INVESTIGATION OF MECHANICAL PROPERTIES OF AZ91D MAGNESIUM ALLOY BY GRAVITY DIE CASTING PROCESS

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ABSTRACT

In this study, the die casting materials particularly AZ91D is selected to know the mechanical properties by gravity die casting process at 680,710,740 and 780°C pouring temperatures. The mould is designed especially for Magnesium alloys and its temperature is maintained at 650°C for all casting process. The tensile specimens were obtained from the as cast sample and the mechanical properties were measured. The percentage, % of porosity is measured at different spots with respect to the ingate. The results shown that the lower pouring temperature results higher strength for Magnesium alloy (AZ91D). Further the highest percentage, % of porosity is obtained in the areas nearer to raiser and lower percentage, % of porosity is obtained nearer to the ingate. The highest tensile strength, yield strength, percentage, % of elongation, hardness and less percentage, % of porosity is obtained for the specimens taken nearer to the ingate which is the starting point of melt entry in to cavity. The effect of the porosity towards the mechanical properties was analyzed and discussed.

Keywords : Magnesium *alloys, Gravity die casting, Mechanical properties, porosity fraction.*

1.0 INTRODUCTION

The die casting alloy AZ91D is widely used due to its excellent castability, corrosion resistance and high strength to weight ratio [1]. Therefore, the demand for complex magnesium and aluminum castings has been increased in the automotive and aerospace industries [2]. However, it is very difficult to produce these castings by gravity die casting. Because of serious oxidation at high temperatures, it results porosity, oxide inclusion defects during pouring of melt [1-4]. This result the lower mechanical properties.In general, the melt is injected at high velocity in to the die cavity leads to turbulent flow which causes entrapment of gas in die cavity, and consequently generates porosities, which is a very main reason for casting rejection [3]. The increase in melt velocity at ingate is also due to high pouring temperature. Although, many researchers have contributed their work on porosity in die casting [5], however the effect of pouring temperature and porosity towards the mechanical properties of gravity die casting is not known. The effect of cooling conditions on cast microstructure is discussed [6]. In this study, the mould especially for magnesium and aluminum alloy is fabricated. The porosity and the mechanical properties of the specimens from the as-cast sample are measured at different pouring temperatures for both alloys. The effect of porosity towards the mechanical properties is analyzed in this paper.

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2.0 EXPERIMENTAL PROCEDURE

The mechanical properties of magnesium alloy depend on various factors such as casting method, pouring temperature, and chemical composition. The effect of pouring temperature is mainly concentrated in this paper. The experiments were conducted at four different pouring temperatures especially 680, 710, 740 and 780°C at mould temperature 600 - 650°C. The samples were obtained by gravity die casting process. The mould with downsprue, raiser, ingate and 200mm long horizontal bar cavity designed with bottom filling gating system is shown in Figure 1.

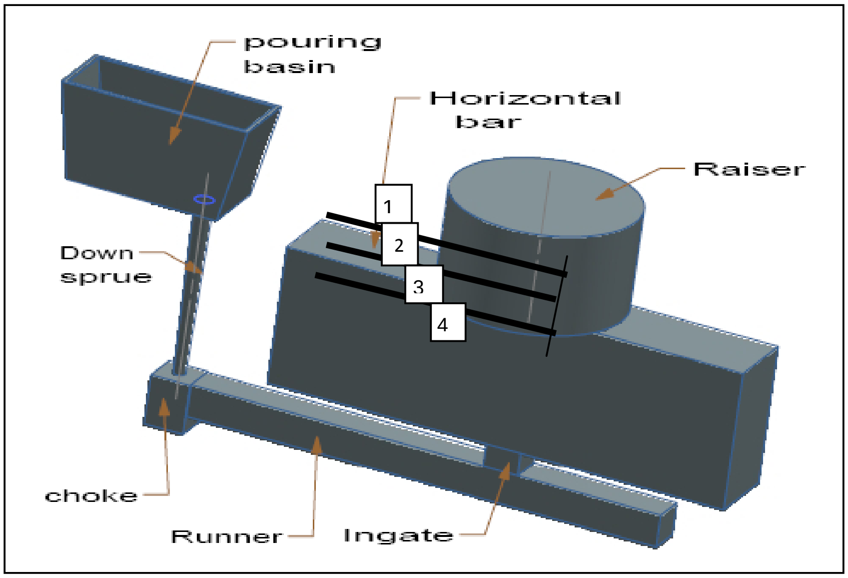

Figure 1 : Mould with downsprue, raiser, ingate and cavity bar with bottom filling gating system.

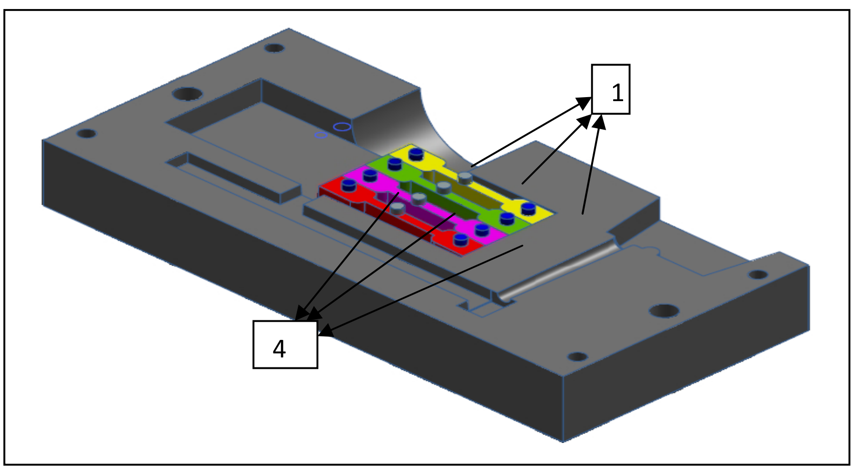

Figure 2 : Three sections namely near to ingate, mid to ingate and far to ingate

The 200 mm horizontal bar is cut into two pieces at the centre in vertical direction. The effect of position tensile specimens were machined from the obtained bar according to ASTM B557M-10 with 9 mm diameter and 45 mm gauge length. Four specimens were obtained starting from top to bottom of the bar. Uniaxial tensile test was performed for the above four specimens for each temperature.

As it was symmetrical, the samples were collected on opposite side to calculate area fraction (percentage, % of porosity) by dividing in to three sections with respect to ingate as starting point namely near to ingate, mid to ingate and far to ingate as shown in Figure 2. Four specimens were prepared for each section from top to bottom. The topmost specimen named as 1 and bottommost as 4. This is repeated for other two sections also. The microstructural area was grabbed with an optical microscope at 50x from the unetched cross-section. The area fraction was compared with the tensile strength and analyzed.

3.0 RESULTS AND DISCUSSION

The variations in the tensile properties and percentage, % of porosity with respect to different position in the gravity casting are described in this section to explain the variation in tensile strength at different pouring temperatures. Further the influence of porosity towards the mechanical properties of gravity die cast of AZ91 magnesium alloy is discussed and analyzed.

3.1 Mechanical properties at different casting temperature

Table 1, 2 and 3 show the ultimate tensile strength, yield strength and percentage, % of elongation values at four tested pouring temperature 680, 710, 740 and 780°C.

Table 1: Tensile strength at 680, 710, 740, 780°C pouring temperatures

Specimen Position No	680°C	710°C	740°C	780°C
1	119	113	97	89
2	128	114	107	97
3	132	116	113	100
4	142	120	119	103

Table 2 : Yield strength at 680, 710, 740, 780°C pouring temperatures

Specimen Position No	680°C	710°C	740°C	780°C
1	103	98	92	88
2	104	100	100	89
3	115	101	101	92
4	123	110	104	94

Table 3: Percentage, % of elongation at 680, 710, 740, 780°C pouring temperatures

Specimen Position No	680°C	710°C	740°C	780°C
1	3.00	2.53	1.75	1.98
2	3.01	2.60	1.90	1.97
3	3.23	2.64	2.07	1.82
4	3.43	3.22	2.29	1.99

Tensile strength and yield strength at 680°C is higher than the other casting temperatures. Tensile and yield strength increases gradually from specimen 1 to 4 as shown in Figure 3 and Figure 4.

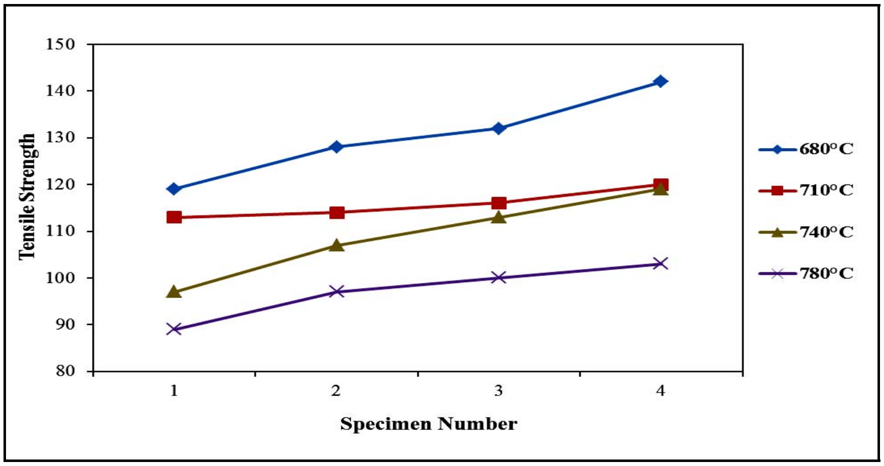

Figure 3: Tensile strength at 680, 710, 740 and 780°C

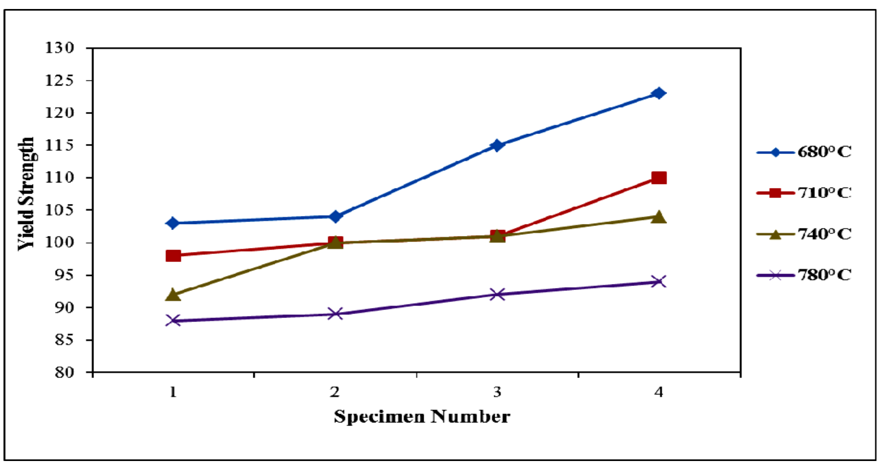

Figure 4: Yield strength at 680, 710, 740 and 780°C

The variations in tensile and yield strength are shown in Figure 3 and Figure 4. There is a significant difference in terms of strength with respect to position in the castings. The cooling rate of cast specimens and microstructure are influenced by wall section thickness [7]. It is seen that the tensile strength, yield strength is higher for specimen 4 taken near to the ingate at all casting temperatures. Similarly the specimen 1 obtained low strength at all casting temperatures. The specimen 4 is located near to the ingate which is the starting point of melt entry in to cavity. While specimen 1 is located near to raiser or faraway from ingate in which the melt filled lastly at this portion. It is also observed that the strength decreases with increase of pouring temperature.

The tensile strength, yield strength decreases from 680 to 780°C pouring temperature. The yield strength values are nearer for 710 and 740°C. The lower tensile, yield strength is obtained for all the positions in the castings at 740 and 780°C. Therefore the higher tensile strength is obtained for specimen 4 taken nearer to ingate at 680°C about 142 MPa. Likewise the higher yield strength is obtained for specimen 4 taken nearer to ingate at 680°C about 124 MPa. Lowest tensile, yield strength is obtained for specimen 1 taken nearer to raiser or faraway from ingate, this phenomenon is observed for all the pouring temperatures as shown in Figure 3 and 4.

The present study concludes that the strength is higher for the samples taken nearer to ingate compared to other positions. The strength of samples decreases gradually taken from ingate until the end portion that is nearer to raiser. The overall tensile strength values are in good agreement [8].

The percentage, % of elongation for each casting samples at different pouring temperatures is shown in Table 3. It also follows the same trend that of tensile, yield strength as shown in Figure 5.

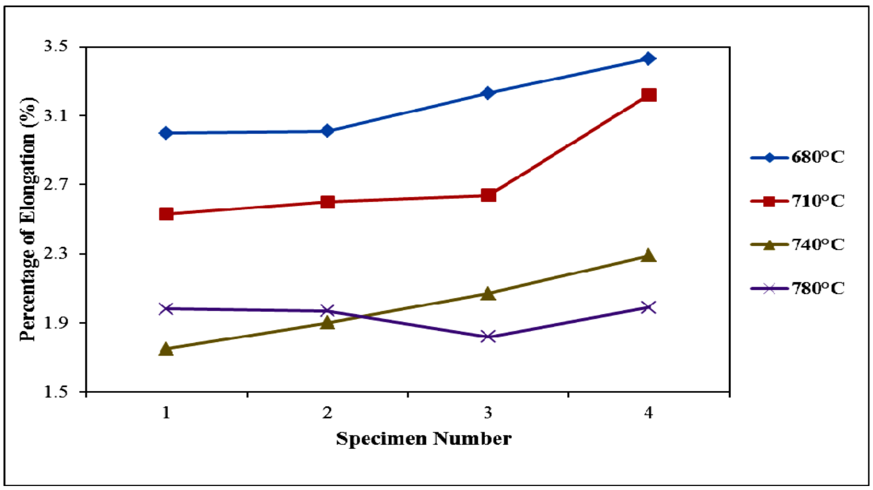

Figure 5: Percentage, % of elongation at 680, 710, 740 and 780°C

The percentage, % of elongation increases for samples taken nearer to the raiser until the samples taken nearer to ingate. It is clear that the higher percentage, % of elongation is obtained for specimens 4 at all pouring temperature, which is taken nearer to ingate. Similarly the lowest percentage, % of elongation is obtained for specimen 1 at all casting temperature. The highest percentage, % of elongation is obtained for all position samples at 680°C casting temperature compared to other casting temperatures. The lowest percentage, % of elongation is obtained for all position samples at 780°C casting temperature. However there is a very nearer percentage, % of elongation for 740 and 780°C casting temperature. Finally the highest percentage, % of elongation is obtained for specimen 4 taken nearer to ingate at 680°C about 3.43%. This value is very close to previous research work [8-9].

3.2 Effect of porosity on mechanical properties

The change in mechanical properties at different casting positions is affected by porosity. The porosity fraction is calculated by dividing the bar into three sections in vertical direction with respect to ingate. The porosity fraction on three sections at 680, 710, 740 and 780°C casting temperature is shown in Table 4, 5, 6 and Table 7.

Table 4: Porosity fraction at 680°C

Spot	Near to ingate	Mid to ingate	Far to ingate
1	1.65	1.96	1.84
2	1.64	1.86	1.80
3	1.52	1.66	1.53
4	1.47	1.33	1.48

Table 5: Porosity fraction at 710°C

Spot	Near to ingate	Mid to ingate	Far to ingate
1	1.78	2.18	2.64
2	1.73	1.91	2.27
3	1.72	1.80	2.15
4	1.58	1.75	1.64

Table 6: Porosity fraction at 740°C

Spot	Near to ingate	Mid to ingate	Far to ingate
1	2.34	2.37	1.37
2	1.50	1.83	1.36
3	1.48	1.70	1.28
4	1.20	1.66	1.25

Table 7: Porosity fraction at 780°C

Spot	Near to ingate	Mid to ingate	Far to ingate
1	4.41	2.04	2.92
2	3.35	1.89	2.86
3	2.70	1.71	2.48
4	1.55	1.48	1.42

Table 4 shows that the porosity fraction is less compared to other casting temperatures. The highest porosity fraction is distributed in the mid and far regions with respect to ingate. The spot 1 which is nearer to raiser or faraway from ingate in all the sections consists of higher fraction porosity at 680°C casting temperature. Further the lowest porosity is distributed in spot 4 which is nearer to ingate the melt entry in to cavity. This peculiar behavior is observed for all the casting temperatures. The trend for porosity fraction measurements at 680°C casting temperature is shown in Figure 6 and Figure 7.

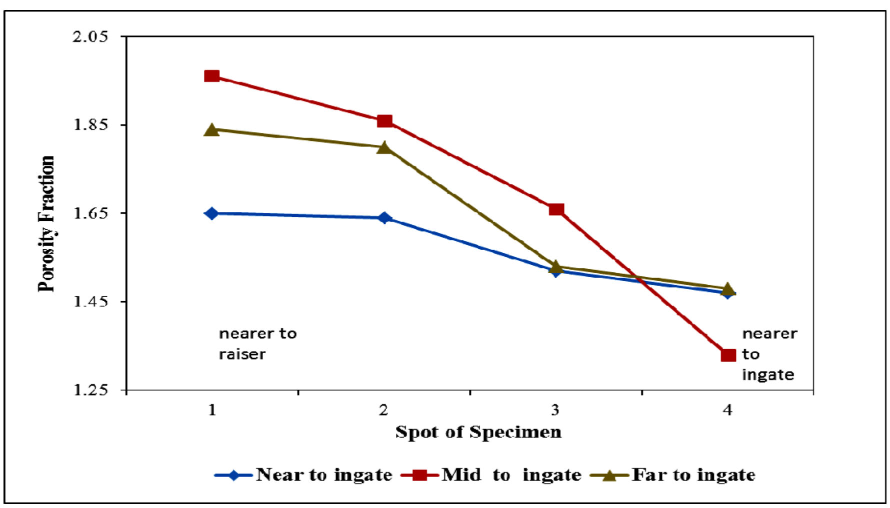

Figure 6: Porosity fraction at 680°C

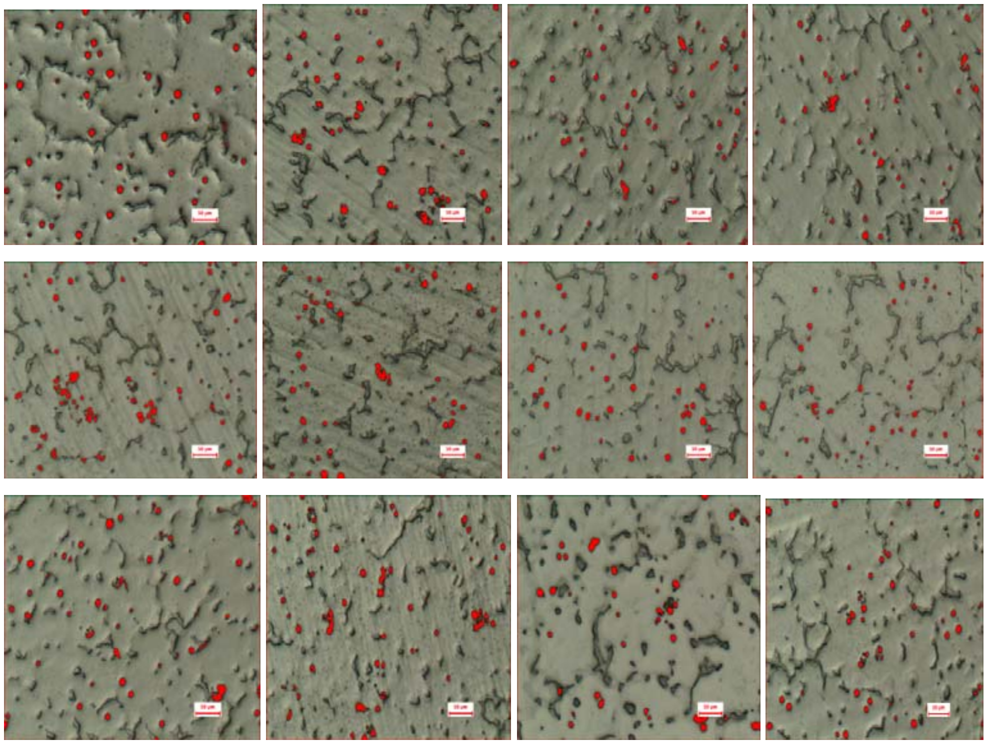

Figure 7: Porosity fraction measurements at 680°C

It is clear that sample 4 has least porosity which is taken nearer to ingate as shown in Figure 6 leads to high strength. As already discussed the tensile, yield strength, percentage, % of elongation is higher for sample 4 taken nearer to ingate at 680°C.

Table 7 shows that the higher porosity fraction is distributed in the near and far sections with respect to ingate. Therefore it is clear that the porosity distribution changes from one section to another with increase of casting temperature. The alloy porosity grows with casting temperature from 630 to 740°C [3]. However the highest porosity fraction is observed in the spot 1 which is nearer to raiser and lowest at spot 4 which is nearer to ingate for all sections at 780°C casting temperature is shown in Figure 8.

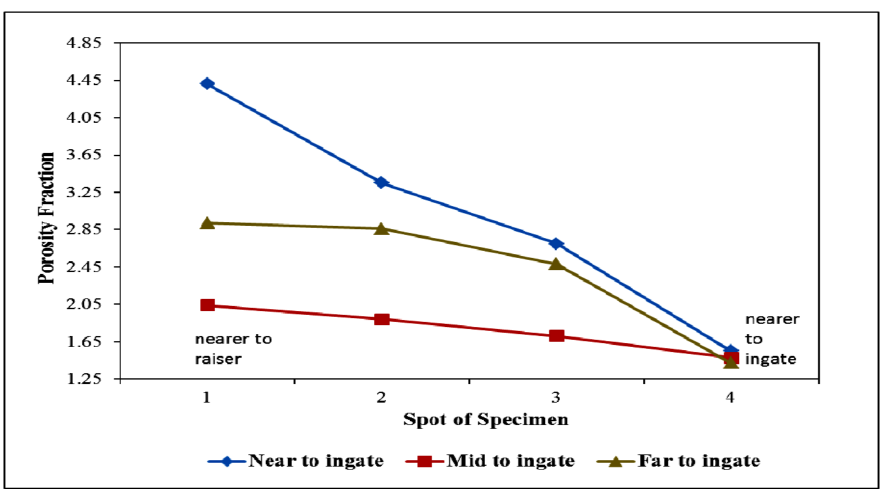

Figure 8: Porosity fraction at 780°C

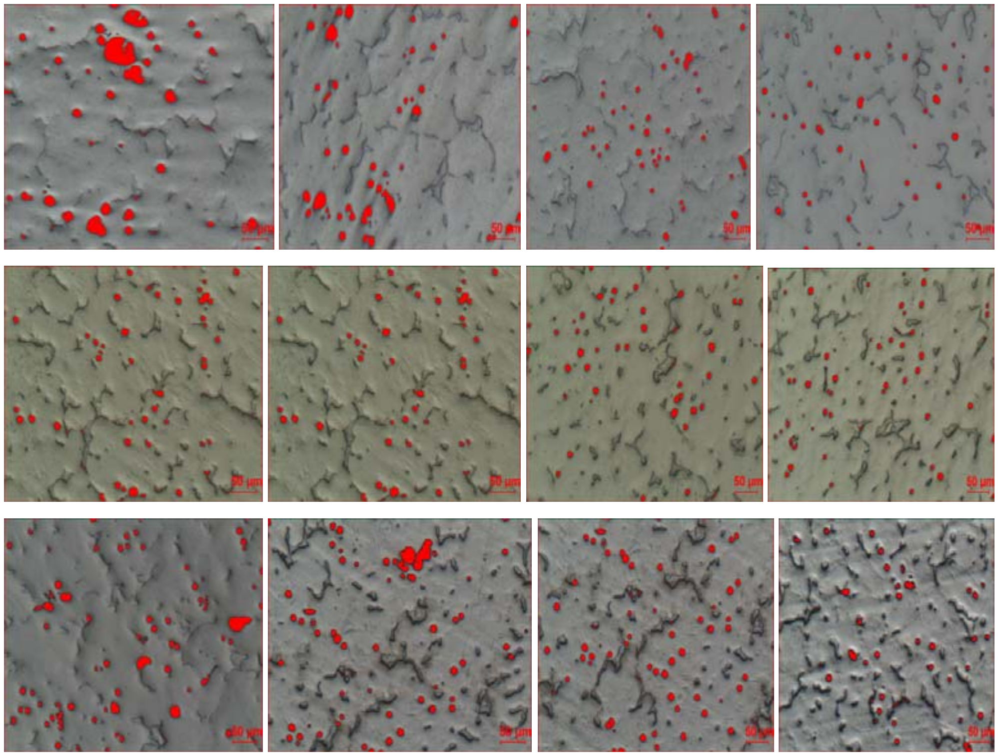

Figure 9: Porosity fraction measurements at 780°C

From the Figure 8 it is clear that the distribution of porosity is further the pore size is bigger compared to the Figure 7. Therefore the higher porosity can decrease the available load area and introduce the stress concentration results crack initiation and crack propagation leads to poor tensile, yield strength and percentage, % of elongation. This is the vital reason for lower strength at 780°C casting temperature. The previous research work found that the internal discontinuities lead to decrease of mechanical properties even at low level of porosity [10]. It is obvious from the Figure 7 that the higher porosity fraction is available in spot 1 specimen which is nearer to raiser and lower porosity fraction in spot 4 specimens which is taken nearer to ingate. Higher porosity fraction is obtained at 780°C casting temperature about 4.41%.

As higher strength is obtained at 680°C casting temperature further the lowest porosity fraction is distributed at 680°C about 1.33%. Therefore the porosity fraction must be maintained below 1.33% to attain higher strength.

4.0 CONCLUSION

In this study, mechanical properties of AZ91D magnesium alloy and effect of porosity towards the mechanical properties at four different casting temperatures were investigated and compared. The following are the crucial findings:

i. The higher porosity fraction is observed in the regions nearer to raiser at all casting temperatures, such that lower tensile, yield strength and percentage, % of elongation is obtained for the specimens selected at these regions.

ii. The lower porosity fraction is observed in the regions nearer to ingate at all casting temperatures, tensile, yield strength and percentage, % of elongation for the specimens selected at these regions.

iii. The higher mechanical properties are obtained at casting temperature 680°C.

iv. It is important to reduce the porosity fraction below 1.33% for magnesium alloy to obtain higher tensile strength, yield strength about 142MPa, 123MPa and 3.43% of elongation.

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