary system. Formation of Cu- and Mg-bearing intermetallic phases often occurs after eutectic formation.

1.3 Introduction to heat treatments

Aluminum alloys that can be heat treated are usually subjected to artificial aging treatments to improve their mechanical properties and change the crystal structure. , to reach the saturated solid solution, where . is formed of follow the elements deposited during aging heat treatment.

Aging in aluminum alloys begins with the formation of Guinier-Preston (GP) regions, which are solutions rich in dissolved atoms spread in the form of cohesive knots, which are caused by a deformation in the crystal structure, these knots resist the movement of dislocations, which leads to an increase in the strength of the metal, for example The strength of the 7xxx series alloys is increased due to the precipitation of the MgZn2 phase in clusters, which forms a second phase in the base aluminum solution. The properties of aluminum alloys can also be improved [12].

Also by adding some other alloying elements, for example, B-boron improves the electrical conductivity of aluminum alloys used in electrical applications, but it increases the difficulty of working the alloys due to its formation of borides, while cadmium (Cd), lead (Pb) and tin (Sn) improves the workability, and Cr improves the corrosion resistance and increases the wear resistance.

Sensitivity to quenching when it is present in high proportions, nickel and Ni with lead are used to enhance the properties at high temperatures and reduce the thermal expansion coefficient, and Ag silver contributes to hardening by deposition and corrosion resistance by stress cracking, and Sn improves the friction resistance so it is used in the manufacture of bearings, and titanium is used to soften grains Cast aluminum castings [13]

The 7xxx series is considered one of the most important aluminum alloys, and it is the alloy containing zinc as a main element, in addition to magnesium and copper (-Al-Zn, Mg-Cu), where the addition of these elements leads to good properties of these alloys. The properties of 7xxx series alloys have been studied by many researchers because of their distinctive properties that are suitable for a large number of applications, especially

Aerospace and aerospace industries applications, as the high-resistance 7xxx series alloys have excellent properties, especially after applying heat treatments such as high tensile strength with light weight, excellent formability, and acceptable corrosion resistance. "(RRA) which leads to properties of

Better mechanical and wear resistance than traditional T6 synthetic aging treatment. This was shown by researcher F. Viana and his colleagues [14] and researcher A.F. Oliveira and colleagues [15], where they studied the effect of heat treatments T6, T7 and RRA on the structure of alloys 7050, 7150 and 7075, their hardness, tensile strength and stress-cracking resistance to SCC, and obtained.

The best results when applying the RRA treatment. The researcher M. Esmailian and his colleagues studied the effect of the retrieval time (30, 40 and 59) min in the processing of RRA on the tensile properties and hardness of alloy 7055, where the RRA treatment performed better tensile properties than the treatment of T6, and the increase in the return time led to an increase in both grain size and sediment density, which affects the mechanical properties [16].

As for the researcher R. Ranganatha and his colleagues, they applied different heat treatments to the alloy 7049, namely: T6 and T73, and finally the treatment of RRA. [17] Another group of researchers studied the effect of aging conditions on the properties of the school alloy, where the researcher Chen Song and his colleagues studied the effect of three-stage aging on the properties of Alloy 7085, three-stage aging improved the tensile strength by 5% over double aging, while improving the corrosion resistance [18] SCC.

Researcher Cheng Cao and his colleagues studied the effect of pre-aging on the hardness of Al-5.2%Mg-2%Zn alloy containing 0.45% copper. to a softer form, and also led to the decay of the needle-like S-Al2MgCu phase, which caused an increase in the hardness values [19 and 20].

Another group of researchers worked on improving the properties of aluminum alloys of the seventh series by adding percentages of some alloying elements, where researcher Zhanying Guo and his colleagues studied the effect of zirconium Zr content at percentages (0, 0.05, 0.1, 0.15%) and the parameters of thermal homogenization treatment on the grain size of the aluminum alloy The two-stage homogenization resulted in a finer grain size of Al3Zr alloy 7150 and a higher density of Al3Zr deposits [21]. [22] Al-5.43% Zn-1.98% Mg Composition Researcher PK Mandala and colleagues add effect.

Scandium 0.4% and 0.45 % on the alloy hardness Al-6% Zn-3% Mg with the application of artificial aging treatment for different periods of time and temperatures, and they obtained the highest result when aging at temperature 120 °C for 16 hours and scandium % [14]. 0.45 The researcher Ch. Shiva Krishna added nickel to the aluminum alloy.

7075 with percentages of nickel by weight of (0.35 -2.3) wt%, and he studied the effect of this addition on the tensile, hardness and shock properties of the alloy without studying the effect of different heat treatments for this alloy containing percentages of nickel [23].

Rematch, et al., [25], described the effects of homogenization, solution treatment, quenching and ageing treatments on the evolution of the microstructure and properties of some important medium to high-strength 7xxx alloys. With a focus on recent work at Monash University, where the whole processing route from homogenization to final ageing has been studied for thick plate products, it is reported how microstructural features such as dispersions, coarse constituent particles, fine-scale precipitates, grain structure and grain boundary characteristics can be controlled by heat treatment to achieve improved microstructure–property combinations. In particular, the paper presents methods for dissolving unwanted coarse constituent particles by controlled high-temperature treatments, quench sensitivity evaluations based on a systematic study of continuous cooling precipitation behavior, and ageing investigations of one-, two- and three-step ageing treatments using experimental and modeling approaches. In each case, the effects on both the microstructure and the resulting properties are discussed.

Aluminum alloys are divided into two groups and they are: those that cannot be heat treated, and those that can. Those that are heat treatable can be hardened by the addition of certain alloying elements, and these elements are copper, zinc, magnesium and silicon, these elements when applied in different concentrations form compositions that display a solubility increase in aluminum at elevated temperatures it is possible conduct heat treatment on them. The process consists of heating the solution followed by quenching or aging. Conducting an appropriate sequence an agreeable ductility with a high strength can be obtained, [26]. Due the scientific importance of the 6xxx aluminum group they have undergone intensive studies because of their ability to increase in strength when subjected to precipitation hardening. These alloys are used in extrusion, construction and automobile manufacturing, because of their low density which makes them simple to shape. In addition to them being low priced they have good weld ability and good corrosion resistance making them desirable, [27].

Different precipitants can be obtained depending on the type of constituents that the alloy is formed of.. This will in turn influence and produce different mechanical properties, [28]. An attempt was made for positioning these precipitates on the phase diagram, via using the precipitates line chart, and the phases that are stable were detected. So as to acquire the best mechanical properties appropriate fabrication process is needed to be chosen. The time needed for aging, temperature, occurrence of deformation and the whole fabrication process are also needed to be taken into consideration, [29]. The significance of the time spent between solution heat treatment and aging, artificially will demonstrate that the time spent from quenching till aging will lead to the natural aging of the specimen and hence lowering its hardness in the end. In another study, [30], deformed samples between quenching and aging and they concluded that this method has positive effects on hardness and strength.

1.3.1 overview of Heat Treatment :

All of the typical processes performed on metals produce heat, whether it's welding or cutting, and any time you heat metal, you change the metallurgical structure and properties of it. Inversely, you can also use heat treatment to restore metals to its original form.

- Heat treatment is the process of heating metal without letting it reach its molten, or melting, stage, and then cooling the metal in a controlled way to select desired mechanical properties. Heat treatment is used to either make metal stronger or more malleable, more resistant to abrasion or more ductile. Whatever your desired properties, it's a given that you'll never be able to get everything you want. If you harden a metal, you also make it brittle. If you soften a metal, you reduce its strength. While you improve some properties, you worsen others and can make decisions based on the metal's end-use. [31]

1.3.2 Treatment Theory :

All heat treatments involve heating and cooling metals, but there are three main differences in process: the heating temperatures, the cooling rates, and the quenching types that are used to land on the properties you want. In a future blog post, we'll cover the different types of heat treatment for ferrous metals, or metal with iron, which consist of annealing, normalizing, hardening, and/or tempering.

To heat treat metal, you'll need the proper equipment so that you can closely control all of the factors around heating, cooling, and quenching. For example, the furnace must be the proper size and type to control temperature, including the gas mixture in the heating chamber, and you need the appropriate quenching media to cool metal correctly. [31]

1.3.3 Stages Heat Treatment :

There are three stages of heat treatment: [31]

- Heat the metal slowly to ensure that the metal maintains a uniform temperature.
- Soak, or hold, the metal at a specific temperature for an allotted period of time.
- Cool the metal to room temperature

1.3.3.1 The Heating Stage :

During the heating stage, the foremost aim is to make sure that the metal heats uniformly. You get even heating by heating slowly. If you heat the metal unevenly, one section may expand faster than another, resulting in a distorted or cracked section of the metal. You choose the heating rate according to the following factors: [31]

- The heat conductivity of the metal. Metals with high heat conductivity heat faster than those with low conductivity.

- The condition of the metal. Tools and parts that have been hardened, or stressed, previously should be heated slower than tools and parts that haven't.

- The size and cross-section of the metal. Larger parts or parts with uneven cross sections need to be heated more slowly than small parts to allow the inside temperature to be close to the surface temperature. Otherwise, there’s a risk of cracking or excessive warping**.**

Figure (1-2) Heat treatments

1.3.3.2 The Soaking Stage :

The purpose of the soaking stage is to keep the metal at the appropriate temperature until the desired internal structure takes shape. The “soaking period” is how long you keep the metal at the appropriate temperature. To determine the correct length of time, you will need the chemical analysis and mass of the metal. For uneven cross-sections, you can determine the soaking period using the largest section.

Generally, you shouldn’t bring the temperature of the metal from room temperature to the soaking temperature in one step. Rather, you’ll need to heat the metal slowly to just below the temperature where the structure will change, and then hold it until the temperature is consistent throughout the metal. After this step of “preheating”, you more quickly heat the temperature to the final temperature that you'll need. Parts with more complex designs may require layers of preheating to prevent warping. [31]

1.3.3.3 The cooling Stage :

In the cooling stage, you'll want to cool metal back to room temperature, but there are different ways to do this depending on the type of metal. It may need a cooling medium, a gas, liquid, solid, or combination thereof. The rate of cooling depends on the metal itself and the medium for cooling. It follows that the choices you make in cooling are important factors in the desired properties of the metal.

Quenching is when you rapidly cool metal in air, oil, water, brine, or another medium. Usually quenching is associated with hardening because most metals that are hardened are cooled rapidly with quenching, but it is not always true that quenching or otherwise rapid cooling results in hardening. Water quenching, for example, is used to anneal copper, and other metals are hardened with slow cooling.

Not all metals should be quenched – quenching can crack or warp some metals. Generally, brine or water can rapidly cool metal, while oil mixtures are better for a slower cooling. The general guidelines are that you can use water to harden carbon steels, oil to harden alloy steels, and water to quench nonferrous metals. However, as with all treatments, the rate and medium of cooling you choose must fit the metal. [31]

1.3.4 Effects of Heat Treatment :

The application of the term heat treatable to aluminium alloys, both wrought and cast, is restricted to the specific operations employed to increase strength and hardness by precipitation hardening thus the term heat treatable serves to distinguish the heat treatable alloys from those alloys in which no significant strength improvement can be achieved by heating and cooling.

Age hardening is a heat treatment method implemented on heat treatable aluminum alloys in order to improve some their mechanical properties. the process rearranges the components that make up the alloy that detach from the aluminum during the cooling phase after it had been heated to a specific temperature during the process , the alloy's elements that are dissolvable will compose a uniform mass by solid diffusion. The alloy is quenched so as to keep the uniform condition in the quenched state. This process produces a malleable supersaturated but insecure alloy. At room temperature ,the alloying elements that form the alloy will start to precipitate from the solid solution, this will cause the alloy's hardness increase considerably. Some alloys need years in order to obtain strength and maximum hardness.

The alloys that have a slower transformation for age hardening can be sped up artificially by heating the alloy to a specific temperature and length of time depending on its dimensions, [32]. A considerable rise in yield and tensile strength is noted together with a decrease in ductility when it is subjected, after solution heat treatment, and cold work. Different compositions produce a variation of properties. Annealing is a heat treatment process used for recrystallization and/or eliminating residual stresses which are induced as a result of cold work and heat treatment. Annealing temperature for most of these alloys reach 650 0 F (343 0C).they are heated at a controlled pace depending on the thickness and which of the several types of annealing desired. The rate at which the part is cooled is not significant so long as it is not quenched as this will lead to residual stresses. [33].

Heat treatment can affect the microstructure of an aluminum-silicon alloy in various ways, including modifications in mechanical properties. During heat treatment, supersaturated solid solutions transform into more stable, balanced structures that yield optimal mechanical properties. In general, heat treatment is beneficial in reducing porosity, optimizing microstructural characteristics, and improving mechanical properties of selected alloys. [33]

1.4.1 Casting process:

It is one of the most important and oldest manufacturing processes in which the material to be cast is smelted Until it reaches a certain temperature, the molten is then poured into a mold. This mold contains The cavity that represents the shape of the desired product, and when it cools and hardens again, the mold is opened to take out The product, which has taken the same shape as the void inside the mould.[34]

There are many types of casting processes that differ in their properties and the degree of accuracy of their resulting castings :

1.4.1 1.Plumbing operations can be divided into:

Casting in sand molds: which constitute more than 09% of the known casting operations, which Sand is used to make molds that are used only once, and this method can be used predominantly Metals that can be alloyed.[34]

1.4.1.2. Casting in permanent molds:

in which metal molds are used to form the required castings The use of molds for many times and is usually used for casting non-ferrous metals.[34]

1.4.1.3.Centrifugal casting :

simple metal molds are used and the metal is formed using the centrifugal feature.[34]

As for the mold used in the casting process, it often consists of two halves, whether the casting is sand Or by using two metal molds, or a multiple combination of more than one part, and it also has the required cavity The production of the product in its shape, and the molds often contain extruders to expel the casting after it has completely cooled As well as internal paths for the passage of cooling water, if necessary, and we will deal with this in our project Sand plumbing with its advantages and disadvantages and everything related to it in some detail. [34]

1.4.1.4.1 sand plumbing:

It is a casting or pouring of metals into sand-containing molds that represent the shape or shape of the piece to be plumbed. [34]

Sand casting steps:

1. sand.
2. form.
3. cores.
4. minerals.

1.4.1.4.2 Advantages of castings: [35]

1. The casting process can be used to produce complex shapes that contain many details.
2. sand casting process can be used to produce relatively large shapes.

3. The casting process can be used on any metal, that is, it can be heated to the melting point and then
4. Making use of the casting process in its production.
5. The casting process is suitable for production in relatively reasonable quantities.
6. Possibility to control casting stations to some extent.
7. The ideal casting can be obtained after the surface finishing operations of the casting.
8. Thin castings or complex shapes can be cast.

1.4.1.4.3 Disadvantages of castings:

The castings containing visible or invisible defects are an undesirable product and do not allow these defects when used and the defects differ in terms of size, shape and damage caused by cutting, and there are defects that are suitable for repair and defects that are not suitable for reconciliation. [35]

1.4.1.5.1 Metal plumbing

Metal plumbing has been a long-standing option for plumbing systems in homes and buildings. While newer materials such as PVC and PEX have started to become popular, metal plumbing continues to offer benefits that are unique.[36] Types of metal plumbing:

There are several types of metal plumbing available, including copper, galvanized steel, brass, and stainless steel. Copper is the most commonly used metal material for plumbing due to its durability and resistance to corrosion. Galvanized steel is also used, as it is less expensive than copper, however, it is more susceptible to corrosion over time. Brass and stainless steel plumbing materials are durable and long-lasting, but they are more expensive.[36]

1.4.1.5.2 Advantages of metal plumbing:

Metal plumbing provides a range of benefits, including durability, longevity, and resistance to high pressures and temperatures. It’s also suitable for high-temperature water supplies and is very resistant to damage from weather and UV radiation. In addition, metal pipes are easily repaired or replaced, and they do not release any harmful chemicals or substances into the water supply.[36]

1.4.1.5.3 Disadvantages of metal plumbing:

While metal plumbing offers many benefits, there are also some downsides to consider. Metal pipes are more susceptible to freeze bursts than plastic pipes. Also, metal pipes can corrode over time, which can cause leaks or damage to the building’s structure.[36]

Overall, metal plumbing is still a viable option for those looking to update or install a plumbing system in their home, especially for those in areas where the water supply may contain high levels of minerals that could damage plastic materials. Copper piping is highly favored due to its durability and perseverance. But, to prolong the life of metal piping, it's suggested to have regular inspections performed. Water pressure should also be kept low to prevent damage to the pipes, and if leaks occur, repairing or replacing the damaged sections should be done immediately to prevent further damage and more costly repairs.[36]

Chapter Two:

Experimental Part

2.1.Introduction:

In this chapter, the we will presented the alloys that has been used in addition to the materials preparation and testing procedure that has been used.

2.2 Experimental Procedure:

2.2.1 Material preparation:

The present investigation was carried out on Al-Si alloy composition shown in Table 2.1 . In addition to pure aluminium**.**

Table (2.1) The chemical composition Al-9Si.

Sample Name:
Oval

	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn
	%	%	%	%	%	%	%	%
1	9.77	0.397	0.204	0.0368	0.452	0.0182	0.0364	0.688
Ø (1)	**9.77**	**0.397**	**0.204**	**0.0368**	**0.452**	**0.0182**	**0.0364**	**0.688**
sd	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
rsd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Ti	Be	Bi	Ca	Cd	Co	Na	P
	%	%	%	%	%	%	%	%
1	0.0514	< 0.00010	0.0297	0.0096	0.0107	0.0342	0.0067	~ 0.0117
Ø (1)	**0.0514**	**< 0.00010**	**0.0297**	**0.0096**	**0.0107**	**0.0342**	**0.0067**	**~ 0.0117**
sd	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
rsd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Pb	Sn	Sr	V	Zr	Al		
	%	%	%	%	%	%		
1	0.0481	0.125	0.0067	0.0149	0.0149	88.0		
Ø (1)	**0.0481**	**0.125**	**0.0067**	**0.0149**	**0.0149**	**88.0**		
sd	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000		
rsd	0.0	0.0	0.0	0.0	0.0	0.0		

2.2.2 Preparing the alloy:

The alloys used in the research were prepared by melting the Al-9Si alloy in a gas furnace using graphite ccuracy, and the melting process was carried out at a temperature of (750 °C) to ensure melting, in addition to continuous stirring with a graphite rod, then after that adding slag remover and mixing well, then Slag is withdrawn from the nozzle of accuracy The casting mold was heated before pouring the molten into it to a temperature (200 °C) in order to prevent hot cracking of the product, then the casting mold is cooled after pouring the molten and then the casting is extracted from inside it.

Figure (2-1) melting furnace**.**

Then, it is cast into a sand mold, and the ingot is also melted at the same temperature above, and casting is carried out according to the following steps:

1. Make a mold by modeling the desired product shape in the sand.
2. Make a suitable hole system in the mold for metal casting and gases to escape.
3. Remove the wooden model from the mold.
4. Pour the molten metal into the mold cavity.
5. Leave the metal to cool.
6. Break the sand mold and remove the cast metal.

The same process is repeated for pure aluminum casting**.**

Figure (2-2) while pouring molten metal**.**

2.2.3 cutting samples:

The produced samples were cut into a cylindrical shape with a diameter of 10.27 mm and a height of 18 mm for the purpose of studying the microstructure and hardness, and samples with a height of 21 mm and a diameter of 10.27 mm for the compression test. The same is true of pure aluminium. To conduct thermal treatments on one part of these samples and the other part without thermal treatments, and for both of them (alloy and pure metal).

2.2.4 heat treatments:

Some samples were treated at a temperature of 200C for two hours in furnace for heat treatments, then the samples were cooled inside the furn.

Figure (2-3) Resistance furnace Electrical.

2.2.5 Microstructure test :

The test samples were cut to dimensions (10.27 mm in diameter and 18 mm in height) for the purpose of microscopic examination, then wet smoothing was performed on them using SiC smoothing papers with different degrees of fineness (200,400,600,800,1000,150,2000,220.3000), respectively. Then the polishing process was carried out using a special polishing cloth and an alumina solution with a grain size of (5µm). The samples were then washed with water and alcohol and air dried. Finally, the samples were exposed using a solution consisting of (5% HF + 95% H_2O). Use an optical microscope With a digital camera installed with special software on Computer to study the microstructure For samples before and after processing thermal.

The microstructure was tested using the microscope shown in Figure (2.4).

Figure (2.4) the microscope**.**

2.2.6 Hardness test:

The test samples were cut to dimensions (10.27 mm in diameter and 18 mm in height) for the purpose of conducting the hardness test, then wet softening was carried out with water and smoothing papers with different degrees of fineness (320, 500, and 1000), respectively. The hardness tester was used to measure the microscopic hardness using the Vickers method A load of (100) duration (10 sec) and it was The amount of readings is taken from the device screen Direct digital readouts Taken at the rate of three strokes per sample.

The hardness was tested by the device shown in Figure (2.5).

Figure (2.5) Vigraz hardness measuring device.

2.2.7 Compression test:

The test samples were cut to dimensions (10.27mm in diameter and 21mm in height) for the purpose of performing the compression test. The device shown in Figure (2.6) was used.

Figure (2.6) Compression device.

Chapter Three

Results and Discussion

3.1. Introduction :

In the current chapter, the results that have been obtained from the experimental part were presented in addition to the discussion of that results .

3.2. Microstructure results :

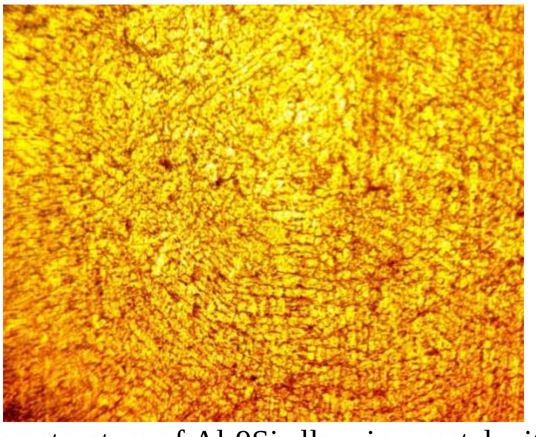

Figure (3-1) microstructure of Al-9Si alloy in a metal without thermal treatments**.**

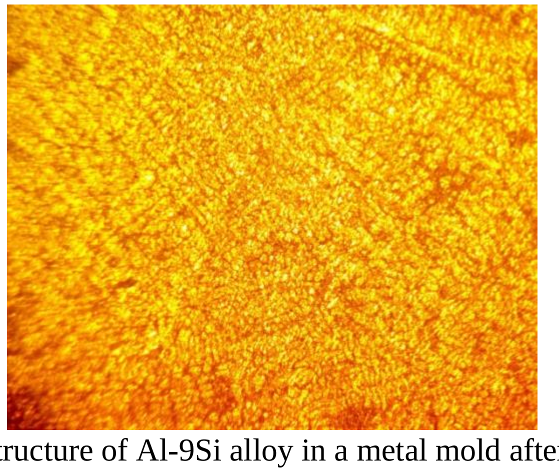

Figure (3-2) microstructure of Al-9Si alloy in a metal mold after heat treatment.

In figure (3-1) Cast (Al-9Si) usually exhibits a microstructure that can be observed under an optical microscope, consisting of solid grains of aluminum and silicon alloys. After conducting the heat treatment, as shown in fig (3-2) the microstructure of (Al-9Si) alloy consists of a very fine equiaxed grain structure, which is a mixture of alpha and beta phases.

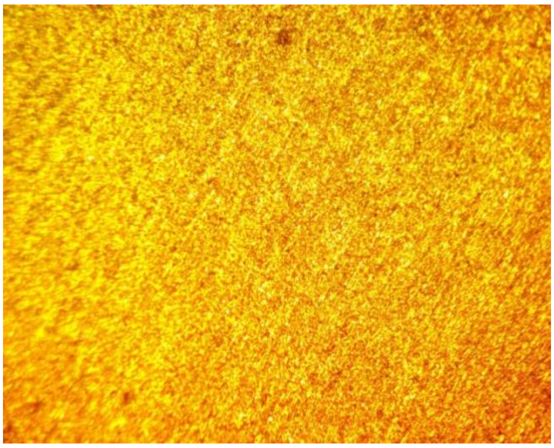

Figure (3-3) shows the microstructure of pure aluminum in a metal mold after heat treatment.

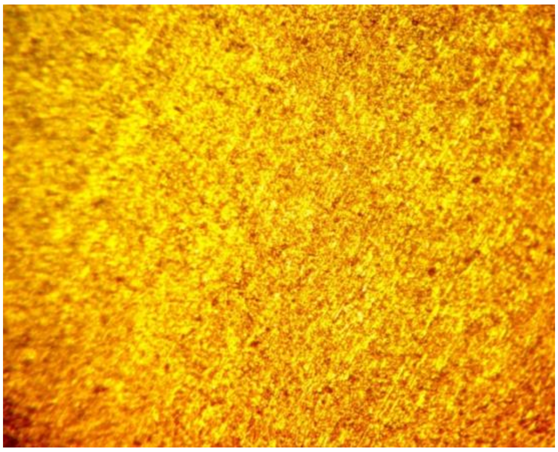

Figure (3-4) shows the microstructure of pure aluminum in a metal mold before heat treatment**.**

Pure aluminum used in plumbing is made in a metal mold and has a randomly irregular microstructure of crystals, which is characterized by weak mechanical properties compared to heat-treated alloys . Heat-treated aluminum alloys are available with a modified and more regular microstructure, which is achieved by precise heating and cooling in a programmed manner to adjust the microstructure and improve the mechanical properties of the alloy, fig (3-3)

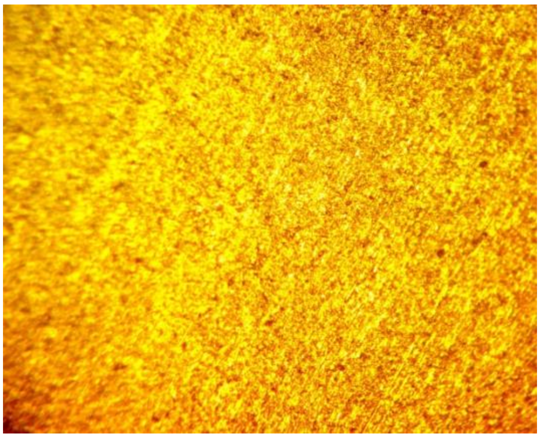

Figure (3-5) shows the microstructure of pure aluminum cast in a sand mold.

The microstructure of pure aluminum during casting in a sand mold is composed of semi-regular and irregularly shaped crystals, which give the actual shape of the metal. These crystals range in size and shape from very small and interlocking crystals to larger and less dense crystals. Generally, the microstructure of pure aluminum is characterized by weak mechanical properties compared to heat-treated alloys.

3.3 Hardness results :

(3-1) Table showing the hardness values of pure aluminum alloy and (Al-9Si) alloy before and after heat treatment.

Alloy type	casting type	Heat treatment	Average hardness values
Al-9Si	**Metal mold**	**With heat treatment**	**101.75 HV**
Al-9Si	**Metal mold**	**Without heat treatment**	**95.76 HV**
Al pure	**Metal mold**	**With heat treatment**	**70.7 HV**
Al pure	**Metal mold**	**Without heat treatment**	**77.33 HV**
Al pure	**Sand mold**	**Without heat treatment**	**73.47 HV**

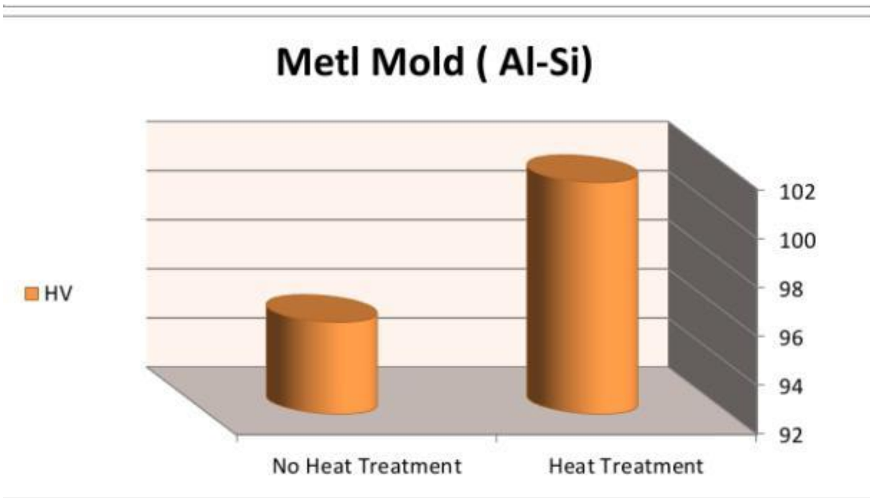

Figure (3-6) hardness values of (Al-9Si) alloy.

Figure (3-6) shows the hardness values of (Al-9Si) alloy before and after heat treatment. It was found that after heat treatment, the hardness values of the alloy will increase due to:

1. Elimination of impurities: Aluminum alloys contain several impurities and contaminants that increase softness and lower hardness. Heat treatments help to eliminate these impurities and clean the material, which increases the hardness.
2. Better distribution of elements: The distribution of alloy elements appears irregular before heat treatment, which leads to a decrease in hardness. However, after heat treatment, the distribution becomes more uniform and the average values of the elements converge, increasing the strength and hardness**.**
3. Formation of solid state crystals: Solid state crystals form to a greater extent after heat treatment, and these crystals form regularly and are larger in size, increasing the strength and hardness of the material.
4. Increase in silicon content: (Al-9si) alloy contains a high percentage of silicon, and the system is greatly affected by heat treatments. The hardness rate increases significantly with an increase in the silicon content, and after
5. applying heat treatments, the silicon content is improved and, consequently, the hardness is improved.

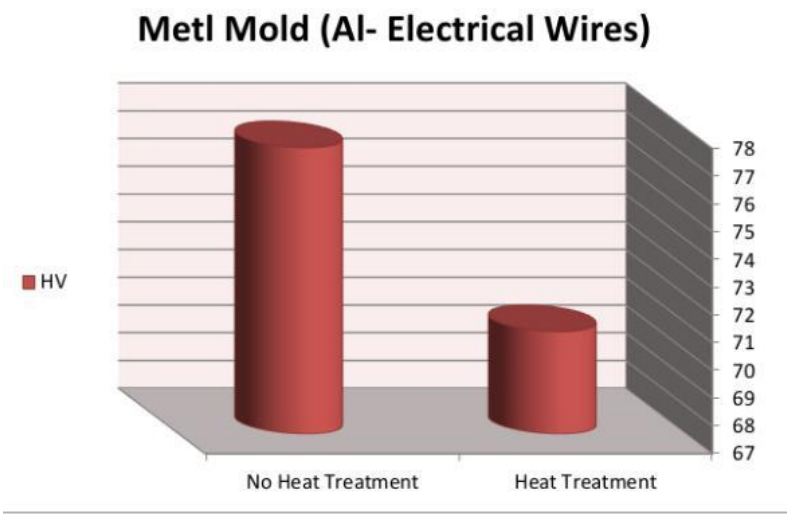

Figure (3-7) hardness values of pure aluminum**.**

Figure (3-7) shows the hardness values of pure aluminum cast in a metal mold before and after heat treatment **.**It was found that the hardness values decrease when conducting the heat treatment, due to the formation of small and semi-regular size crystals, and the size of the smaller crystals increases the number of granular boundaries in the material, which reduces the ease of sliding of the granules on each other, which reduces the strength of the materials and thus the hardness value.

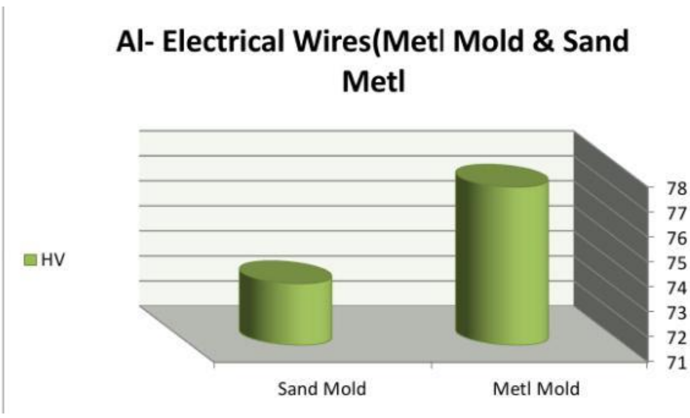

Figure (3-8) hardness values of pure aluminum.

Figure (3-8) shows the hardness values of pure aluminum when casting it with a sand mold and another metal mold . It was found that the hardness in the metal mold is better because: Metal casting using molds is considered more accurate and controllable in terms of temperature and cooling rate compared to sand molds. This precision and control allows for better structural and higher mechanical properties of the cast material, because controlling the temperature and cooling reduces the changes in the structure of the cast material, which in turn reduces distortion and gradients in hardness. Additionally, the metal casting process provides the opportunity to produce complex shapes with greater ease and precision, which leads to an overall increase in product quality. Due to these advantages, the hardness values achieved by metal casting products are considered to be better and higher than those achieved by sand molds.

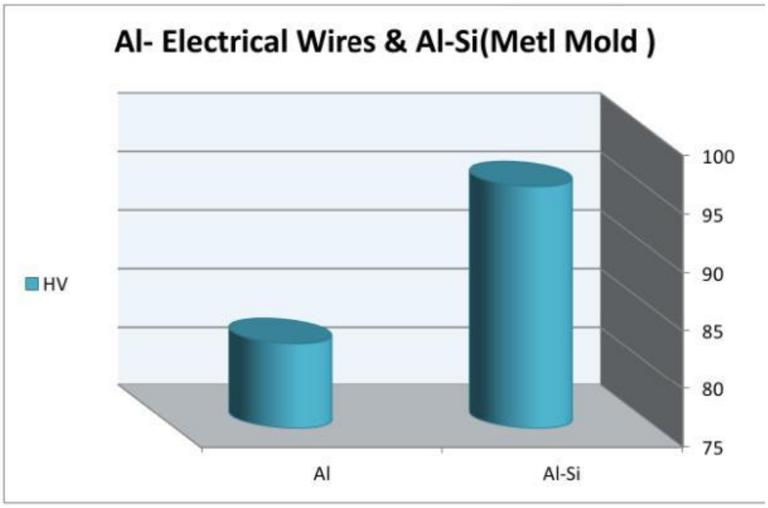

Figure (3-9) hardness values between pure aluminum and (Al-9Si) alloy**.**

Figure (3-9) shows the hardness values between pure aluminum and (Al-9Si) alloy cast in a metal mold, and before conducting a heat treatment for them, it was found that the hardness value of (Al-9Si) alloy is better than that of pure aluminum due to the presence of silicon.

3.4 compression results :

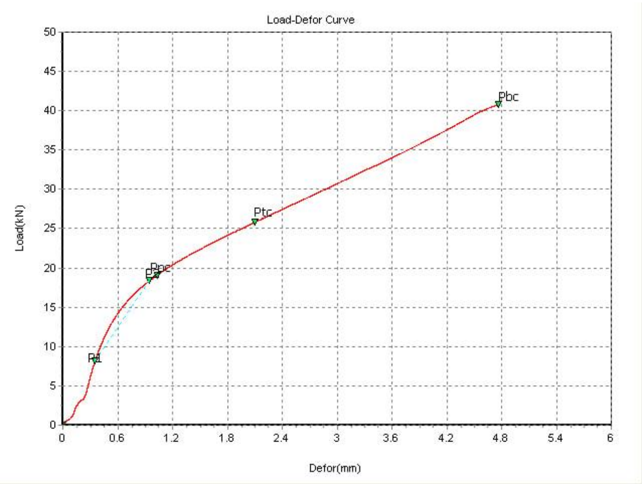

Figure (3-10) show the compression diagram of (Al-9Si) alloy with a metal mold before heat treatment**.**

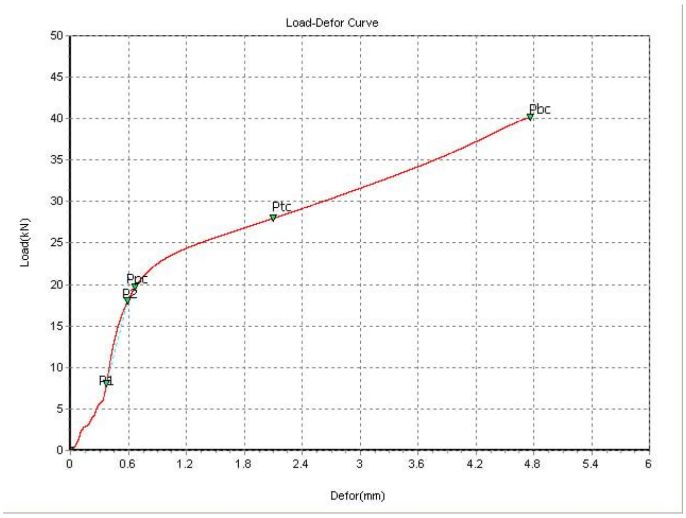

Figure (3-11) shows the compression test of (Al-9Si) alloy After heat treatment.

For the alloy (Al-9Si) and in general, the extent of its resistance to the test depends on the percentage of silicon (Si) added to it and the heat treatment it is exposed to. It is expected that alloys containing higher amounts of silicon will show better resistance to the test.

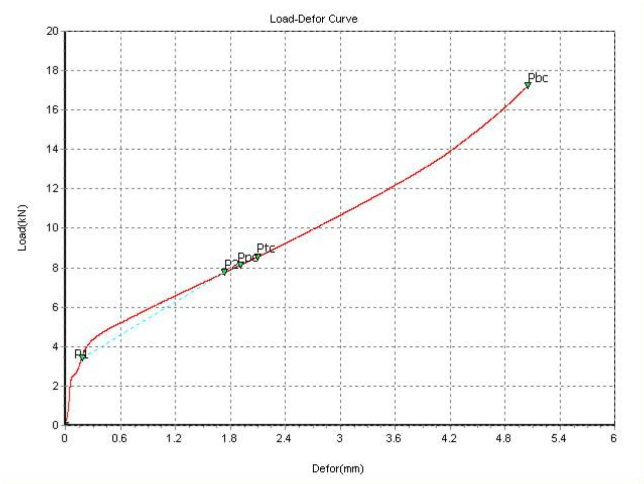

Figure (3-12) shows the compression diagram of pure aluminum after casting it with a metal mold and before heat treatment.

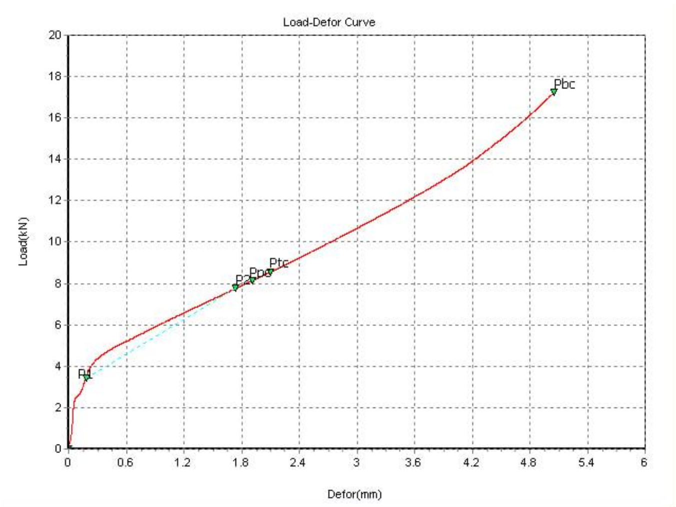

Figure (3-13) Compression chart of pure aluminum after casting it with a metal mold and conducting heat treatment for it

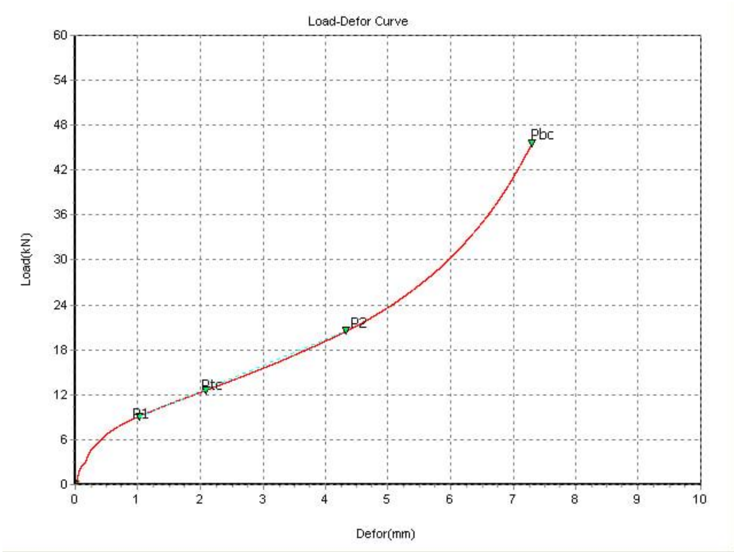

Figure (3-14) shows the compression diagram of pure aluminum after casting it with a sand mold without heat treatment.

In the case of pure aluminum, it is considered non-resistant to testing because it is soft and easy to bend. It is also possible for the durability and resistance to testing to increase after a thermal process.

Chapter four Conclusion and Recommendation

4.1 Conclusion:

Metal molds are usually more precise and less error-prone in plumbing because metal molds are durable and rigid and contain some intricate details like dots and lines that can be used to shape the precise details of the part to be cast.

Al-9Si alloy is better than pure aluminum because it contains silicon (Si) which enhances the hardness and durability of the alloy. Additionally, adding silicon to aluminum also helps to improve its resistance to corrosion, friction, and scratch corrosion. Furthermore, adding silicon leads to improving the weldability of the alloy and improving its response to heat treatment. Therefore, alloys containing silicon as an alloying material are highly popular in industries that require lightweight, high-strength, and highly formable materials, such as engineering, aerospace, automotive, and aviation industries.

4.2. Recommendation for Future Works

1. Applying the same procedure and testing, but with using different aluminum alloy .
2. Using the same alloys but with adding other metals particles in order to improve the strength of each alloys such as Ni particles .

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