INVESTIGATION OF THE EFFECT OF POURING TEMPERATURE AND RATES ON THE MECHANICAL PROPERTIES OF ALUMINIUM ALLOY CASTING

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ABSTRACT

The investigation of the effect of pouring temperatures and rates on the mechanical properties of aluminum alloy casting. The casting is produced at different pouring temperatures and speeds. The speed range is 2.0cm/s to 16.0cm/s, while the temperature range for the investigation is 680ºC to 750ºC.

To making the specimens with different speed and temperature ranges after that to checking the all specimens of strength and hardness. By testing of aluminum alloy specimens in that which one is having good strength and hardness that is the fine optimum pouring speed and temperature. Due to finally we are getting the good casting components of aluminum alloys.

I. INTRODUCTION

To an engineer, the knowledge and understanding of casting parameters in casting different metals and alloys is as significant as the cast products. Metal casting is by definition any process of melting metal and pouring them into mould in order to produce the required shapes. Specific casting parameters such as pouring temperatures, rate of pouring, fluidity and composition of metals are of topmost importance for consideration if sound casting is to be achieved.

It has been observed [1] that melting and pouring conditions directly or indirectly affects such mechanical properties of cast materials as: hardness, percentage elongation, percentage reduction in diameter, toughness and so on. For instance an investigation on pouring rate of some ferrous metals [2] revealed that metals such as steels have very high freezing rate compared to most other alloys castings. The optimum pouring speed is also found to be a function of the casting size and shape.

Aluminum alloy casting has melting temperature of 660°C [3] with its corresponding pouring temperature range to be between 700°C-750°C. It was also stated by Lindberg [4] that this melting temperature may be as low as 649°C.

II.DIFFERENT TYPES OF MATERIALS

CAST IRON:

One of several types of iron (such as gray iron and white iron) containing 1.8 to 4.5 percent carbon by weight whereas carbon steel contains less than 0.5 percent. The additional carbon makes the molten iron more fluid and easier to cast in complex shapes. Highly suitable for casting large and heavy objects (such as engine blocks) it has high compression strength but low ductility.

Different Types Of Cast Iron

Cast iron is a ferrous alloy that is made by re-melting pig iron in a cupola furnace until it liquefies. The molten iron is poured into molds or casts to produce casting iron products of the required dimensions. Based on the application of cast iron, the alloying elements added to the furnace differ. The commonly added alloy elements are carbon followed by silicon. The other alloying elements added are chromium, molybdenum, copper, titanium, vanadium, etc.

Types of cast iron:

1. Gray cast iron 2.White cast iron 3. Ductile cast irons 4.Malleable cast irons

Cast Iron Properties

Mechanical property reference data for various grey cast irons, includes Tensile strength, Compressive Strength, Shear Modulus of Rupture, Tensile Modulus of Elasticity, Torsional Modulus of Elasticity, Endurance Limit and Brinell hardness data.The American Society for Testing Materials (ASTM) numbering system for grey cast iron is established such that the numbers corespond to the minimum tensile strength in KPSI. Thus an ASTM No. 20 cast iron has a minimum tensile strength of 20 KPSI.

IRON	Shear			Modulus of Elasticity				
ASTM Number	Tensile strength KPSI	Compressive strength KPSI	modulus of rupture KPSI	MPSI		Endurance limit KPSI	Brinell Hardness Hb
				Tension	Torsion		
20	22	83	26	9.6 - 14	3.9 - 5.6	10	156
25	26	97	32	11.5 - 14.8	4.6 - 6.0	11.5	174
30	31	109	40	13.0 - 16.4	5.6 - 6.6	14	201
35	36.5	124	48.5	14.5 - 17.2	5.8 - 6.9	16	212
40	42.5	140	57	16.0 - 20	6.4 - 7.8	18.5	235
50	52.5	164	73	18.8 - 22.8	7.2 - 8.0	21.5	262
60	62.5	187.5	88.5	20.4 - 23.5	7.8 - 8.5	24.5	302
AISI-SAE STEEL	Tensile strength KPSI		Yeild	MPSI		Brinell Hardness Hb	Brinell Hardness Hb @ 425°F
	As rolled	Heat treated	KPSI	Tension	Torsion		
1020	65	~100	48 / 80	29.5		143	~300
1050	105	145	60 / 100	30		229	375
1095	140	216	83 / 139	30		293	388

WHAT IS MANGANESE?

Description Manganese is a naturally occurring substance found in many types of rocks and soil. Pure manganese is a silver-colored metal; however, it does not occur in the environment as a pure metal. Rather, it occurs combined with other substances such as oxygen, sulfur, and chlorine. Manganese is a trace element and is necessary for good health.

PHYSICAL PROPERTIES & CHEMICAL PROPERTIES:

Manganese exists in four allotropic forms: α, β, γ, and δ. Data of the different phases are given in Table 1.

Manganese dissolves in acids with liberation of hydrogen and formation of Mn (II) salts. Hot concentrated sulfuric acid dissolves manganese with evolution of SO_2, and nitric acid with evolution of hydrogen, nitrogen, and dinitrogen monoxide. At normal temperatures, pure manganese is not attacked by oxygen, nitrogen, or hydrogen. At high temperatures it reacts violently with oxygen, sulfur, and phosphorus.

WHAT IS COPPER?

Copper is an excellent electrical conductor. Most of its uses are based on this property or the fact that it is also a good thermal conductor. However, many of its applications also rely on one or more of its other properties. For example, it wouldn't make very good water and gas pipes if it were highly reactive. On this page, we look at these other properties:

WHAT IS ALUMINIUM?

Light, durable and functional these are the qualities that make aluminum one of the engineering materials of our time. we can find aluminum in the home s we live in the automobiles we drive , the trains and aero planes that take us across long distance, in the mobile phone and computers we use on a daily basis, in the shelves inside our fridges and in modern interior designs, but a mere 200 years ago very little was known about this metal.

HISTORY OF ALUMINIUM:

Aluminium is a silvery-white metal, the 13 element in the periodic table. One surprising fact about aluminum is that it's the most widespread metal on Earth, making up more than 8% of the Earth's core mass. It's also the third most common chemical element on our planet after oxygen and silicon. At the same time, because it easily binds with other elements, pure aluminium does not occur in nature. This is the reason that people learned about it relatively recently.

HOW ALUMINIUM IS MADE?

PROPERTIES OF ALUMINIUM:

Aluminium offers a rare combination of valuable properties. It is one of the lightest metals in the world: it's almost three times lighter than iron but it's also very strong, extremely flexible and corrosion resistant because its surface is always covered in an extremely thin and yet very strong layer of oxide film. It doesn't magnetise, it's a great electricity conductor and forms alloys with practically all other metals.

Aluminium can be easily processed using pressure both when it's hot and when it's cold. It can be rolled, pulled and stamped. Aluminium doesn't catch fire, it doesn't need special paint and unlike plastics it's not toxic. It's also very pliable so sheets just 4 microns thick can be made from it, as well as extra thin wire.

Advantages and disadvantages of aluminium compared with other materials

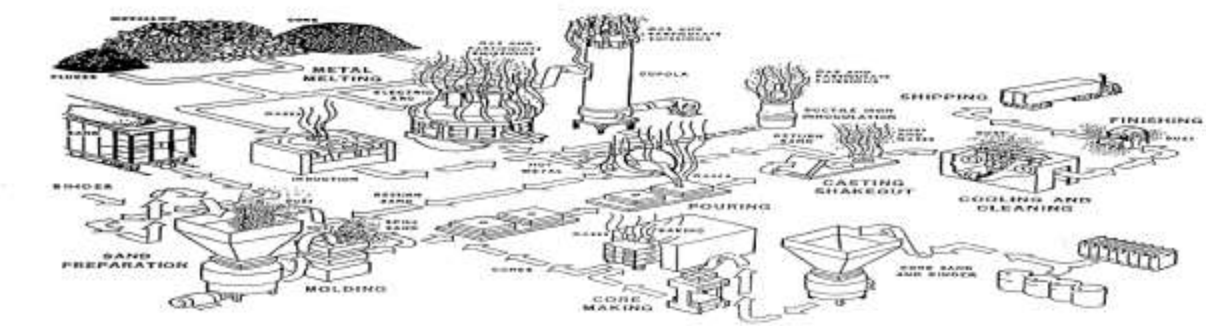
- The term **steel** is used to denote metallic alloys whose main constituent is iron and which (in contrast to cast iron) can be reworked and reformed.
- The term plastic is used to denote an organic, polymeric solid which is manufactured synthetically or semi-synthetically from monomeric organic molecules or biopolymers.
- The term **wood** is used in general parlance to denote the solid or hard tissue of the shoots (trunk, boughs and branches) of trees and shrubs. Wood is the world's most important raw material.

III.WHAT IS CASTING?

Casting is a manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a *casting*, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various *cold setting* materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods. Casting is a 6000-year-old process. The oldest surviving casting is a copper frog from 3200 BC.

CASTING PROCESS SIMULATION

Casting process simulation uses numerical methods to calculate cast component quality considering mold filling, solidification and cooling, and provides a quantitative prediction of casting mechanical properties, thermal stresses and distortion. Simulation accurately describes a cast component's quality up-front before production starts. The casting rigging can be designed with respect to the required component properties. This has benefits beyond a reduction in pre-production sampling, as the precise layout of the complete casting system also leads to energy, material, and tooling savings.The software supports the user in component design, the determination of melting practice and casting mothering through to pattern and mold making, heat treatment, and finishing. This saves costs along the entire casting manufacturing route.



Casting process simulation was initially developed at universities starting from the early '70s, mainly in Europe and in the U.S., and is regarded as the most important innovation in casting technology over the last 50 years. Since the late '80s, commercial programs (such as Autocast and MAGMA) are available which make it possible for foundries to gain new insight into what is happening inside the mold or die during the casting process.

- High quality**:** Parts created through die casting deliver a long service life.
- High reliability**:** Uniformity of mass-produced parts is exceptional.
- Quick production**:** Die cast tooling requires minimal maintenance.
- Versatile design**:** Die casting can createvirtually any size, part geometry, surface texture or luster.
- Minimal assembly**:** Assembly features such as studs, drill holes and bosses can be integrated into mold design.

Applications of Die Casting Processes

Die casting is a process that has far-reaching applications. Any part production process that creates high-volume metal components will likely benefit from die casting. A variety of manufacturing industries currently rely on one or many types of die casting processes, including the auto, aerospace and power tools industries.

Advantages

- Cost of castings is relatively low with high volumes.
- High degree of design complexity and accuracy.
- Excellent smooth surface finish.
- Suitable for relatively low melting point metals (1600F/871C) like lead, zinc, aluminum, magnesium and some copper alloys.
- High production rates.

Disadvantages

- Limits on the size of castings - most suitable for small castings up to about 75 lb.
- Equipment and die costs are high.

IV.WHAT IS MOLDING?

Molding or moulding (see spelling differences) is the process of manufacturing by shaping liquid or pliable raw material using a rigid frame called a mold or matrix.[1] This itself may have been made using a pattern or model of the final object.

A mold or mould is a hollowed-out block that is filled with a liquid or pliable material like plastic, glass, metal, or ceramicraw materials.[2] The liquid hardens or sets inside the mold, adopting its shape. A mold is the counterpart to a cast. The very common bi-valve molding process uses two molds, one for each half of the object. Piece-molding uses a number of different molds, each creating a section of a complicated object. This is generally only used for larger and more valuable objects.

Types of molding include:

- Blow molding
- Powder metallurgy plus sintering
- Compression molding
- Extrusion molding
- Injection molding
- Laminating

Sand Molding

The green sand process utilizes a mold made of compressed or compacted moist sand packed around a wood or metal pattern. A metal frame or flask is placed over the pattern to produce a cavity representing one half of the casting. The sand is compacted by either jolting or squeezing the mold.

High-Density Molding (High Squeeze Pressure / Impact) Large air cylinders, hydraulics, and innovative explosive methods have improved the sand compaction around the pattern, improving the standards of accuracy and finish which can be achieved with certain types of castings.

EXPERIMENTAL METHODS:

For this investigation, the casting parameters varied were the pouring temperature and the pouring rate. Specimens of sand-cast Aluminum alloy were produced with the aid of wooden pattern. The standard casting procedure, which comprises of pattern making, molding, melting, pouring and cleaning/fettling, was followed. After molding, scraps of Aluminum alloy were melted in an oil fired crucible furnace. Charging and melting was for 1 hour. Temperature measurement was done with thermocouple, and the alloy was always heated to a temperature of $10^{o}C$ above the specified pouring temperature. This allows for temperature drops encountered during reloading and temperature loss during the time required for pouring of the castings to be compensated for. The same sizes and shapes were cast to present uniformity in measurements.

Determination of pouring speed

Pouring speed of molten metal, V may be defined as the flow of the metal per unit time. In determine the pouring speed, the parameter, V, is expressed as the distance of the ladle above the pouring basin per unit time of pouring the metal. This is expressed as:

$$V = \frac{H}{T}\left(\frac{cm}{sec}\right)$$

where: V = pouring speed (cm/s); H = Height of ladle above pouring basin (cm); T = Time for pouring the molten metal (sec).

The sand mould for each specimen to be cast was placed on a mould board and the distance between the pouring basin and the ladle was measured as 80cm. The molten metal was then poured into the mould and the pouring time for each mould to be filled up was varied for eight specimens so as to obtain different pouring speeds for the castings. The pouring temperature was maintained at 700°C.

Test of the Cast Products :

Standard specimen dimensions were prepared out of the castings for the test of mechanical properties. The tests conducted are tensile and hardness tests. A tensile testing and Rockwell hardness testing machines were used for these tests.

V.RESULTS AND DISCUSSIONS:

The chemical composition of the Aluminum alloy casting is presented in Table 1.

Table1. Composition of the Aluminum Alloy Casting Element	Composition (%)	*Standard Composition (%)
Iron	0.5	0.5
Silicon	0.4	0.3
Copper	0.1	0.1
Nickel	0.1	0.1
Magnesium	4.2	3.0 - 6.0
Manganese	0.5	0.3 - 0.7
Zinc	-	0.1
Aluminum	Balance	Balance

The composition in Table 1 can be used to compare with the properties of a typical Aluminum - Magnesium - Manganese alloy in 'as cast' condition. Kempster [9] gave their composition of such an alloy to be in the following ranges: Magnesium - (3.0 - 6.0), and Manganese - (0.3 - 0.7).

The experimental results obtained for the mechanical properties of aluminum alloy casting have been computed and plotted in graphs. A series of results were obtained for the properties at different pouring speeds, with the pouring temperature kept constant at 700^{o}C. From the tensile testing, the ultimate tensile strength, percentage elongation and reduction in area were computed. The hardness values: both across and along the axis were also determined. The variations of these properties with pouring speed are presented in figure 1 to 3

Similar properties were investigated when the pouring speed was kept constant at 2.5cm/s, while the pouring temperature was varied in the temperature range of 680.0°C and 750.0°C. The behaviors of the properties in the specified range are presented in figures 4 to 6.

Castings Properties at Different Pouring Speeds

The Rockwell hardness number determined for the casting at different pouring speeds is presented. The hardness value across axis increases initially with pouring speed from 63.0. It latter attained its maximum value of 65.4 at the speed of 2.2 cm/s. Thereafter, it falls sharply to a value of 58.0 at the rate of 3.2 cm/s. It then rose to 62.0 from where it finally falls with any increase in pouring speed. For hardness along axis, the hardness value increases initially with pouring speed from 60.0 to maximum value of 63.1 at the speed of 3.2 cm/s, until it finally fall to a value of 50.0 at the pouring speed of 16.0 cm/s.

The ultimate tensile strength decreases initially with increasing pouring speed from 123.0 N/mm^2 to 112.0 N/mm^2. It reaches a maximum value of 127.5N/mm^2 at the pouring speed of about 2.8 cm/s. Subsequent increase in pouring speed reduces the tensile strength. The lowest value of 68.5 N/mm^2 was obtained at the pouring rate of 16 cm/s.

From these results, the maximum values obtained for the properties are consistent with the existing standards [9] when the pouring rate is in the range of 2.2 - 2.8cm/s. Thus, the hardness value of 65.4 compares well with 50.0 [10], as obtained in standards. Similarly, the maximum tensile strength and elongation are in close comparison with 140.0 N/mm^2 and 2.0 respectively as found in standards [9, 10]. Therefore, all the discussions on the variation trends would be taken to be valid.

Properties of Casting at Different Pouring Temperatures

The variation of Rockwell hardness with pouring temperature. Generally the hardness across the axis is shown to be always higher than that along axis. The hardness across the axis increases initially with pouring temperature to a maximum of 65.5 at temperature of 688°C.

The maximum hardness attained along the axis is 62.8 at the pouring temperature of 688°C. The behavior of the two hardness types follows waveforms, but generally decreases at higher pouring temperatures. For instance, at the pouring temperature of 760°C, the Rockwell hardness across the axis is 51.0, while that along the axis is 40.0. It has been observed [5] that pinholes in aluminum castings are caused by the absorbed hydrogen. This can be minimised by pouring the alloy at temperatures just necessary for casting. Therefore, once this optimum pouring temperature is identified, it should be properly applied.

The Ultimate tensile strength decreases with increasing pouring temperature (fig.5).The minimum value attained is 79.5N/mm^2 at the pouring temperature of 740^{0}C.

In figure 6, the percentage elongation is seen to increase with pouring temperature from 208% to a maximum value of 3.1%.

VI.CONCLUSION

From both the quality and mechanical property assessments, it was found that for Aluminum alloys the optimum pouring temperature range is between 700^{o}C and 750^{o}C. This is the region where good quality casts are produced with good mechanical properties. The pouring speed range, which gave the best surface finish, is between 2.0cm/s and 2.8cm/s. Optimum values of hardness, tensile strength and deformations were obtained at this temperature range.

Further studies on the metallurgical investigations on the castings produced at varied ranges of these parameters {temperature & speed} are currently in progress. This is to check the grain sizes, non- metallic inclusions and submicroscopic pinholes.

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