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The effect of high pressure die casting parameter on the porosity and mechanical properties of Aluminum SiliconADC12 alloy

[1]Muhammed K. A., M. Waly[2] and M. Samy El-Gayyar[3]

[1]*MSc, Student, Faculty of Engineering, Mansoura University Egypt.*
[2]*Foundry Technology Laboratories, Manufacturing Technology Department, Central Metallurgical R&D institute, Cairo, Egypt.*
[3]*Production Engineering and Mechanical Design Department University of Mansoura, Egypt.*

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ABSTRACT

The mechanical properties of aluminum alloy are affected by porosity which is caused by a combination of dissolved gases and shrinkage. The objective of this research is to study the effects of multiplied pressure in die casting pressure on the porosity formation and mechanical properties of Aluminum alloy ADC 12, Aluminum castings were produced by cold- chamber die casting machine HPDC (Toshiba 250J) has been favored for its unique ability to transform the injected molten aluminum into an accurately dimensioned form in the shortest possible cycle time. Although high pressure die casting is a very precision process; there are lots of factors which are effective on the product quality and mechanical properties. The microstructures of as-cast samples were examined by using optical microscopy, and scanning electron microscopy (SEM), whereas The soundness of the casting was examined by x-ray radiography process, the mechanical properties were investigated by tensile test which performed on samples of casting .The results showed that the effect of various input parameter (holding furnace temperature (ºC), plunger velocity of 2nd stage (m/s) and multiplied pressure (kg /cm^2), on the mechanical properties and porosity formation of casting. The optimum process parameters values predicted for casting of minimum shrinkage porosity could by summarized as follows: holding furnace temperature 650∘C, plunger velocity of 2nd stage 1m/s, multiplied pressure 280 kg /cm^2, the model proposed in this paper gives satisfactory results for the optimization of pressure die casting process.

Key words: Aluminum alloy ADC12; High-pressure die casting; cold- chamber; porosity; parameter of HPDC

Introduction

Development of aluminum alloys will open new applications for structural components in transportation, aerospace, electronics industries, and military applications with considerable cost savings. Aluminum considered being second lightest material next to magnesium and there for used widely in aircraft application. The main reason for introducing aluminum into vehicle components, structural modules and full vehicle structures is to achieve a significant weight reduction compared to a conventional design. High pressure die casting (HPDC) is a manufacturing process in which molten metal is injected with a die casting machine under force using considerable pressure into a steel mold or die to form products. High pressure die casting (HPDC) is considered as high productivity process for the production of complex, thin walled near net shape castings, with part weights ranging from a few grams to more than 15kg (Laukli, 2004). Cast aluminum components are mainly used in chassis and suspension applications, wheels, steering parts, cylinder heads, brake drums, connecting rods, etc. (Lus, 2011; Senthiil *et al.,* 2014).

Porosity in aluminum castings affects mechanical properties, fatigue life and fracture toughness. An increase in the porosity in a casting decreases ultimate tensile strength and elongation. The presence of porosity in a casting also decreases the time required for fatigue crack initiation resulting in reduced fatigue strength and fracture toughness (Sorina *et al.,* 2009; Tsoukalas, 2008).

This current work is aimed at conducting a study on the effect of various parameters such as,

Corresponding Author: Muhammed K. A.,, Ph.D. MSc, Student, Faculty of Engineering, Mansoura University Egypt. E-mail: khaledemtarres@gmail.com

multiplied pressure on the mechanical properties and porosity formation of ADC 12 die cast alloy

Experimental Work

Materials:

The material of this interest investigation was consists of commercial aluminum-silicon based alloy, (die cast alloy as per Japanese standard JIS5032 ADC 12). It is similar to LM2 as per BS 1490, Aluminum Association 384.0, ISO AlSi10Cu2Fe, and AC 46100 as per EN 1706. Showed chemical composition in Table (1).

Table 1: Standard chemical composition of ADC12 (AlSi10Cu2Fe)(www.amexresources).

Element	Si	Fe	Mn	Cu	Zn	Sn	Al
Wt.%	9.6-12	0.9 max	0.5 max	1.5-3.5	1.0 max	0.3 max	Remainder

Commercial this alloy was provided by the supplier "Aluminum Company of Egypt, the delivered alloy ADC12, was analyzed with the help optical emission spectrometer process and the result is show in Table (2).

Table 2: Chemical composition of delivered ADC12 alloy (www.amexresources)

Element	Si	Fe	Cu	Mn	Zn	Sn	Al
Wt.%	9.8	0.9	3.453	0.358	0.312	0.0625	Remainder

Experimental procedure:

The nominal composition of ADC12 aluminum alloy used in this work is given in Table (2). The experiments were performed on cold chamber die casting machine. The used high pressure die casting machine consists of control box panel, fixed plate, hydraulic cylinder, moving plate, back plate, automatic ladle, accumulator, holding furnace, injection cylinder, injection rod, ejection system, oil tank, regulating valve and pressure regulating valve, The injection pressure can be varied through the pressure regulating valve. Control is provided on this machine for die opening time, closing time and the injector time for the ejection of cat product. The machine can be operated in manual as well as in automatic mode. Die casting was conducted without the vacuum assistance for comparison. The effect of process parameters was studied after the machining of die to form the required shape. Different parameters such as (holding furnace temperature (ºC), plunger velocity of 2nd stage (m/s) and different level of multiplied pressure (kg /cm^2)), The methodology involves identification of controllable of parameters and the establishment of a series of experiments to find out the optimum combination of the parameters, investigation all possible conditions in an experiment involving multiple factors while the fractional design investigates only a fraction of all the combinations showed in Table (3). Determination of the tensile properties of the cast parts, and porosity measurements by optical microscopy and scanning electron microscopy (SEM) JSM 6510LV, are carried out. The mechanical testing and SEM were conducted at foundry laboratories of Central Metallurgical Research and Development Institute (CMRDI), Halwan, Egypt.

Three process parameters have been selected as potentially important in affecting the mechanical properties and on the porosity formation in ADC 12 die cast alloy. The selected process parameters and their values at different levels are given in Table (3).

Table 3: Process parameters with their ranges and values at three levels

Parameter Destination	Process Parameter	Parameter Range	Level 1	Level 2	Level 3
A	Holding furnace temperature (ºC)	650	650	650	650
B	Multiplied Pressure (kg /cm^2)	226 – 648	280	390	490
C	Plunger Velocity of 2nd stage (m/s)	3-5	1	3	5

Design of Experiments:

The distribution of variables with each other as shown in the Table (4), are designed to study all possible conditions in minimum number of experiments, allowing the simultaneous effect of several process parameters to be studied efficiently. The purpose of conducting an experiment is to determine the optimum level for each factor and to find the optimal process conditions of high pressure die casting resulted with the minimum porosity percent and high ductility with high strength level.

Table 4: Experimental layout of the distribution of variables

Run	A (°C)	B (kg/cm^2)	C (m/s)
1	650	280	1
2	650	280	3
3	650	280	5
4	650	390	1
5	650	390	3
6	650	390	5

Manufacturing of the Specimens

The melting process was carried out in the holding furnace and hold at temperature of approximately 650 degrees Celsius. The machine was operated at standard operating conditions except the injection pressure which was varied at (280, 390 and490 kg/cm^2) as planned in experimental design. The pouring temperature of the molten metal was (650°C), plunger velocity of 2nd stage was (1, 3 and 5 m/s). Ware used for conducting the experiments. All the trial conditions are listed in Table (4). High pressure die casting steps are conducted as follows:

1-Holding furnace is started 8 hours before begging the casting process for melting and keeping preheating the molting metal .
2- After that 30 min holding for homogenization, subject the melt for degassing and fluxing using N2 gas for 3 min and the granular flux covered the top surface of the melt during degassing.
3- Hold the melt in the furnace for about 20 min for homogenization before taking sample for controlling the chemical composition.
4- At the same time (1-3), die is heated up to (150 – 200) °C.
5-Dosing volume parameters are set according to the size of casting part.
6-Casting parameters of the HPDC machine are adjusted.
7- Closes the die of the HPDC machine.
8-Molten metaling is dosed in to the shot sleeve automatically.
9- Molten metaling is injected into the die from the shot sleeve.
11-Injected liquid is let to solidify for 6 to 10 seconds with applied intensification pressure.
12-Die is opened and part is ejected as shown in Fig (1).

Examinations and test equipment used

Microstructural Analysis

The specimens are examined by optical and scanning electron microscopy to determine microstructure, porosity content. The microstructure of a high pressure die casting part contains significant amount of porosity. Formation of porosity is one of the major problems faced in HPDC process.

Figure (2) shows the effect of holding furnace temperature (injection temperature) (650ºC) with different multiplied Pressure (280,390,490(kg /Cm^2)) and different plunger velocity of 2nd stage (1, 3, 5 (m/s)) on the porosity formation (soundness of casting).

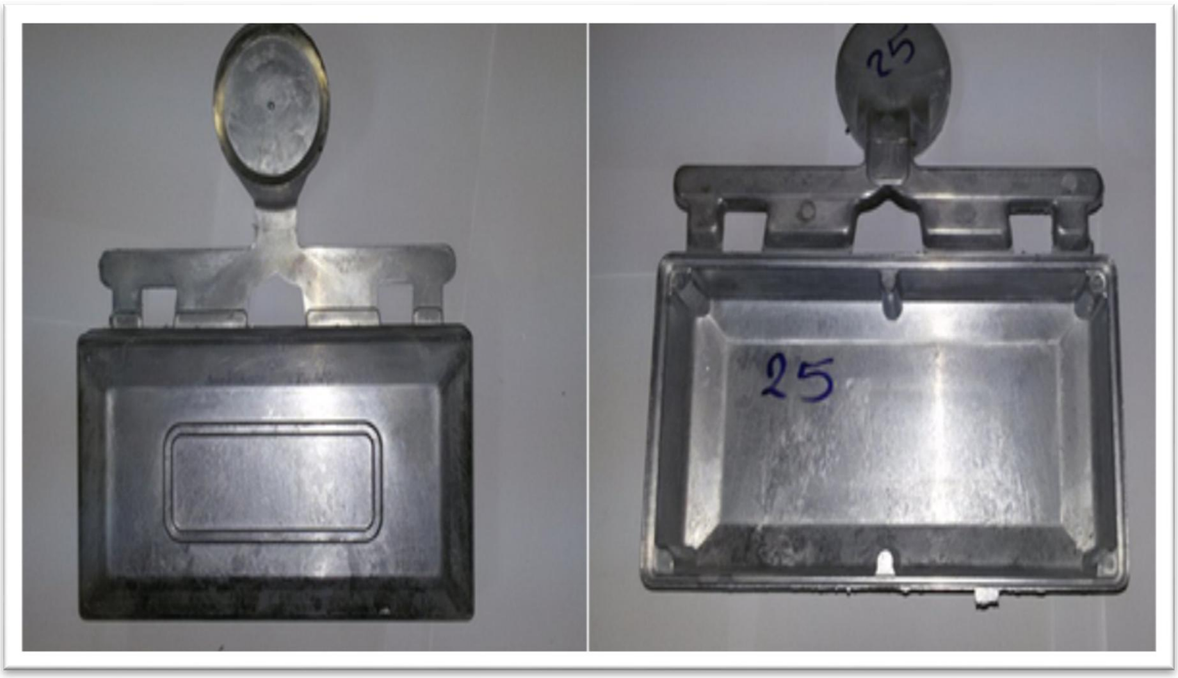

Fig. 1: Final sample of material of ADC12 after casting

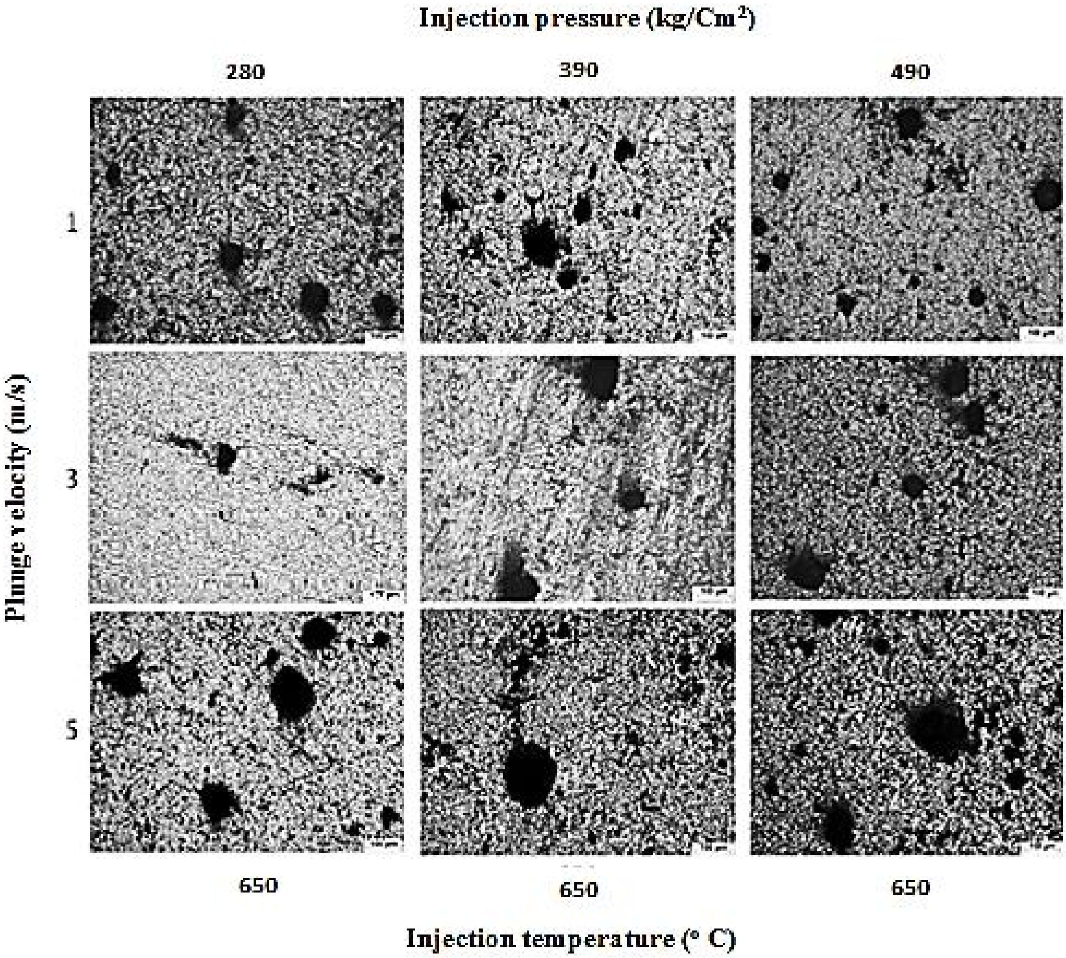

Fig. 2 Effect of holding furnace temperatures (injection temperature) (650ºC) with different multiplied pressure (280,390,490(kg /cm2)) and different plunger velocity of 2nd stage (1, 3, 5 (m/s)) on the porosity formation.

X-ray Radio graphs

Figure: 3 showed X-ray radiographs of the test pieces used for Nondestructive inspection these photos indicated that fewer porosity formations in tensile specimens resulted the best value for mechanical properties and less worthless as seen in Figure (3), sample (1,5and 9) X-ray radio graphs was mead to determine the quantity of gas porosity and their distribution all over the tensile testing specimen.

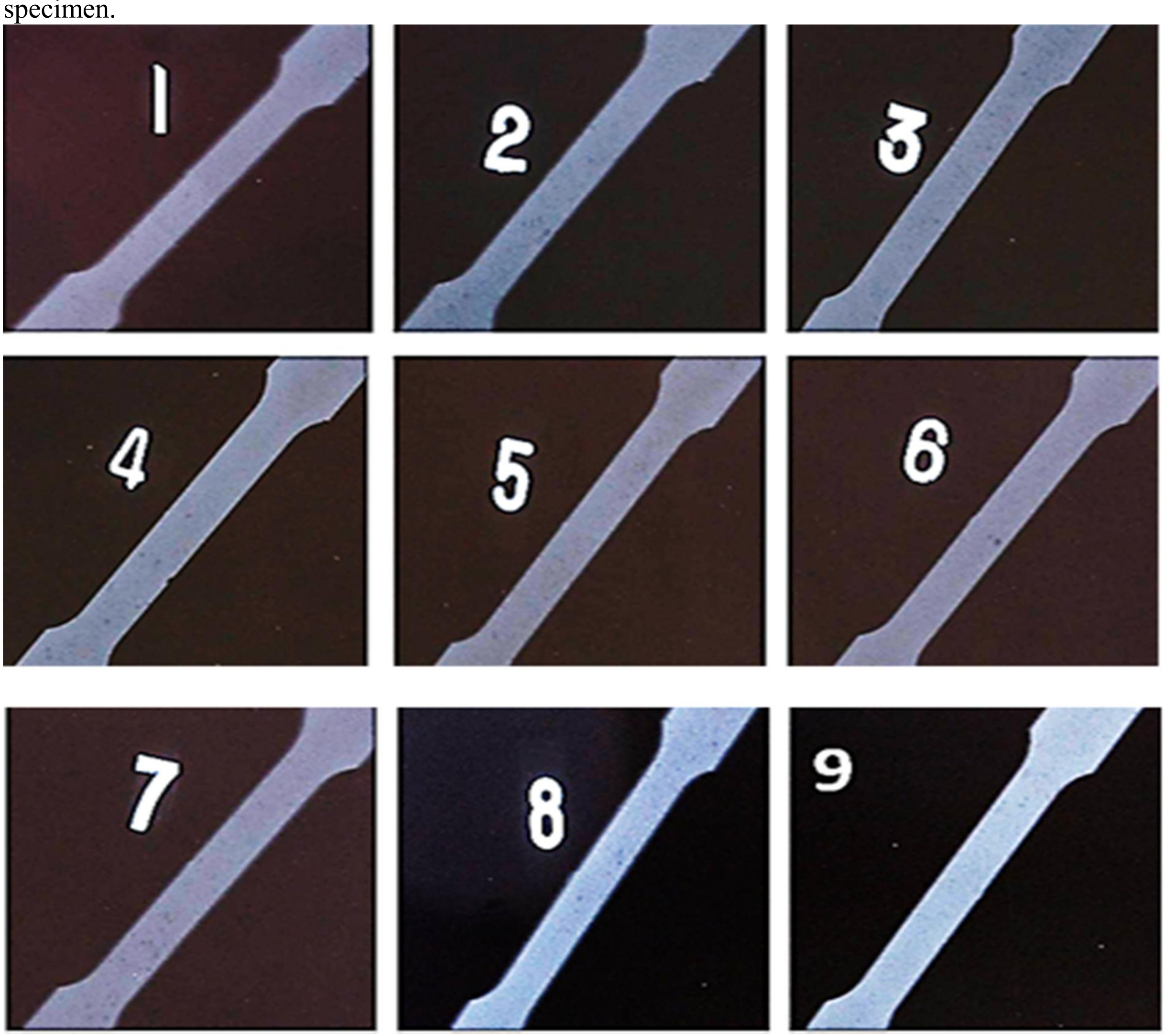

Fig: 3. Photo of porosity formation and their distribution in tensile

It is obvious from the microstructure fig (2) and x-ray photos fig (3) that amount of porosity is variable according to the condition of casting. The porosity level of the specimen numbers (1, 5and 9) are containing less porosity than the others. Sample (No.1) is produced with injection pressure (280kg /cm2) and plunger velocity of 2nd stage (1m/s) at poring temperature (650ºC).where (No.5) is cast with injection pressure (390kg /cm2) and plunger velocity of 2nd stage (3m/s) at poring temperature (650ºC).Also sample (No.9) is with injection pressure (490kg /cm^2) and plunger velocity of 2nd stage (5m/s) at poring temperature (650ºC).

Mechanical properties

Tensile test:

Tensile tests are conducted to the sample parts machined from HPDC cast part. The geometry of the specimens is compatible with standard test methods for tension testing wrought and cast aluminum alloy products, specimens are machined directly from the manufactured parts on wire-cut machine. Tensile test results can be summarized as in table (5)

Table 5: Mechanical properties of casted parts

Sample	A (ºC)	B (Kg/cm^2)	C (m/s)	UTS(MPs)	Elongation (%)
1	650	280	1	205	2.5
2	650	280	3	227.08	3.375
3	650	280	5	226.65	3.03
4	650	390	1	216.58	2.125
5	650	390	3	210.73	1.375
6	650	390	5	220.055	2.415
7	650	490	1	197.865	2.29
8	650	490	3	219.415	2.085
9	650	490	5	212.835	2.29

Based on these results, correlations between mechanical properties and various input parameter could be illustrated as shown in Figs (4, 5).

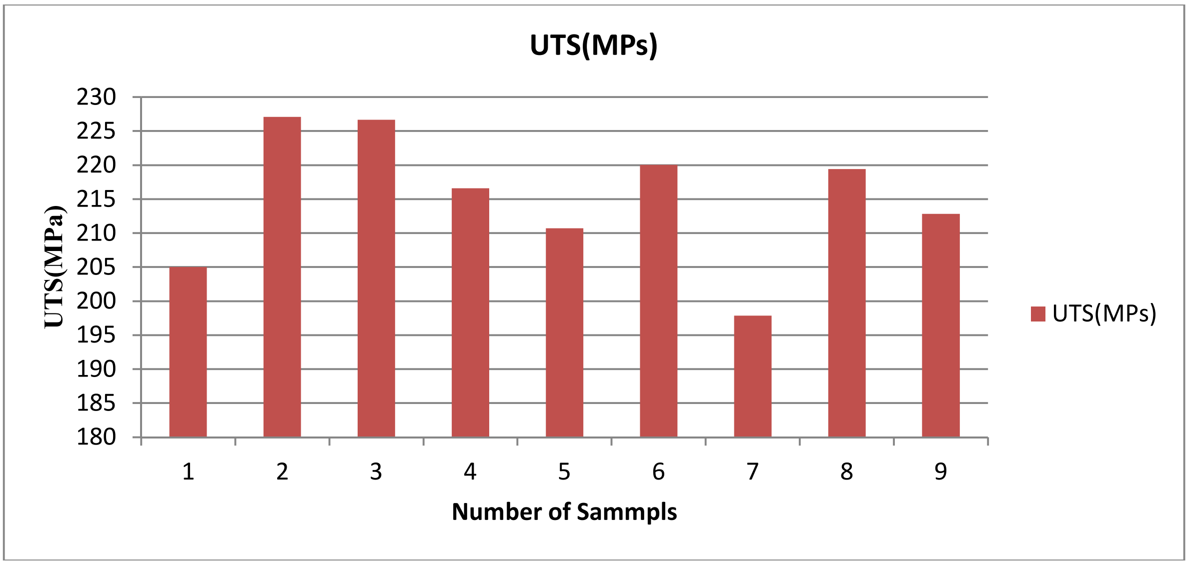

Fig. 4: Effect of various input parameter on UTS.

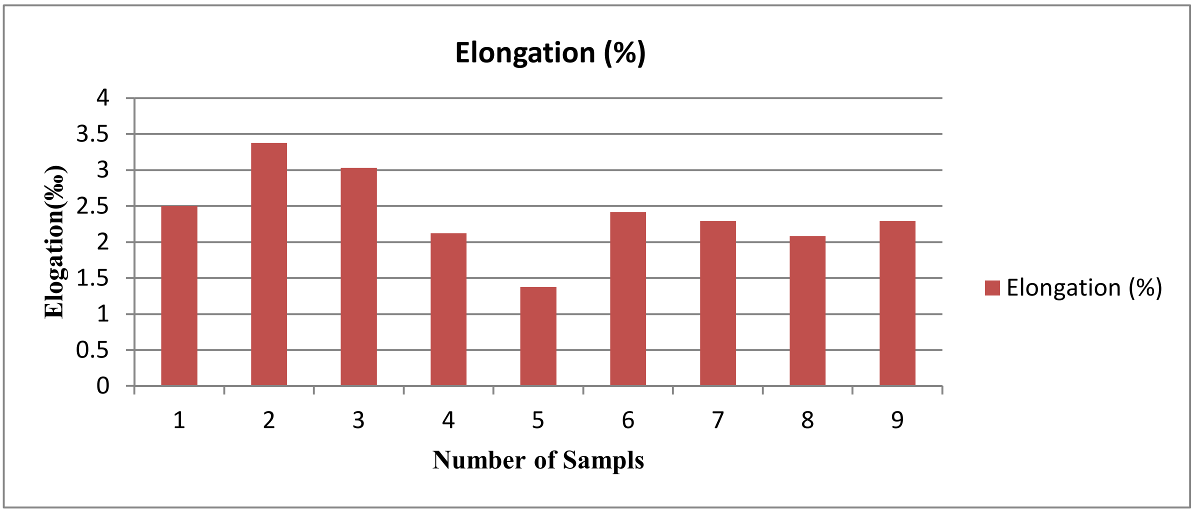

Fig. 5: Effect of various input parameter on elongation.

Effect of Multiplied Pressure

The mechanical properties of investigated ADC12 alloy are presented in Figures: (6) showing the effect of die casting parameter on the tensile strength and elongation of ADC12 alloy at the different multiplied pressure. Tensile test results could be summarized as in Table (6).

Table 6: Tensile test results at the different multiplied pressure under (650 (ºC) and 3 (m/s))

A (ºC)	B (kg/Cm^2)	C (m/s)	σ(MPs)	Elongation (%)
650	280	3	227.08	3.375
650	390	3	210.73	1.375
650	490	3	219.415	2.085

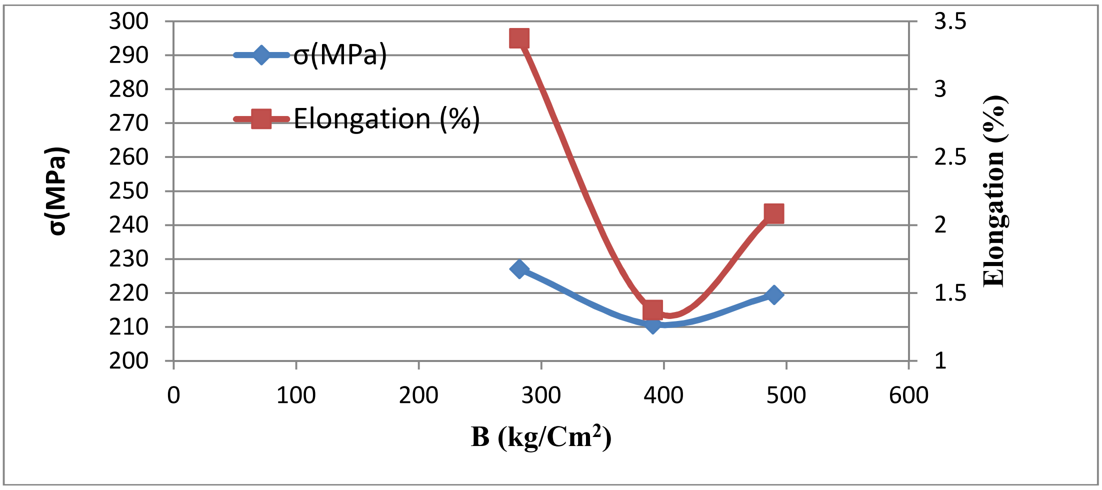

Fig. 6: Tensile test results at the different Multiplied Pressure Under (650 (ºC) and 3 (m/s))

The results showed that the UTS increased with increasing multiplied pressure and at the same time negligible effect of intensification pressure on proof strength and ductility is observed.

Conclusion

The effect of various input parameter (holding furnace temperature (ºC), plunger velocity of 2nd stage (m/s) and multiplied pressure (kg /cm^2)), on the mechanical properties and porosity formation of HPDC ADC12 aluminum alloy were investigated in this study. The optimum process parameters values resulted for this investing to set casting of minimum shrinkage porosity and the best combination parameters could by summarized as follows:

1. Holding furnace temperature 650◦C,
2. Plunger velocity of 2nd stage 1m/s,
3. Multiplied pressure 280 kg /cm^2,

Also some other condition produced good casting free of porosity with higher ejection pressure (390 kg /cm^2) with plunger velocity of 2nd stage (1 and 5 m/s) respectively.

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