

PAPER • OPEN ACCESS

## Effect of Pouring Temperatures on Porosity and Mechanical Properties of Gravity Die Casting Magnesium Alloy

To cite this article: I P Nanda *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **602** 012093

View the [article online](#) for updates and enhancements.

A promotional banner for the 240th ECS Meeting. The banner features a colorful striped border at the top. On the left, the ECS logo is displayed in a green circle. To the right of the logo, the text reads: "240th ECS Meeting", "Digital Meeting, Oct 10-14, 2021", "We are going fully digital!", "Attendees register for free!", and "REGISTER NOW" in bold orange letters. On the right side of the banner, there is a photograph of a diverse group of people in a professional setting, with a man in a white shirt and tie clapping and smiling.

**ECS** **240th ECS Meeting**  
Digital Meeting, Oct 10-14, 2021  
**We are going fully digital!**  
Attendees register for free!  
**REGISTER NOW**

# Effect of Pouring Temperatures on Porosity and Mechanical Properties of Gravity Die Casting Magnesium Alloy

I P Nanda<sup>1</sup>, M H Jahare<sup>2</sup>, M H Idris<sup>2</sup>, S B Kumar<sup>2</sup>, M H Hassim<sup>2</sup>, and A Arafat<sup>3</sup>

<sup>1</sup>Department of Mechanical Engineering, Universitas Andalas, Padang, Indonesia

<sup>2</sup>School of Mechanical Engineering, Universiti Teknologi Malaysia, Johor, Malaysia

<sup>3</sup>Department of Mechanical Engineering, Universitas Negeri Padang, Padang, Indonesia.

E-mail: arafat@ft.unp.ac.id

**Abstract.** Gas entrapment and porosities are the two common drawbacks associated with gravity die process. In this study, the effect of gravity die different pouring temperatures at 680, 710, 740, and 780 on die casting material particularly AZ91D mechanical properties namely; tensile strength, yield strength, elongation percentage, and porosity percentage were investigated. The result showed that higher strength was obtained at lower pouring temperature. The highest porosity percentage was observed at the areas nearer to the riser, and lower porosity percentage was obtained nearer the ingate. The highest tensile strength, yield strength, percentage of elongation and less percentage of porosity was obtained for the specimens taken nearer to the ingate which is the starting point of melt entry into the cavity.

## 1. Introduction

Magnesium alloy has several advantages over other light alloys. Apart from having high corrosion resistance, it has a distinctive fluidity which favors castability compared to copper and aluminum [1]. In processing magnesium components, casting is regarded as the dominant manufacturing process which contributes approximately 98% of magnesium-based structural applications [2]. Gravity dies to cast is a derivation from sand casting with improved process capabilities to produce precise and consistent dimensional accuracy. Also known as permanent mold casting, it is designed to suit large-scale production ranging from 100 to 250000 castings depending on the complexity of the product. Nonetheless, porosity defect has always been associated with magnesium casting thus affecting the mechanical properties [3, 4]. Improvement of the issue includes proper gating system, pouring temperature, mold temperature and composition of the molten metal. Nevertheless, the effect of various pouring temperature on the casting mechanical properties is still ambiguous, and most of the recent works by previous researchers are limited to simulation method [5]. Therefore, this study investigates the effect of different gravity die casting pouring temperature on the porosity and mechanical properties of magnesium alloy.

## 2. Material and method

In this study, AZ91D magnesium alloy was selected as workpiece material. The chemical composition of AZ91D is shown in Table 1.

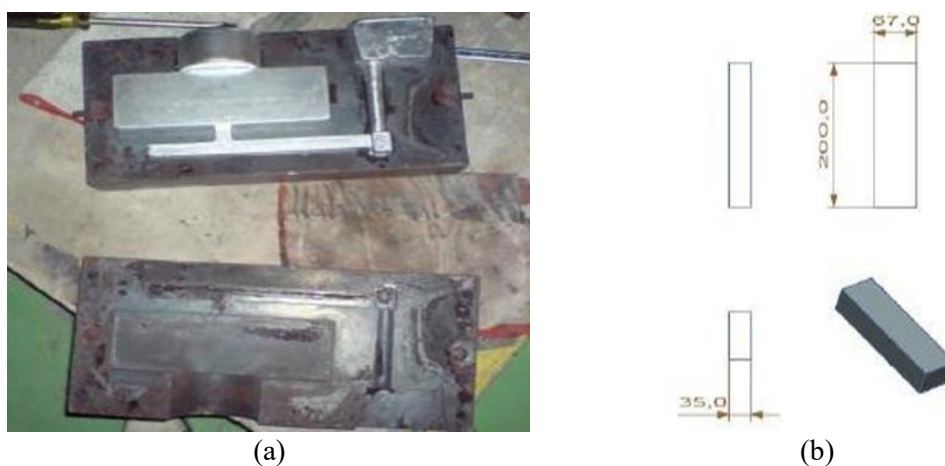


**Table 1.** The chemical composition of AZ91D magnesium alloy

Element	Mass (%)
Al	8.300 – 9.700
Zn	0.350 – 1.000
Mn	0.150 – 0.500
Si	0.100 max
Fe	0.005
Cu	0.03
Ni	0.002
others	0.02
Mg	Balance

### 2.1. Samples Preparation

Samples preparation include fabrication of mold with a bottom gating system which is more compatible with magnesium alloys [6]. Upon retrieval from the casting process, the as-cast magnesium sample dimension was 200mm x 67mm x 35mm as depicted in Figure 1.

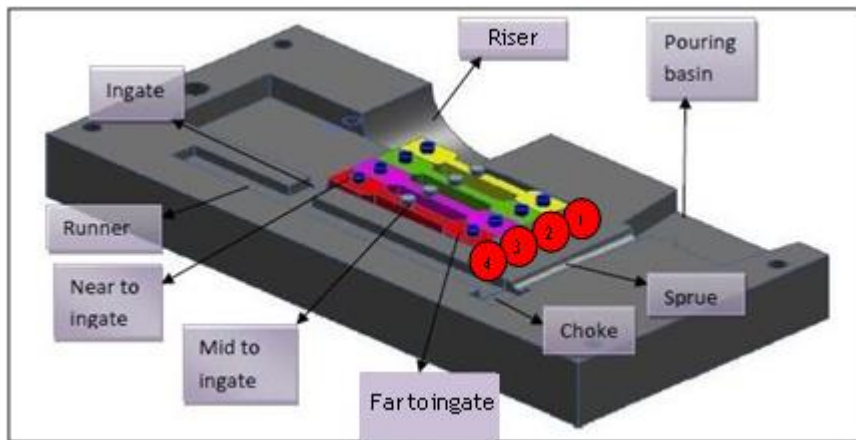


**Figure 1.** (a) Mold with bottom gating design (b) As cast sample dimension.

### 2.2. Experimental Run and Analysis

A total of four gravity castings were executed at four different pouring temperatures; 680°C, 710°C, 740°C, and 780°C. The mold was heated inside a firing furnace and was kept constant at a temperature of 650°C before the casting process. This is to ensure fluidity and to avoid misruns during filling of molten metal. Subsequently, a total of 16 tensile specimens at different points; Faraway to ingate (1) until Nearer to ingate (4) were machined from each samples respectively.

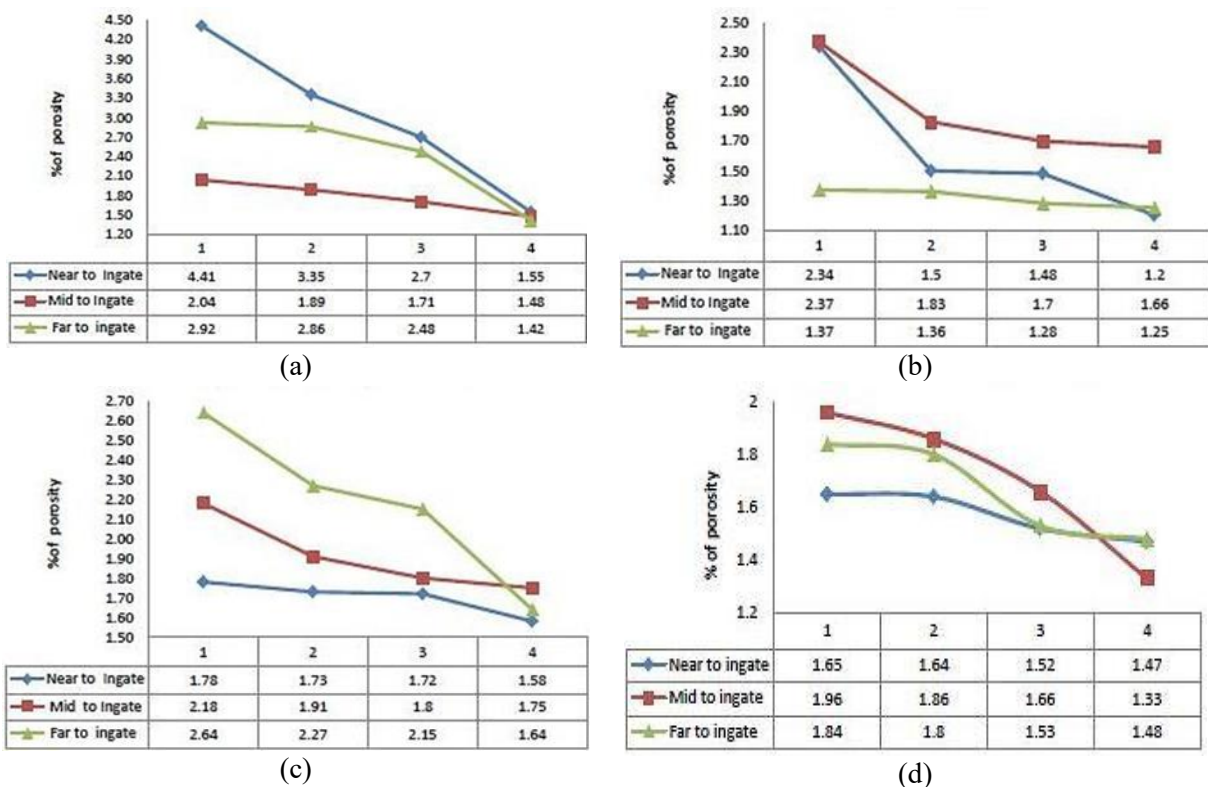
The tensile test was performed using Instron 5892 tensile test machine at a deformation rate of 2 mm/min. Yield strength and elongation percentage were then computed based on the result obtained. Specimens for porosity percentage calculation were also prepared accordingly. All specimens were ground using SiC grit paper ranging from 240 grit to 1200 grit before polishing. Microstructure analysis was performed using Nikon microscope (SN:15584) at a 50x magnification at three allocated spots namely; near to Wingate, mid to ingate and far to ingate on each tensile specimens concerning each pouring temperature making a total of 48 spots as shown in Figure 2 were analyzed. Afterward, porosity percentage was calculated by using image analyzer software Material plus 4.1 in accordance with ASTM B-276[7].



**Figure 2.** Allocated points and spots for porosity percentage measurement

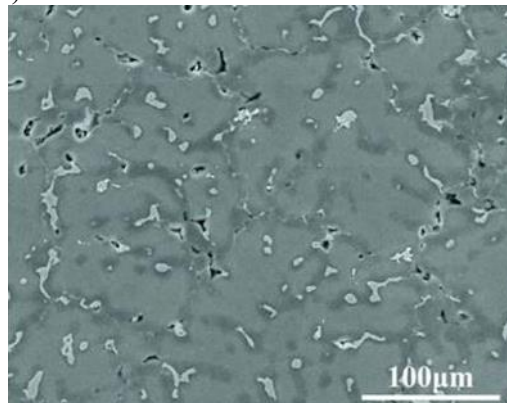
**3. Result and discussion**

The result of the porosity percentage calculation and mechanical properties assessment are shown in Figure 3 and Table 2 respectively. The result dictates that the fraction of porosity are fairly decreasing from higher pouring temperature towards lower pouring temperature. Meanwhile, the distribution of porosity percentage at the allocated horizontally and vertically spots are somewhat reduced from point 1 and far to ingate towards the coincide spot of point 4 and nearest to ingate. Likewise, the result also suggested that mechanical properties, yield strength, and elongation percentage are notably higher at lower pouring temperature whereby the tendency of increasing mechanical properties are noticeable at points nearer to ingate.



**Figure 3.** Porosity percentages along the three designated spots at different pouring temperatures (a)

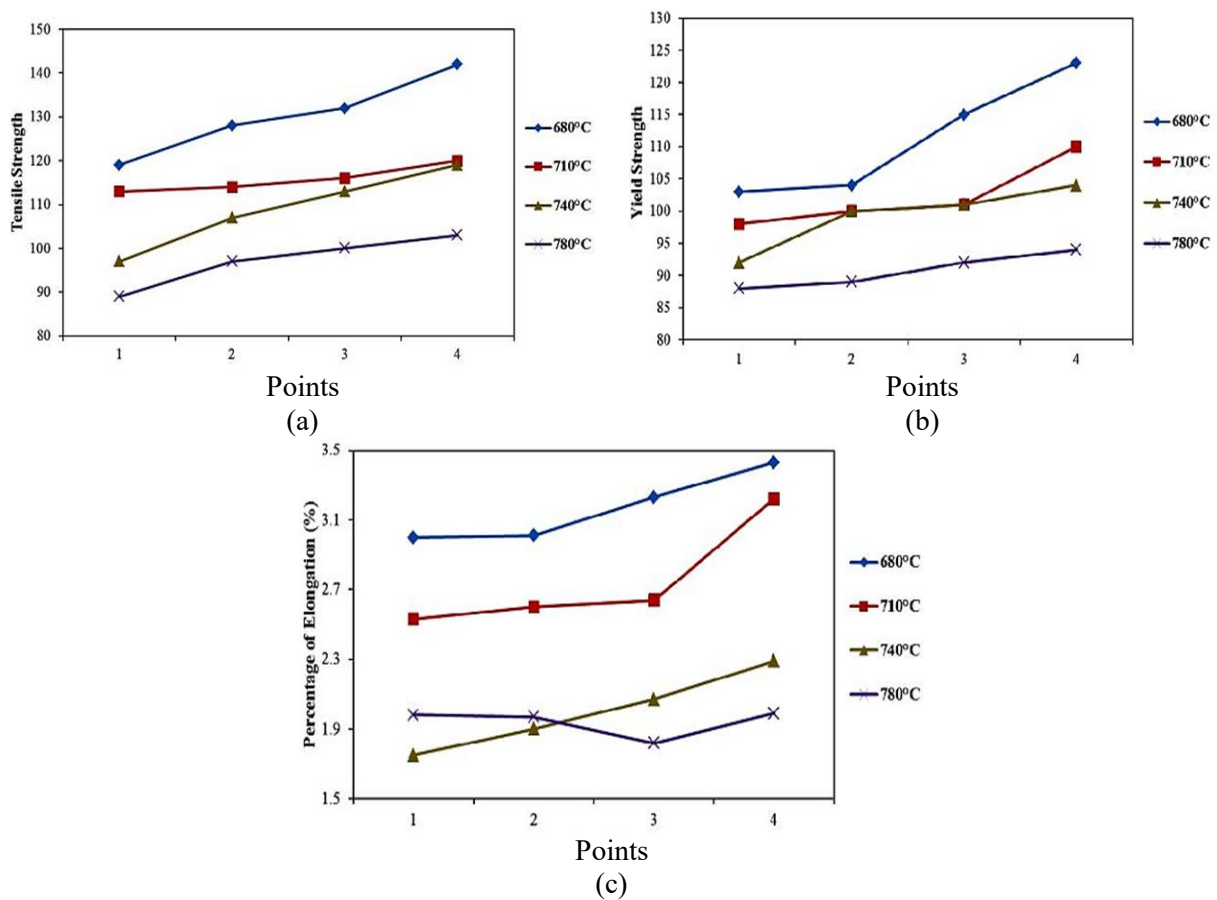
780°C (b) 740°C (c) 710°C (d) 680°C

**Figure 4.** Micro gas porosity in as cast AZ91-0.4Ca alloy [13]**Table 2.** Mechanical properties result at different pouring temperatures and locations

Pouring Temp.	780	740	710	680
Points	Tensile strength (MPa)			
1	89	97	113	119
2	97	107	114	128
3	100	113	116	132
4	103	119	120	142
	Yield strength (MPa)			
1	88	92	98	103
2	89	100	100	104
3	92	101	101	115
4	94	104	110	123
	Elongation Percentage (%)			
1	1.98	1.75	2.53	3
2	1.97	1.9	2.6	3.01
3	1.82	2.07	2.64	3.23
4	1.99	2.29	3.22	3.43

### 3.1. Effect of pouring temperature on porosity percentage

Porosity inclusion within die-cast magnesium alloy is inevitable although its die-castability is considered superior compared to aluminum alloys [8]. Based on the experimental result, lower pouring temperature contributes to the reduction of porosity fraction aside from other factors like casting thickness, material composition, and the type of manufacturing process. Ultimately, the main cause of porosity in magnesium alloy is due to high hydrogen solubility in its molten form compared to solidified form [9]. Whenever hydrogen content exceeds the solubility limit, microporosities or small gas pores nucleate grows around the grain boundaries [4, 5]. This condition explains the lowest porosity percentage recorded at the spot nearest to ingate which is also among the last point to solidify. Figure 3 shows the typical micro gas porosities in the as-cast AZ91-0.4Ca alloy. These porosities range from several to dozens of micrometers and are located inside the grains and around the grain boundaries. However, according to Li et al. [10], hydrogen can be expelled from the solid into the residual liquid due to the reduced hydrogen solubility in magnesium at decreasing temperature which further describes the lower porosity percentage found at 680°C pouring temperature.



**Figure 5.** Tensile strength, yield strength and elongation percentage at different points and pouring temperature

### 3.2. Effect of pouring temperature on mechanical properties

As described in Table 2, tensile strength, yield strength and elongation percentage are considerably increasing from point 1 (Faraway to ingate) to point 4 (Nearer to ingate) for all the casting temperatures. The variation in points location has produced a different result with point 4 being adjoined to melt entrance possess superior mechanical properties than point 1 being approximately at the end of melt flow. Such condition could be associated by the influence of wall section thickness on the cooling rate of cast specimens and microstructure [11, 12]. Consequently, the lowest tensile, yield strength and elongation percentage are being characterized at point 1. Such occurrence is depicted at all pouring temperatures as shown in Figure 5.

## 4. Conclusion

The mechanical properties and porosity fraction of magnesium alloy (AZ91D) gravity die castings were measured quantitatively. The effect of porosity on the mechanical properties was investigated. The following are the crucial findings.

1. The higher tensile strength, yield strength and percentage of elongation were obtained for the specimen with less porosity fraction for both alloys.
2. The less percentage of porosity was observed for the points selected nearer to the ingate while a higher percentage of porosity was observed for the points taken nearer to the riser.
3. The higher mechanical properties were obtained at 680°C casting temperature compared to other pouring temperatures.

**References**

- [1] Luo A A and Sadayappan K 2011 *Technology for Magnesium Castings* (Schaumburg: American Foundry Society) pp 29-47
- [2] Avedesian M M and Baker H 1999 *Magnesium and Magnesium Alloys*, (Materials Park: ASM International)
- [3] Liu X *et al.* 2015 *Ultrason. Sonochem* **26** 73-80
- [4] Zhang Y *et al.* 2015 *Mater. Des.* **67** 1-8
- [5] Bruna M *et al.* 2017 *Procedia Eng.* **177** 488-95
- [6] Campbell J 2004 *Casting Practice* (Oxford: Butterworth-Heinemann)
- [7] ASTM B276-05 *Standard Test Method for Apparent Porosity in Cemented Carbides* (West Conshohocken: ASTM International)
- [8] Luo A A 2013 *Journal of Magnesium and Alloys* **1** 2-22
- [9] Okamoto H 2001 *J. Phase Equilib.* **22** 598-9
- [10] Li X *et al.* 2016 *Mater. Sci. Eng. A* **672** 216-25
- [11] Lun S S *et al.* 2008 *Materials Characterization* **59** 178-87
- [12] Wei Y H *et al.* 2009 *J. of Mater. Pro. Technol.* **209** 3278-84
- [13] San-Martin A and Manchester F 1987 *J. Phase Equilib.* **Eight** 431-37