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Investigation and numerical analysis as cast heat treated aluminium alloy, (Al-20% with mg) by tensile test

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Abstract
This is articles, the need for lightweight materials for Equipments, Aircrafts, vehicles and space stations, has become imperative. In view of this, Micro structural analysis of Aluminum alloys becomes very essential in establishment of their physical properties. The samples will be cast and heat treated at 450 ^{o}C for 1 hr, after which the samples will be annealed, and quenched in used engine oil and water. Tensile and hardness tests will be carried out on the samples. The ultimate tensile strength observed which will be increased with decreasing quench severity of quench media. The samples will be characterized by hardness as-cast, annealed, used engine oil quenched and water quenched samples. The results will show that the hardness increased with increasing quench severity. And test samples will be investigated their Mechanical properties and their numerical analysis will be taken and compared by finite element analysis.

Keywords: Sand casing technique, tensile test & hardness test

1. Introduction

The presence of magnesium improves strain, hardens ability and enhances the material strength by solid solution. Aluminum–Magnesium alloys have excellent resistance to corrosion in seawater. This is the main reason for their widespread use in the naval industry. In most naval applications, these alloys are exposed to severe hydrodynamic conditions. To date, only a few studies have been reported in the open literature on the use of A1-Mg alloys in composite solid rocket propellants. One study reported that the use of Mg-A1 alloy resulted in the complete consumption of the metal in the reaction. Although the Al-Mg alloy sheets have many advantages compared to conventional materials, their formability is lower than that of steel sheets. Moreover, on the surface of sheets the stretcher-strain (st-st) marks frequently appear during the metal-forming processes. Obviously, such st-st marks are not required, since they decrease the quality of final products such as outer panels of cars. Moreover, the marks may sometimes lead to strain localization and fracture.

Heat treatment involves solution and aging heat treatments during which a series of changes in microstructure occur which then lead to the improvement of strength. These changes in microstructure include the dissolution of precipitates, homogenization of the cast structure, such as minimization of alloying element segregation, spheroidization and coarsening of eutectic silicon, and precipitation of finer hardening phases. Liquid Aluminum is prone to hydrogen absorption and oxidation, gas porosity and oxide incursion are inevitably found in Aluminum casting. If casting is not properly done, shrinkage porosity occurs. Quantitative methods of predicting the relationship between mechanical properties and defects has been developed. Although it is still not possible to fully account for effect of pore shape and defect type on the mechanical properties, but the fact is that there is deterioration in mechanical properties with increasing porosity. Cast Aluminum alloys are often considered to be unreliable in view of their mechanical properties due to the presence of variety of casting defects. Consequently design stresses in casting are usually very low compared with those allowed in forging.

Axial tensile test is known as a basic and universal engineering test to achieve material parameters such as ultimate strength, yield strength, % elongation, % area of reduction and Young's modulus. These important parameters obtained from the standard tensile testing are useful for the selection of engineering materials for any applications required. The tensile testing is carried out by applying longitudinal or axial load at a specific extension rate to a standard tensile specimen with known dimensions (gauge length and cross sectional area perpendicular to the load direction) till failure. The applied tensile load and extension are recorded during the test for the calculation of stress and strain. A range of universal standards provided by Professional societies such as American Society of Testing and Materials (ASTM), British standard, JIS standard and DIN standard provides testing are selected based on preferential uses. Each standard may contain a variety of test standards suitable for different materials, dimensions and fabrication history. For instance, ASTM E8: is a standard test method for tension testing of metallic materials and ASTM B557 is standard test methods of tension testing wrought and cast Aluminum and Magnesium alloy products. A standard specimen is prepared in a round depending on the standard used. Both ends of the specimens should have sufficient length and a surface condition such that they are firmly gripped during testing. Any heat treatments should be applied on to the specimen prior to machining to produce the final specimen readily for testing. This has been done to prevent surface oxide scales that might act as stress concentration which might subsequently affect the final tensile properties due to premature failure. There might be some exceptions, for examples, surface hardening or surface coating on the materials. These processes should be employed after specimen machining in order to obtain the tensile properties results which include the actual specimen surface conditions**.**

2. Overview of Aluminum

The name aluminum is derived from the ancient name for alum (potassium aluminum sulphate), which was alumen (Latin, meaning bitter salt). Aluminum was the original name given to the element by Humphry Davy but others called it aluminum and that became the accepted name in Europe. However, in the USA the preferred name was aluminum and when the American Chemical Society debated on the issue, in 1925, it decided to stick with aluminum. Aluminum is a soft and lightweight metal. It has a dull silvery appearance, because of a thin layer of oxidation that forms quickly when it is exposed to air. Aluminum is nontoxic (as the metal) nonmagnetic and non-sparking. Aluminum has only one naturally occurring isotope, aluminium-27, which is not radioactive.

3. Overview of Magnesium

Magnesium is a chemical element with symbol Mg and atomic number 12. Its common oxidation number is +2. It is an alkaline earth metal and the eighth most abundant element in the Earth's crust and ninth in the known universe as a whole. Magnesium m is the fourth most common element in the Earth as a whole (behind iron, oxygen and silicon), making up 13% of the planet's mass and a large fraction of the planet's mantle. The relative abundance of magnesium is related to the fact that it is easily built up in supernova stars from a sequential addition of three helium nuclei to carbon (which in turn is made from three helium nuclei). Due to magnesium ion's high solubility in water, it is the third most abundant element dissolved in seawater.

The free element (metal) is not found naturally on Earth, as it is highly reactive (though once produced, it is coated in a thin layer of oxide (see passivation), which partly masks this reactivity). The free metal burns with a characteristic brilliant white light, making it a useful ingredient in flares. The metal is now mainly obtained by electrolysis of magnesium salts obtained from brine. Commercially, the chief use for the metal is as an alloying agent to make Aluminum-magnesium alloys, sometimes called "magnalium" or "magnelium". Since magnesium is less dense than Aluminum, these alloys are prized for their relative lightness and strength.

In human biology, magnesium is the eleventh most abundant element by mass in the human body; its ions are essential to all living cells, where they play a major role in manipulating important biological polyphosphate compounds like ATP, DNA, and RNA. Hundreds of enzymes thus require magnesium ions to function. Magnesium compounds are used medicinally as common laxatives, antacids (e.g., milk of magnesia), and in a number of situations where stabilization of abnormal nerve excitation and blood vessel spasm is required (e.g., to treat eclampsia). Magnesium ions are sour to the taste, and in low concentrations they help to impart a natural tartness to fresh mineral waters. In vegetation magnesium is the metallic ion at the center of chlorophyll, and is thus a common additive to fertilizers. Figure 3 shows a pulsating heat pipe. It comprises a serpentine channel of capillary dimension, which has been evacuated, and partially filled with the working fluid. Surface tension effects result in the formation of slugs of liquid interspersed with bubbles of vapor. A PHP is essentially a non-equilibrium heat transfer device whose performance success depends primarily on the continuous maintenance of these non-equilibrium conditions within the system. The liquid – vapor slug transport is due to thermally driven pressure pulsations in the respective tubes.

4. Sand Casting

Sand casting, the most widely used casting process, utilizes expendable sand molds to form complex metal parts that can be made of nearly any alloy. Because the sand mold must be destroyed in order to remove the part, called the casting, sand casting typically has a low production rate. The sand casting process involves the use of a furnace, metal, pattern, and sand mold. The metal is melted in the furnace and then ladled and poured into the cavity of the sand mold, which is formed by the pattern. The sand mold separates along a parting line and the solidified casting can be removed. The steps in this process are described in greater detail in the next section.

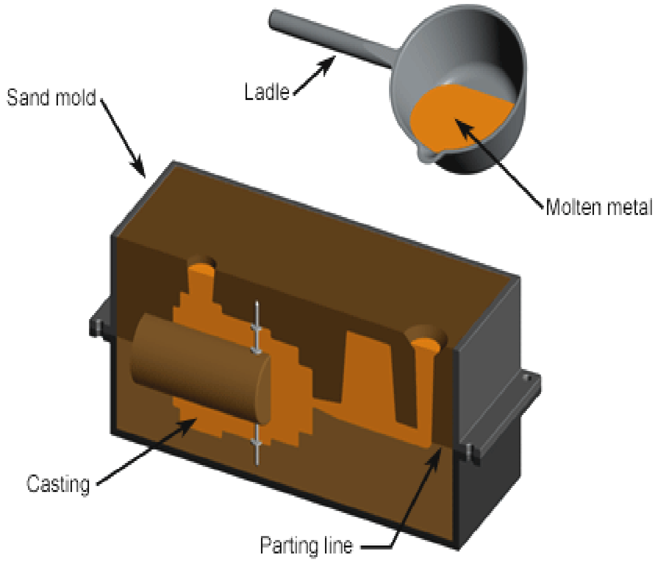


Fig 1: Sand Casting Overview

5. Process Cycle

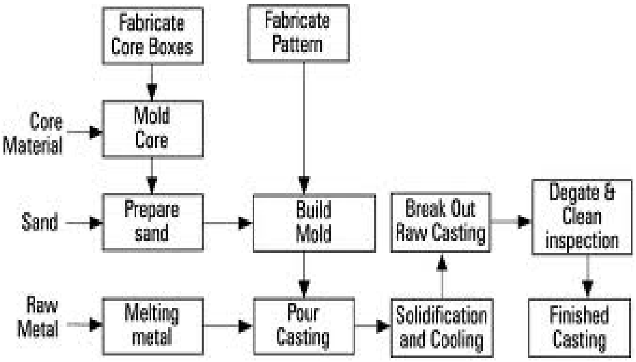


Fig 2: Process Cycle

6. Standard Tensile Test Specimen:

The samples in their pure form were obtained as Aluminum and magnesium. From the percentages of various weights of alloying elements were calculated by taking into consideration the specific gravity of the base metal, aluminium-2.7g/cm^3. Since the samples to be cast are in cylindrical shape, the formula for the volume of a cylinder $\pi r^2 h$ was used for the calculation. Before performing the test Specimen of standard size and shape must be produced from the material to be tested for the result to be comparable. It is strongly advised to manufacture. The specimen size and shape according to standard. We are using the round test bar. We are show the standard size specimen.

7. Experimental Calculation of Test Specimen

Fig 3: Magnesium Metal Powders

The cylindrical rods of dimensions 200mm long, 12mm diameter was used as pattern for moulding. The samples to be cast in cylindrical form, therefore the volume of the cylinder = $\pi r^2 h$, where h -height of the rod = 200mm, r -radius of the rod = 12/2 mm = 6mm, m -mass, ρ -density, V – volume, density of Aluminum = 2.7g/cm^3, 80% Aluminum, 20% magnesium

$$V = \pi r^2 h = 22/7 \times 0.6^2 \times 20 = 22.63 \text{ cm}^3$$

$m = \rho \times V = 2.7 \times 22.63 = 61.1$g

Mass of Aluminum

m Al = 80/100 x 61.1 = 48.88 g.

Mass of magnesium

m Mg = 20/100 x 61.1 = 12.22 g.

The following figure shows the ASTM rules followed during making of standard tensile test specimen.

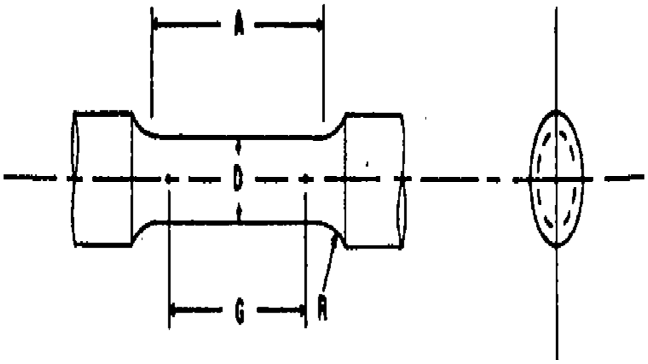


Fig 4: Standard Tensile Test Specimen

8. Heat Treatment

Heat treatment of the castings was carried out in muffle furnace. This was done by heating the samples to 450◦C and holding temperature constant for 1 hour. Some of the samples were quenched in Water and used engine oil (Engine Oil) at a room temperature and the remaining samples were left in the furnace to cool with the furnace for annealing. The different types of quenching media were selected arbitrarily to investigate the effect of heating on hardness and tensile properties.

9. Tensile Test

The samples used for tensile tests were machined into various test piece sizes with the aid of lathe machine. The test piece was machined to comply with ASTM B557 (standard test methods for tension testing wrought and cast aluminum- and magnesium-alloy products). The test pieces were subjected to constant extension rate tensile test (CERT). The samples were clamped to the tensiometre and a load of 100 kg was used to apply stress in a tensile manner. As the stress is being increased, the test piece showed an increase in length and the pointer to the machine automatically indicates the value of the stress applied. When the elastic limit is reached, the pointer on the dial flickers, as soon as the yield point is exceeded there is an indication of increased stress.

10. Brinell Hardness Test

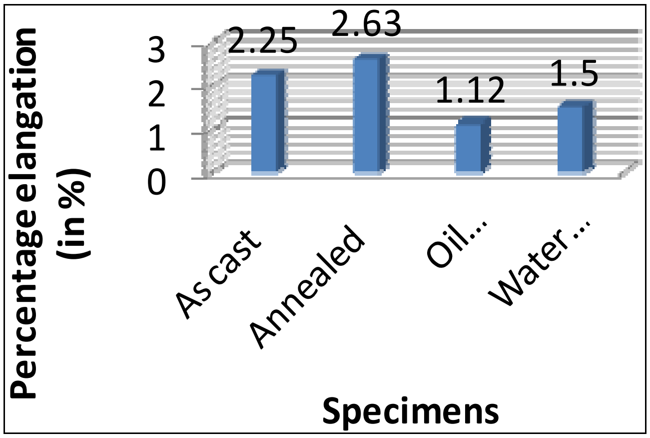
The samples used for the hardness test were machined to conform to ASTM standard E 10.This was done on the universal testing machine by assembling the brinell test compression attachment to the machine. The compression dial and the ball bolster were inserted. The mercury was adjusted up to zero, and the polished test piece was held against the steel ball indenter of 5mm diameter and the load was applied with quick acting handle. The applied load of 250kg was held for 25 seconds. The specimen was then removed from the machine and the diameter of the impression will be measured with brinell reading microscope and the corresponding load recorded.

11. Results and Discussion

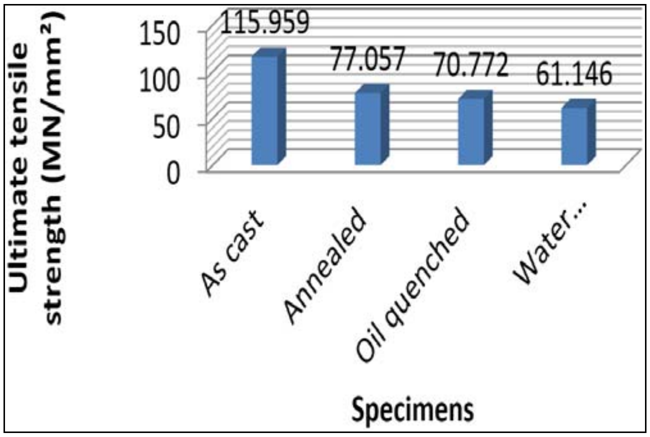
Tensile Properties

The variations of the tensile properties of the as cast, annealed, water quenched and used engine oil quenched samples are shown in figure 12 and figure 13. The tensile test result of the

as-cast sample indicated an ultimate tensile strength of 115.159 MN/m^2 while as the samples were being heat treated the strength reduced to 77.057, 70.772 and 61.146 MN/m^2 for annealed, used engine oil quenched and water quenched respectively. While the percentage reduction in area varied from the annealed sample has the highest of 4.30% and the water quenched sample having the lowest of 1.99%. In case of percentage elongation, the highest is annealed with 2.63% and used engine oil quenched having the lowest of Mass of Aluminum
m Al = 80/100 x 61.1 = 48.88 g.
Mass of magnesium
m Mg = 20/100 x 61.1 = 12.22 g.
The following figure shows the ASTM rules followed during making of standard tensile test specimen.

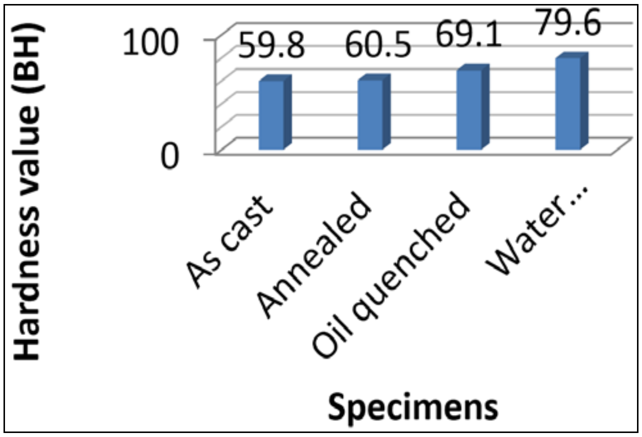


Graph1: Standard Tensile Test Specimen



Graph 2: Hardness Properties

The distribution of the Brinell hardness properties of the samples is shown in fig 14. The Brinell hardness test result shows that the water quenched sample has the highest hardness, while the as-cast sample has the least hardness. This is an indication that the hardness of Al-20%wtMg increases as the material is heat treated, which is in reverse to the ultimate tensile strength. As quenching is carried out on a metal basically in order to harden it, different quenching media have varying Cooling rates that affect how the hardness is distributed across the metal cross section as the quenching process is taking place. Water that has a fast cooling rate is observed to have the highest hardness value while the used engine oil quenched has a slower cooling rate to that of water. In annealing the cooling rate is much slower and has the least value. Although too fast cooling rate leads to uneven distribution of hardness, therefore leading to defects and eventually cracks.



Graph 3: Hardness Value

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