Effect of Pouring Temperature on Defect Formation and Tensile Strength in Brass Castings

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ABSTRACT
This investigation addresses the influence of varying pouring temperatures on the mechanical performance and quality of brass castings. Brass melt was poured in the same green sand molds at controlled temperatures of 950°C, 1000°C, 1050°C, and 1100°C. The tensile strength was obtained using a universal testing machine, and visual observation, radiography, and metallographic testing for defect examination. The results showed that while high temperatures promoted shrinking porosity, low temperatures caused cold closes and poor filling. Maximum tensile strength with least defects was achieved at an optimum pouring temperature of 1000°C, which indicates that the same temperature is suitable for consistent and defect-free brass castings.

Keywords:- Tensile strength, shrinkage porosity, pouring temperature, casting defects, sand mold, and brass casting.

1. Introduction

Casting is one of the simplest and most common methods of production, and it finds particular application in making intricate metal parts with high accuracy and material utilization. Due to its high resistance to corrosion, ease of machinability, attractive looks, and average mechanical strength, brass, an alloy of zinc and copper, is a common material used in industrial as well as ornamental applications [1]. Brass castings find extensive applications in electrical connectors, valves, bearings, plumbing fixtures, and decorative items. Nevertheless, process parameters, more so pouring temperature, play an important role in determining the quality of brass castings as they have direct influence on the metal flow, solidification characteristics, gas absorption, and, ultimately, the mechanical properties of the final product [2]. A successful or unsuccessful casting process mainly depends upon the pouring temperature. The molten metal is not able to fill the cavity of the mold completely, if the temperature is below a certain level, which can lead to surface defects like misruns or cold shuts [3]. Conversely, excessive temperatures may lead to oxidation, gas entrapment, and turbulence under pouring, resulting in internal porosity, shrinkage defects, and lower mechanical properties [4], [5]. In addition, the cooling rate, which controls the microstructure, such as dendritic arm spacing and grain size, is controlled by the pouring temperature. This, in turn, influences mechanical properties such as ductility and tensile strength [6].Despite limited research attempting a systematic correlation of pouring temperature with both mechanical strength and defect analysis in a controlled experiment, existing studies have highlighted the importance of process optimization of brass casting [7]. To achieve a balance of fluidity and defect prevention, foundry engineers need to understand such a relationship, especially when applying traditional molding technologies such as green sand molds. The effect of four controlled pouring temperatures of 950°C, 1000°C, 1050°C, and 1100°C on the formation of casting faults and the resultant tensile strength of brass parts is experimentally evaluated in this work. To find the optimum pouring temperature that minimizes defects while maximizing mechanical property, the study will utilize both non-destructive (visual examination, radiography) and destructive (tensile testing, metallography) testing techniques.In addition to providing valuable guidance to small- and medium-sized foundries producing brass castings, this study improves our understanding of how temperature considerations and solidification processes interact in non-ferrous alloy casting [8].

2. Materials & Method

The materials, composition of alloy, preparation of mold, process of casting, temperature regulation, and testing methods employed to analyze the effect of pouring temperature on tensile properties and defect generation in brass castings are discussed extensively under this section.

A. Material selection

Commercial yellow brass, which is a binary copper-zinc alloy with a great reputation for corrosion resistance, high strength, and ease of casting, was employed in the experiment[4]. The chemical composition of the brass, which was bought in ingot shape, was verified using Optical Emission Spectroscopy (OES). The average composition is indicated in Table I.

B. Mold Preparation :-

The molds were made with the use of the green sand molding method, which is the commonly applied process in small- and medium-scale foundries because it is affordable and reusable. Green sand composition was comprised of[5]:

- 88% silica sand (AFS 60 grain)
- 9% bentonite clay (as a binder)
- 3% water (to impart plasticity)

A split wood pattern adhering to ASTM B208 tensile test geometry was employed to form a cavity appropriate for machining tensile test specimens. Cope and drag boxes were prepared with molds, to which gating and riser systems were added to ensure directional solidification and minimize shrinkage defects[6].

C. Temperature Control Pouring:-

A silicon carbide crucible furnace with a maximum temperature rating of 1200°C was employed to melt the ingots of brass. A K-type thermocouple and digital display pyrometer (accuracy ±5°C) were employed to record the melt temperature.

Four pouring temperatures were chosen on the basis of preliminary testing and industry standards:

- Lower limit: 950°C; reduced fluidity expected
- Predicted ideal casting behavior at 1000°C
- High superheat and moderate risk of oxidation at 1050°C
- Overheated at 1100°C; likely increased porosity

To ensure statistical significance, three specimens were cast for each temperature. To maintain the temperature stable and reduce turbulence, the melt was maintained at the correct temperature for two minutes prior to being cast into the mold.

D. The Casting Process:-

The hand-poured, gravity-fed, molten brass was poured into the green sand molds. Attention was taken to ensure that:

- a smooth flow into the mold cavity that is not turbulent.
- Consistency was achieved through keeping the same operator and ambient conditions.
- The effect of temperature as the primary variable was isolated without the introduction of any other additives or degassing agents.

The castings were allowed to cool under ambient temperature using natural convection. Shake-out was performed after 20 minutes to ensure complete solidification.

E. Vision and Radiography Inspection:-

All the castings were inspected visually for surface defects after shakeout, such as:

- Cold shuts
- Misruns
- Surface porosity
- Mold erosion marks

X-ray radiography was employed to locate internal defects using a 200 kV portable industrial X-ray unit and a digital detector panel. ASTM E192 standards were adhered to in interpreting the images.

3. Experimental Details

A controlled experiment was devised to test the impact of pouring temperature on the formation of casting defects and mechanical properties in brass castings. The sole parameter which was varied systematically was the pouring temperature, and the rest of the experimental variables were carefully monitored and controlled. The materials, casting setup, temperature control, specimen preparation, and testing procedures are detailed in the following sections.Since yellow brass ingots are extensively employed in foundry and mechanical industries, they were procured from commercial sources. The ingots were subjected to Optical Emission Spectroscopy (OES) before melting for ensuring the uniformity of the alloy during the experiment by confirming the composition of elements. From Table 1, the primary constituents were copper (Cu) and zinc (Zn), with a trace composition of lead (Pb) and iron (Fe).

Table I: Chemical Composition of Brass Alloy Used

Element	Cu	Zn	Pb	Fe	Others
wt%	61.5	36.8	0.8	0.3	<0.2

Since green sand molding is appropriate for small-to medium-sized castings and is highly thermally stable, it was employed in making the molds [1]. The mold mixture consisted by weight of 3% water, 9% bentonite clay, and 88% silica sand. Cavities according to ASTM B208 tensile test geometry were created using a split pattern. In order to ensure stable metal flow and feeding, the gating and riser system was added manually into the cope and drag areas. A silicon carbide crucible furnace with the capability of reaching temperatures of up to 1200°C was utilized to melt brass. The viable foundry ranges and recommendations provided in previous work [1]–[3] were employed in selecting the pouring temperatures.In accordance with Table 2, a total of 12 castings were produced by varying the pouring temperature at four levels: 950°C, 1000°C, 1050°C, and 1100°C. Three duplicates were taken for each condition.

Table 2: Pouring Temperature and Number of Castings

Pouring Temperature (°C)	**950**	**1000**	**1050**	**1100**
No. of Specimens	61.5	36.8	0.8	0.3

Following superheating to a level of approximately 10°C above the desired pouring temperature and held at that temperature for two minutes, each melt was then gravity poured into the mold with a sprue. Manually pouring with standard ladling equipment and a K-type thermocouple on a digital pyrometer (±5°C accurate) were employed to monitor the process [3]. After solidification, the castings were shaken out and washed after having been left to cool to ambient temperature (27 to 30°C). Cold shuts, blowholes, and misruns were some of the surface defects that were observed upon a preliminary visual examination. Radiographic testing was then conducted using a 200 kV portable X-ray unit and the ASTM E192 standard was employed for the interpretation of the images [4]. As indicated in Table 3, observations were categorized into three groups: surface defects, internal porosity, and general severity.

Table 3: Summary of Defects at Different Pouring Temperatures

Temp (°C)	**Surface Defects**	**Internal Defects**	**Severity**
950	Misruns, cold shuts	High porosity, shrinkage	Severe
1000	Clean surface	Minimal porosity	Mild
1050	Minor blowholes	Moderate porosity	Moderate
1100	Swelling, surface pitting	Gas porosity, shrinkage	Severe

According to ASTM B208 standards, the cleaned castings were subsequently machined into tensile test specimens. Tensile testing was conducted under a constant crosshead speed of 2 mm/min using a 20 kN capacity Universal Testing Machine (UTM). Elongation at Break (%EL), Yield Strength (YS), and Ultimate Tensile Strength (UTS) were some of the parameters that were tested. The average mechanical properties of each condition are presented in Table 4.

Table 4: Mechanical Properties of Brass Castings

Pouring Temp	UTS (MPa)	YS (MPa)	% Elongation	Remarks
950	172	125	6.1	Cold Shuts, Weak Joints
1000	285	210	10.8	Optimal Casting, Fine structure
1050	240	185	8.2	Minor Porosity Observed
1100	198	145	6.5	Shrinkage, Gas Entrapment

Ferric chloride solution was employed for slicing, mounting, polishing, and etching specimens of each casting to relate mechanical findings to microstructure. We examined the grain shape and porosity under optical microscopy (100x and 500x magnification). At 950°C, coarse dendritic structures were seen, while fine equiaxed grains and minimal porosity were produced at 1000°C, which accounts for the improved tensile performance. Grain coarsening and micro-shrinkage were a result of retarded solidification and the trapping of gas at elevated temperatures (1050°C and 1100°C) [5]–[7].

Optimum pouring temperature for brass casting under conditions in investigation is 1000°C, based on the coordination of metallographic, mechanical, and radiographic information. Integrity and mechanical properties of casting are greatly compromised due to both underheating and overheating.

4. Result & Conclusion

The findings of the experiment indicate that the pouring temperature significantly influences mechanical performance and the quality of the yellow brass castings. Tensile strength, defect generation, and microstructure were measured in the research at four temperatures: 950°C, 1000°C, 1050°C, and 1100°C. Weak fluidity of the molten metal at 950°C caused excessive porosity, misruns, and cold closes. Among all specimens, it produced lowest elongation (6.1%) and tensile strength (172 MPa).

The quality of casting was significantly better at the optimal temperature of 1000°C. With very few minor defects, the metal filled the mold completely. The highest UTS (285 MPa), strength (210 MPa), and elongation (10.8%) were recorded in tensile tests. Fine, equiaxed grain structure with minimal porosity was confirmed by microstructural examination.Moderate internal porosity and considerable grain structure coarsening were found when the pouring temperature increased to 1050°C. Trapped gasses and over-oxidation resulted in slight reduction of UTS (240 MPa) and elongation (8.2%), although the strength was still very high. The castings possessed extensive porosity, shrinkage pores, and coarsening of grains at 1100°C, all of which indicated compromised casting quality. Tensile properties significantly reduced (UTS = 198 MPa, elongation = 6.5%).

Table 5: Summary of Casting Performance at Different Pouring Temperatures

Pouring Temp (°C)	Surface Defects	UTS (MPa)	% Elongation	Microstructure	Overall Quality
950	Cold shuts, misruns	172	6.1	Coarse dendrites, porous	Poor
1000	Smooth, defect-free	**285**	**10.8**	Fine, uniform grains	Excellent
1050	Minor blowholes	240	8.2	Slightly coarsened grains	Moderate
1100	Blowholes, shrinkage	198	6.5	Irregular grains, porosity	Poor

We can see that the correlation between pouring temperature and tensile strength is not direct. At exactly 1000°C, maximum mechanical performance was combined with minimum internal defects and the best microstructure.

This paper presents experimental evidence that the pouring temperature plays an important role in the tensile properties and defect formation of brass castings. Based on the experimental results, the following conclusions may be drawn:

- The optimal conditions of casting with excellent mold filling, low porosity, and high mechanical properties were established by pouring at 1000°C.
- As a result of the lack of fluidity, cold closes and misruns were caused by low temperatures (950°C), which took a severe toll on the castings.
- Grain coarsening, shrinkage, and gas porosity caused by high temperature (1050–1100°C) lowered the material's ductility and strength.
- After a certain limit, metallurgical instability makes higher temperature lead to lower mechanical returns.

5. REFERENCE

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