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Study the Effect of Ingate Area on Mechanical Properties of as Cast (AL-0.4%Cu) Using ANN

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Abstract

In the present work the effect of Ingate Area on the Mechanical properties (σ_{max}, σ_{yield}, E and hardness, stiffness) of as cast Al-4%Cu alloy had been studied, molds were made by sand casting with different ingate area (1cm×1cm, 1.2cm×1.2cm, 1.4cm×1.4cm, 1.6cm×1.6cm, 1.8cm×1.8cm, 2cm×2cm, 2.2cm×2.2cm, 2.4cm×2.4cm and 2.6cm×2.6cm). The process was done in normal condition (T=25C^{o}, dry sand, constant speed, constant pour distance), while the casts prepared for the testing as a work piece to get the results. Also, Artificial Neural Network (ANN) had been adopted to predict the values of outputs (mechanical properties) and getting the mathematical equations that describe the relations between input and outputs parameters. From the results of the proposed work it conclude that mechanical properties magnitudes had been increased due to increasing in ingate area cast, and the relations between the ingate area and mechanical properties) had been detected depending on the results that gotten from ANN.

Keywords: As cast Al-0.4%Cu, Ingate Area, Mechanical properties, ANN.

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1. Introduction

The ingate system is the location at which molten metal inters the cavity, it often seen as a small nub or project known as the gate mark [1], so it is important to control the entered molten metal to the mold with different factors in shape or area effect such as pouring cup, sprue, runner and ingate area. This is illustrated in Figure 1.

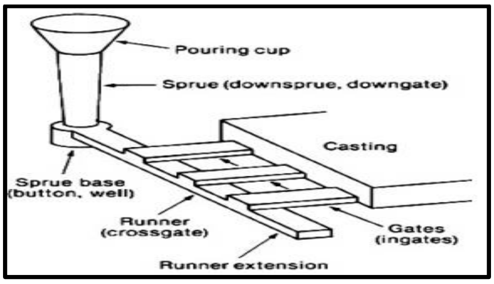

Figure 1: shows the ingates location in sand casting [2]

Previous work shows the area effect in the quantity of metal pass through the operation that has been shown by Masoumi A. [3] who studied the effect of ingate system design was investigate including the geometry and size on flow pattern, molten metal of A413 alloy poured into sand mold, finally the geometry and size of the ingate and ingate system ratio influence greatly on the pattern of mold filling. Also, Shafiee, Binhashim and Bin-Said [4] studied the effect of the design gate on mechanical strength on their section casting and runner design that effected on (Al-Si-Mg) alloy, result agreed conclusion that mechanical properties are real abled and porosity defects decreased, due to the use of shaped runner radius band of casting product. While C. Labrecque, M. Gagné [5] studied the effect of area on hardness for a thin wall ductile iron casting, they found that the production of thin wall gray and ductile iron were possible without deformation of iron carbide due to casting design that couldn't be otherwise disable with process.

2. Experimental work

Present work will be divided into two stages; the first stage will include the experimental work that related to melting, casting (with constant mold cavity for all casts) and machining to prepare the specimen of tensile test, so as to detect the mechanical properties of the proposed alloy. While the second stage include the adoption of ANN to predict the effect of ingate area on mechanical properties, and to find the mathematical description of output variables (mechanical properties) related with input variables (ingate area).

2.1 First stage

This stage contains preparation of tensile test specimen which includes:

a) Mold preparation: mold cavity was made cylindrically with 10cm length and 1.5cm diameter, and ingates designed with different area (1cm×1cm, 1.2cm×1.2cm, 1.4cm×1.4cm, 1.6cm×1.6cm, 1.8cm×1.8cm, 2cm×2cm, 2.2cm×2.2cm, 2.4cm×2.4cm and 2.6cm×2.6cm), all this was done in one sand mold to get constant factors (Temp. 25c, dry sand, constant pouring speed and time, equal distance) to study just the ingate area effect, this was done in Casting Factory in University of Technology.

b) Casting: melting Al with 0.4%Cu in pour and mixture used to homogenize the molten metal in about 700c in gas furnaces thin pore it

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in the cavity mold enters from the different ingate areas.

c) Machining: after the molten alloy solidified the molds removed and the casts are cleaned from rust sand and machined by turning with 150Rpm to get the standard (ASTM) tensile specimen, this was done in turning Factory in University of Technology.

d) Test: test was done in University of Technology Dept. of materials engineering in strength materials lab as shown in Figure 2.

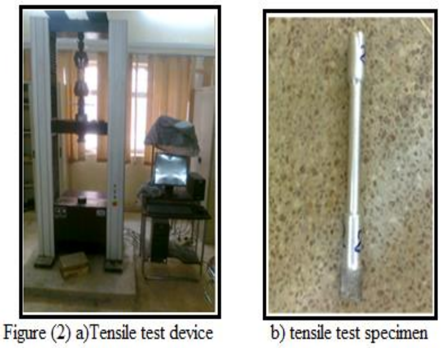


Figure 2: a) Tensile test device
b) Tensile test specimen

e)Tensile test: The test was performed on all specimens with speed of 2mm/s, test also shows the fracture point of the specimen and average stress-strain curves was taken as shown in Figures 3, 4 and 5.

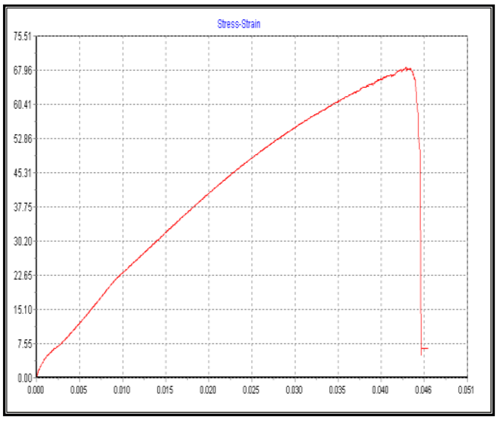


Figure 3: Average of Specimens for ingate areas (1×1cm, 1.2×1.2cm, 1.4×1.4cm)

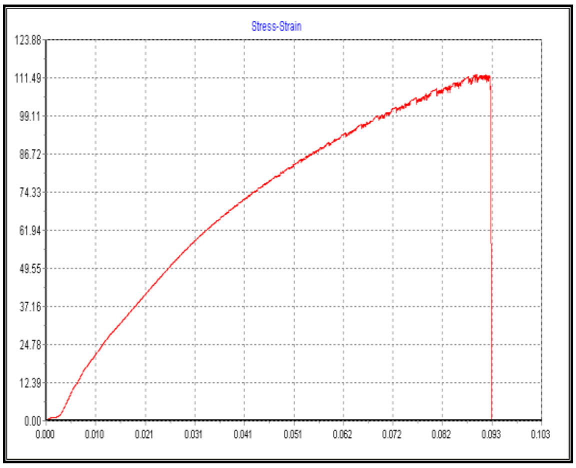


Figure 4: Average of Specimens for ingate areas (1.6×1.6cm, 1.8×1.8cm, 2×2cm) `

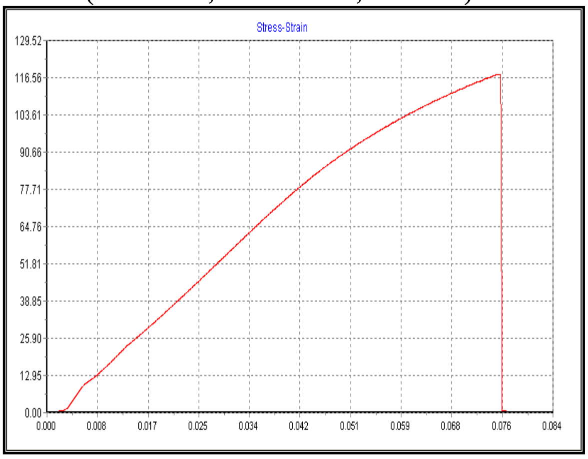


Figure 5: Average of Specimens for ingate areas (2.2×2.2cm, 2.4×2.4cm, 2.6×2.6cm)

f) Hardness test: Brenill hardness test was performed on all specimens and the ball weight was 5kg with force of 9.8 KN as shown in Figure 6.

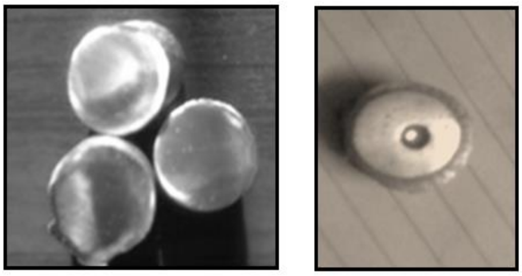


Figure 6: a) Before the Dent b) after dent

g) Calculating Stiffness value by Numerical Integration to determine the Area under a Curve: this means that X-axis (y=0) will bound with y-axis by a curve as shown in Figure 7, the area can be in positive part if the curve above X-axis and negative if it below the X-axis.

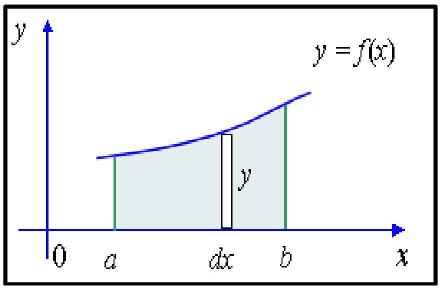


Figure 7: shows how to calculate the area under X-axis – Y-axis Curve [6]

Simply the calculation method of stiffness approximate the x-axis area taken as a rectangular shape with equal high- two point data as shown in Figure 7. Numerical integration used to calculate the divided rectangular areas as shown in Equation 1 and Equation 2 [6].

$$\text{area A} = \sum_{i=1}^{n-1} y_i(x_{i+1} - x_i) \qquad 1$$

Using the average of two Y values is more accuracy as the height of the rectangle [7].

$$A = \sum_{i=1}^{n-1} \frac{y_i + y_{i+1}}{2}(x_{i+1} - x_i) \qquad 2$$

After perform the mechanical tests on all specimens and calculation of stiffness, the results will be shown in Table 1.

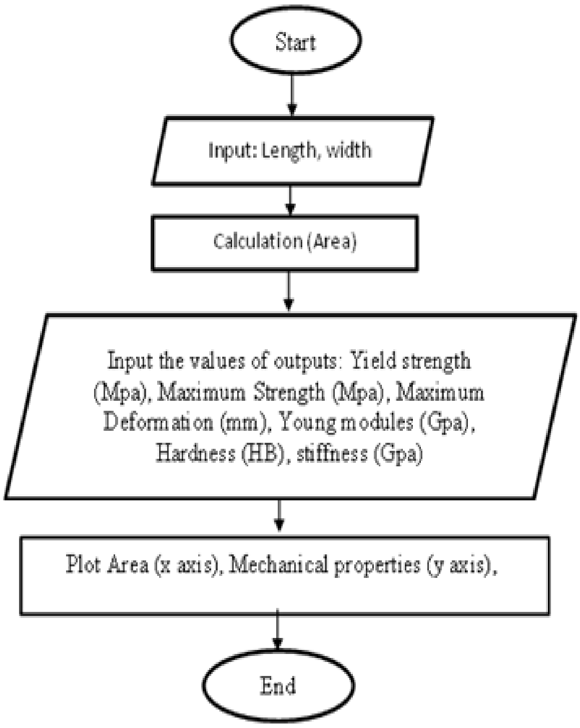
Table 1 The result of the mechanical tests.

Ingate area dimensions	Yield strength (Mpa)	Max. strength (Mpa)	Max. deformation (mm)	Young modules (Gpa)	Hardness HB	Stiffness (Gpa)
Specimen (1×1)cm	7	69	6.053	1.3×10^9	39.4	0.6530
Specimen (1.2×1.2)cm	7.1	68.7	6.054	1.3×10^9	39.8	0.6525
Specimen (1.4×1.4)cm	7.1	69	6.061	1.35×10^9	38.6	0.6543
Specimen (1.6×1.6)cm	60	113	8.500	1.67×10^9	49.2	1.51
Specimen (1.8×1.8)cm	58	114	8.504	1.66×10^9	50.1	1.51
Specimen (2×2)cm	58.6	113.3	8.530	1.68×10^9	49.1	1.52
Specimen (2.2×2.2)cm	81	118	4.055	2.16×10^9	54.9	2.34
Specimen (2.4×2.4)cm	83	120	4.054	2.15×10^9	55.3	2.42
Specimen (2.6×2.6)cm	81.5	122	4.070	2.16×10^9	55.1	2.41

2.2 Second Stage

This stage can be dividing into two parts:

2.2.1 part one: A program had been created using MATLAB, so as to study the effect of ingate area on the mechanical properties that adopted as shown in flow chart 1 and Figure 8.



Flow chart 1: shows the program

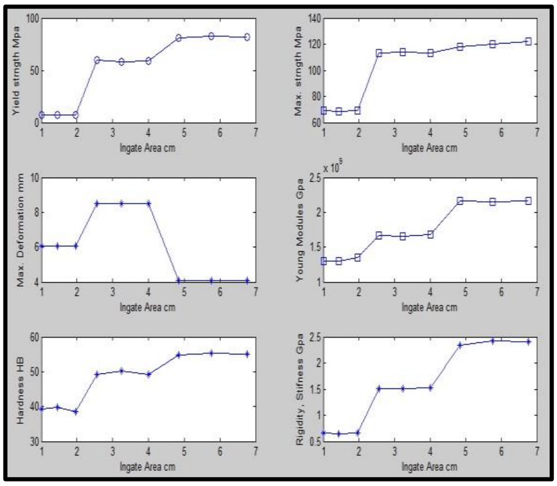
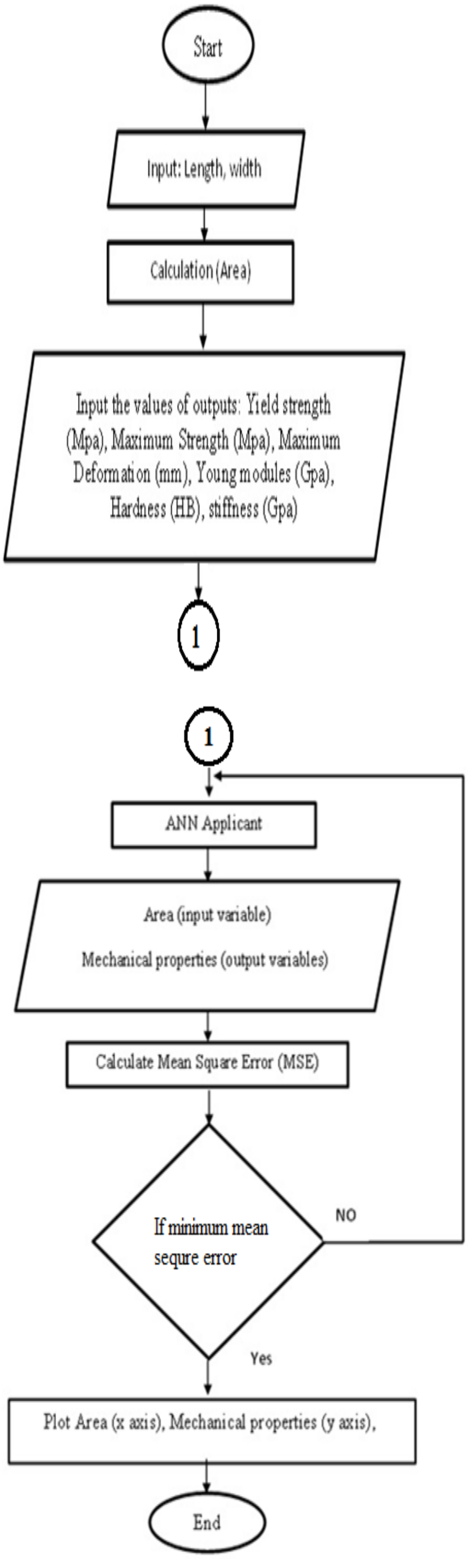


Figure 8: shows the effect of ingate area on mechanical properties

2.2.2 Part two: Mathematical equations can be created from ANN Tanique so as to describe the relations between input and outputs variables. A program had been created using MATLAB to apply ANN technique and detect the mathematical description between input and outputs parameters as shown in flow chart 2 and Figures 9, 10, 11, 12, 13 and 14.



Flow chart 2: shows the program

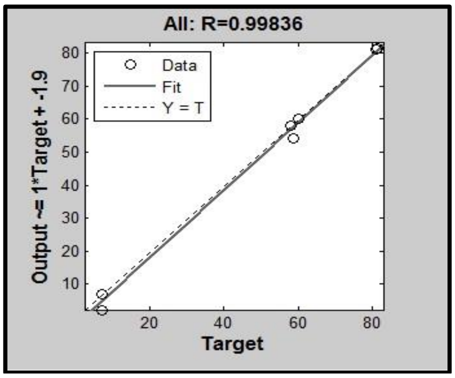


Figure 9: shows relation between area and yield strength

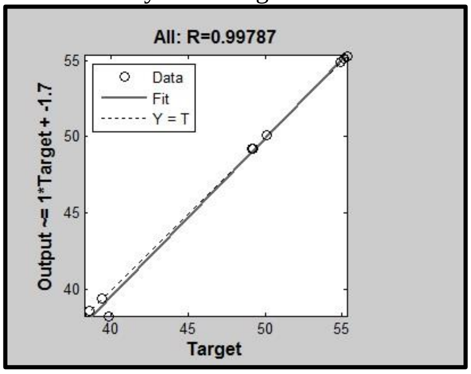


Figure 10: shows relation between area and Hardness

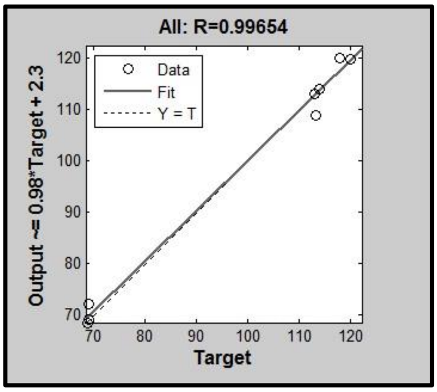


Figure 11: shows relation between area and Maximum strength

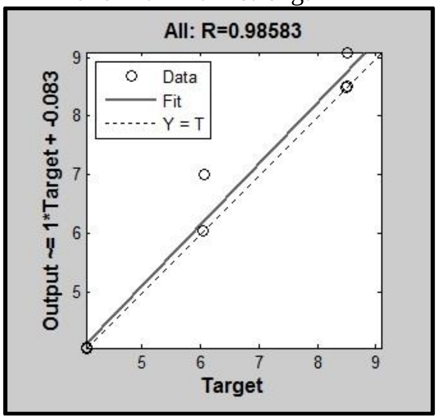


Figure 12: shows relation between area and Maximum deformation

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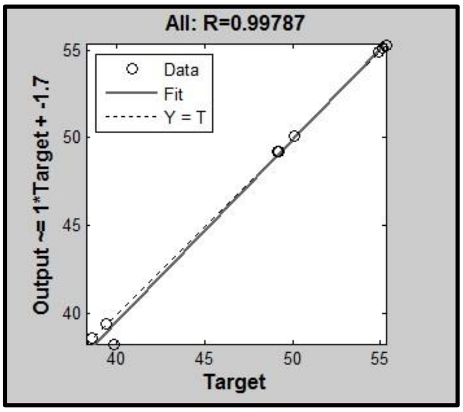

Figure 13: shows relation between area and young modulus

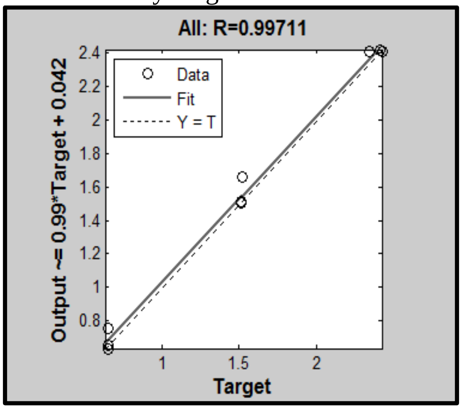

Figure 14: shows relation between area and Stiffness

3. Conclusions

From the results that had been shown in pervious figures and table it can be conclude that mechanical properties magnitudes, which includes (yield strength, max. strength, young modules, hardness, and rigidity) have been increased when the area of the ingate increased. Also, a mathematical model that gives the magnitude of outputs variables (mechanical properties) can be detected theoretically depending on ANN by verifying the minimum values of mean square error.

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