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STUDY THE EFFECT OF STIRRING SPEED AND PARTICLE SIZE ON THE TENSILE STRENGTH OF THE ALUMINUM MATRIX COMPOSITE (Al6063-2wt% Al_2O_3).

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ABSTRACT: - This research examines the effect of stirring speed and size of the alumina particles added of Al6063 on the tensile properties of the Al-6063 reinforced by Al_2o_3 Particle$_s$ using the program MINITAB 16. Stir casting method has been used to produce a composite material, the ingot was smelted, vortex of molten metal were created by stirring using different speeds (1000,900,800,700,600 rpm) and a fixed period of time (10min.) and then alumina particles of (2% wt) and different sizes of (700,500,355,250,106 μm) were added. It was concluded that the best tensile strength of (107.5989 Mpa) can be obtained when the variables were (X_1 = 1000 rpm) (X_2 =374.4μm). The lights value of X_1 and X_2, obtained using the programs, was used in practice giving tensile strength (109 Mpa) which it nearly similar to that obtained by program. Also results show that the variables Stirring Speed (X_1) & Particle Size (X_2) have a significant effect on tensile strength. Moreover, the tensile strength increases with increasing stirring speed. Alumina particle size increases the tensile strength until the particles reach the size of particulate (335μm) and after that go down.
Keyword: Stirring Speed, Particles size, Tensile Strength, Al6063-2wt%Al_2o_3.

1- INTRODUCTION

Nowadays many industries need materials having good mechanical properties and resistance to withstand high temperature such as composites. Composites are the materials manufactured by adding two or more materials which are in physically and/or chemically distinct phases, the metal matrix composite in the real world are used to produce materials with mechanical properties like high tensile strength, hardness, and toughness. Such materials are used in aerospace, jet engine exit vanes, blades sleeves of helicopters, parts of space shuttle, piston, cylinder liners, brake drums and discs (1).

The best way in the manufacture of composite materials of metal in liquid state is stir casting which includes incorporation of particulate into liquid aluminum melt and allowing the mixture to solidify. Creating good wetting between the particulate reinforcement and the liquid aluminum alloy is very important. The simplest and most commercially used technique is known as vortex technique or stir-casting technique. In this method, after the matrix material is melted, it is stirred vigorously to form a vortex at the surface of the melt, and the reinforcement material is then introduced at the side of the vortex. During stir casting for the synthesis of composites, stirring helps in two ways: (a) transferring particles into the liquid metal and (b) maintaining the particles in a suspension state [(2)]. K.V. Mahendrai[(3)] in their paper on fabrication of Al-4.5% Cu alloy with fly ash metal matrix composites and its characterization studied Metal matrix composites (MMCs) are engineered materials, formed by the combination of two or more dissimilar materials to obtain enhanced properties. In the present investigation, an Al-4.5% Cu alloy was used as the matrix and fly ash as the filler material. The composite was produced using conventional foundry techniques. The fly ash was added in 5%, 10%, and 15 wt. % to the molten metal. The composite was tested for fluidity, hardness, density, mechanical properties, impact strength, dry sliding wear, slurry erosive wear, and corrosion. Microstructure examination was done using a scanning electron microscope to obtain the distribution of fly ash in the aluminum matrix. The results show an increase in hardness, tensile strength and wear resistance properties with increasing fly ash content.

Sudarshan et al.[(4)] studied characterization of A356 Al - fly ash particle composites with fly ash particles of narrow range (53-106μm) and wide size range (0.5-400 μm) and found that addition of fly ash lead to increase in hardness, elastic modulus and 0.2% proof stress. Indumati B.D. and G.K. Purohit [(5)] have used four factors, five level factorial design to develop the micro-hardness model for Al7075 matrix, Al_2O_3 reinforced metal matrix composite fabricated by stir-casting. Reinforcement size and weight fraction of reinforcement, among other factors, are observed to affect the hardness more severely.

2. EXPERIMENTAL WORK:

2.1 Specimen Preparation

The chemical composition of Al6063 is given in Table1. The hybrid composite is formed by stir casting method is shown in Fig. 1. An electric resistance furnace homemade was used for melting the alloy. The ingots of the alloy were cut into small pieces and were put into silicon carbide crucible which was heated for melting in the furnace. Molten metal was heated to 700ºC. The pre-heated Al_2O_3 particles of (2%wt) at 400°C, were then added into the crucible and by using a mechanical stirrer they were thoroughly mixed and then poured into a preheated die to (200°C), getting rid of the moisture. The melt was then allowed to solidify in the die.

2.2 Tensile test:

Tensile test was performed on all specimens produced in this work accordance to specifications of ASTM E-8 standards [(6)]. The samples for the test were machined Into round specimen configuration with 7 mm diameter and 36 mm gauge length. To the test was carried out at room temperature using an Instron universal testing machine operated at an extension rate of 1mm/min. The tensile properties were evaluated from the stress-strain curves developed from the tension tests covering - the ultimate tensile strength, yield strength and elongation. A typical tensile specimen as per ASTM standard is shown in Fig 2. Tensile specimen after test shown in Fig 3.

3. DESIGN OF EXPERIMENT:

The design of experiments is an experimental technique that helps to investigate the best combinations of process parameters, changing quantities, levels and combinations in order to obtain results of optimal control. It is a systematic route that may be followed so as to find solutions to industrial process problems with greater objectivity by means of experimental and statistical techniques [7] .Since the objective of the investigation is to carry out the parametric studies, therefore experiments are designed based on Central Composites Design (CCD)scheme of Design of Experiments (DOE), CCD is very effective experimental technique in studies involving large number of factors, set of experimental design that can look at (k) factors in (n) observations with each factor at two levels is called two level factorial design, which can prove good and efficient when a line relationship prevails between the factors and the response ,CCD can be used to study factors at five levels in reduced number of tests[8,9]. CCD for 2 factors (stirring speed and Al_2O_3 particles size), with 5 replicates at the center resulting in total ($2^2+2^2+5=13$ runs), as illustrated in Fig.4. CCD is made rotatable by the choice of (α).Value of ($\alpha = [2^k]^{1\backslash 4}$) assures rotation of the CCD, in this study K2 factors are used, therefore α became 1.414 [10]. Stirring speed and alumina particles size are the factors which influence tensile strength of composite material. Table2 show the factors and their levels employed in the experiments. Tensile strength is the measured and responses are used to evaluate the mechanical behavior of Al6063/Al_2O_3composite material. Table (3) provides the experimental plan and the experimental results obtained.

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4. RESULT AND DISCASSION:

4.1 Test of Significance:

The regressed model coefficients were tested for significance by using the Response Surface Method(RSM) in the MINITAB software, so the calculated P- level for each coefficient is shown in Table.4,using significance level ($\alpha = 0.05$), the coefficient with p-value greater than ($\alpha = 0.05$) is not significant (a_{11}, a_{12}) therefore it will be deleted from the model. The remaining coefficients are (a_0, a_1, a_2 and a_{22}). Hence, the developed mathematical model for the tensile strength can be expressed as:

$$Y = -5.53143 + 0.07225 (X_1) +0.19422(X_2) - 0.000016(X_{22}) \ldots\ldots\ldots 1$$

Where the variables represent (X_1) (X_2) stirring speed and change in the size of alumina particles respectively, (Y) represents the tensile strength. It is noted from equation (1), the alumina particle size and square of have the greatest influence on the tensile strength, and either of the effect stirring speed (X_1) has less effect compared with (X_2).

4.2 Analysis of Variance (ANOVA):

ANOVA test was used to determine the design parameters significantly influencing the tensile strength .Depending on the level of significance (0.05), and using the test (F-test) of the regression model, from table 5, it is noted that the value of probabilistic (P-value) is less than 5%, and this means that the Regression model is significant [11]. This result is satisfactory. R-sq Adjusted is equal to (**92.68%**), and this means that the independent variables (X_1, X_2) explain (**92.68%**) of the variables that occur in the variable (Y) and the remainder is due to other factors such as random error. Whenever the coefficient of determination is closed one of the best and this can be satisfactory results.

4.3 The Main Effect Plot of Tensile Strength:

Fig 5 show the effect of stirring speed and size of alumina particles on the tensile strength and individual form, for values between (1.414, -1.414). It is noted that the tensile strength increases gradually with increasing stirring speed and this is attributed to the good distribution of alumina particles in the matrix alloy with increasing stirring speed. This leads to increase the tensile strength [12]. Alumina particle size causes the tensile strength to increase with increasing the size of the alumina particles to get the size (335μm) then the tensile strength begins to decrease with the size of alumina particles. This is attributed to the big-particles which has great probability to segregation from of low-particles and consequently deposition within the matrix alloy, therefore causing a decrease in tensile strength, this result confirmed by study [13].

4.4 Normal Probability Plot

Fig.6 shows the normal probability plot of residuals. Normal probability plots were generated by using computer software MINITAB it can be seen from the plotted data that, all data residuals are approximately normally distributed because the overall points make approximate straight line and from Fig.7 it is noted that the spread and distribution of residuals take the random form on both sides of the line, which represents a value of zero (the line that separates the residuals positive and negative) this is due to the error result is a random error, cannot be monitored specific form of these residuals, it not increasing or decreasing or present on one side, this tend to these residuals do not have constant variance. This result is satisfactory and agree with study [(14)].

4.5 Optimization of Tensile Strength

Fig.8 shows the optimization chart for the tensile strength at different levels for two factors (X_1, X_2). The optimization of result is shown in the left column, while the optimum setting of each parameter is shown at the middle of the top row. The behavior curve of each factor is shown underneath. As shown, the chart predicts that an optimum run at stirring speed (1000 rpm), size of alumina particles (374.4 µm), which would result in tensile strength of (107.5989 Mpa).

The lights value of stirring speed (X_1) and size of alumina particles (X_2), obtained using the programs, was used in practice giving tensile strength (109 Mpa) which it nearly similar to that obtained by program.

4.6 Response Surface Analysis

Fig.9 A and B, show a contour and three-dimension plot which describes the effect of factors (X_1, X_2) on response (Y). Three-diminution plot show tensile strength affected by the stirring speed and size of alumina particles, contour plot show an increase in tensile strength with increasing stirring speed and the stability of the value of the particle size. On the other hand constant value of stirring speed increases in the value of particle size. It is worth noting tensile strength increases and then decrease. Increasing (X_1, X_2) lead to get a tensile strength be higher than reduced (X_1, X_2).

CONCLUSIONS

From the present study of the effect of stirring speed and Al_2O_3 particles size on tensile strength of Al6063\2wt% Al_2O_3 using MINITAB [16] program, the following conclusion can be drawn.

1- Tensile strength increased with increasing of stirring speed (X_1), this may be because distribution of the particles in the matrix becomes uniform.
2- Tensile strength increases with increasing the size of the alumina particles (X_2) to get into the size (335µm) then begins to decreasing tensile strength with increasing the size of alumina particles.
3- The optimum of the tensile strength is obtained at the stirring speed (X_1) 1000 rpm and size of the alumina particles (X_2) 374.4 µm , where the value of the tensile strength (107.5989 MPa). This is the best result can be obtained when applying these variables. The lights value of X_1 and X_2, obtained using the programs, was used in practice giving tensile strength (109 Mpa).
4- Regression models can be represented by the following equation

$$Y = -5.53143 + 0.07225 (X_1) +0.19422(X_2) - 0.000016(X_{22})$$

Where the X_1 and X_2 have significant effect on tensile strength. And note that X_2 has the greatest influence compared with influence X_1.

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Table (1): Chemical composition of 6063 alloy.

Alloys	Al%	Fe%	Si%	Mg%	Cr%	Ti%	Zn%
6063	Bal	0.355	0.281	0.6	0.0001	0.0276	0.068

Table 2: The factors and their levels employed in the experiments

Parameters	Symbol	Units	Levels				
			-1.414	-1	0	1	1.414
Stirring Speed	X1	(rpm)	600	700	800	900	1000
Alumina particle size	X2	(µm)	106	250	355	500	710

Table (3): Experimental design matrix and observed values of the tensile strength.

No	X1	X2	Stirring Speed (rpm)	Alumina Particle Size (µm)	Tensile Strength (Y) (Mpa)
1	-1	-1	700	250	**82**
2	1	-1	900	250	**93**
3	-1	1	700	500	**85**
4	1	1	900	500	**95**
5	-1.414	0	600	335	**75**
6	1.414	0	1000	335	**103**
7	0	-1.414	800	106	**76**
8	0	1.414	800	710	**80**
9	0	0	800	335	**93**
10	0	0	800	335	**90**
11	0	0	800	335	**92**
12	0	0	800	335	**91**
13	0	0	800	335	**93**

Table (4): Response Surface Regression of Y

Term	Coef	SE Coef	T	P
Constant	-5.53143	44.4140	-0.125	0.049
X1	0.07225	0.0915	0.789	0.045
X2	0.19422	0.0811	2.395	0.048
X1X1	0.00002	0.0001	0.349	0.737
X2X2	-0.00016	0.0000	-6.577	0.000
X1X2	-0.00007	0.0001	-0.762	0.641

Table (5): ANOVA table for Y

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	1004.85	1004.85	200.971	31.38	0.000
Linear	2	690.30	37.14	18.570	2.90	0.121
Square	2	310.84	310.84	155.418	24.26	0.001
Interaction	1	3.72	3.72	3.719	0.58	0.471
Residual Error	7	44.84	44.84	6.405		
Lack-of-Fit	3	38.04	38.04	12.679	7.46	0.041
Pure Error	4	6.80	6.80	1.700		
Total	12	1049.69				

S = 2.53088	R-Sq = 95.73%	R-Sq (adj) = 92.68%

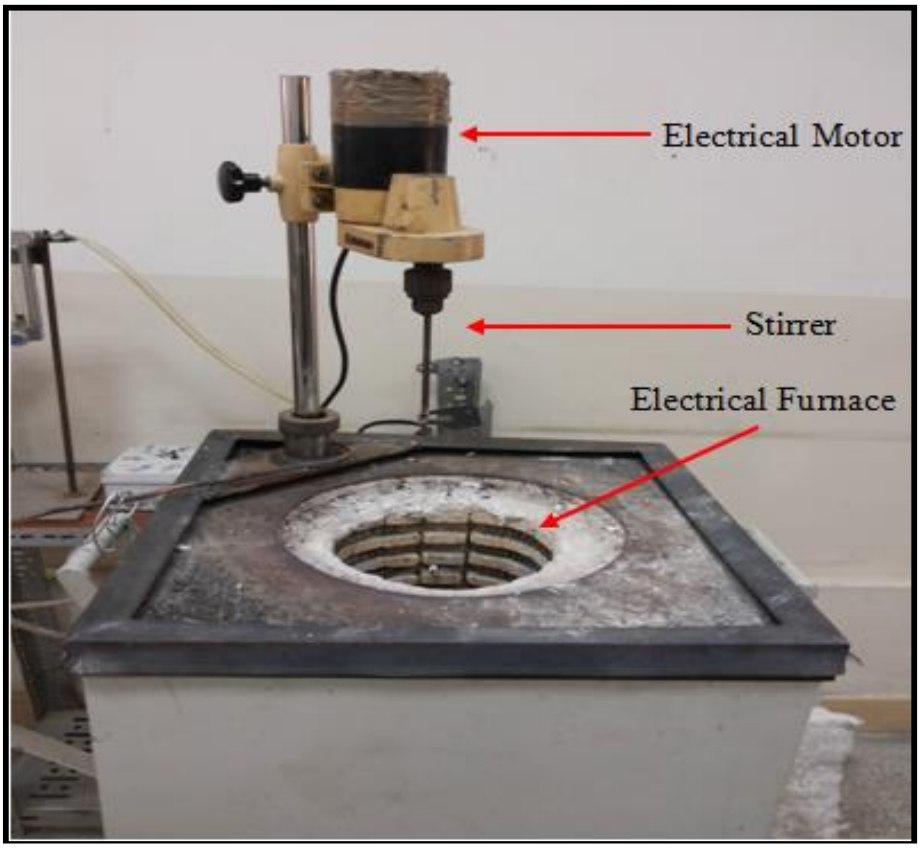

Fig. (1): Casting stir instrument method

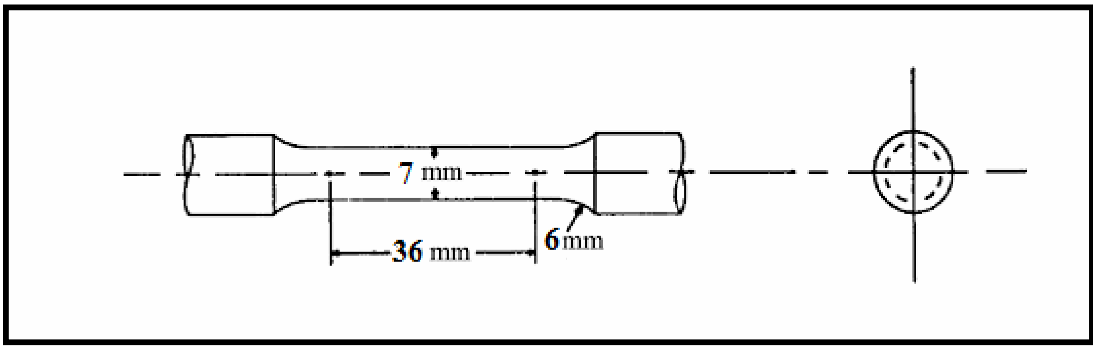

Fig. (2): ASTM standard tensile specimen.

Fig. (3): Tensile specimen after test.

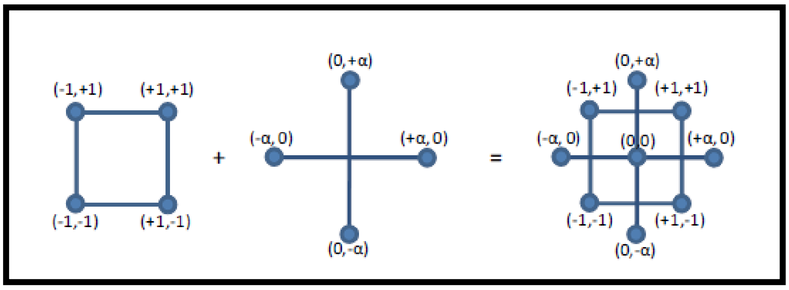

Fig. (4): The dimensionless coordinate system for 2 factors

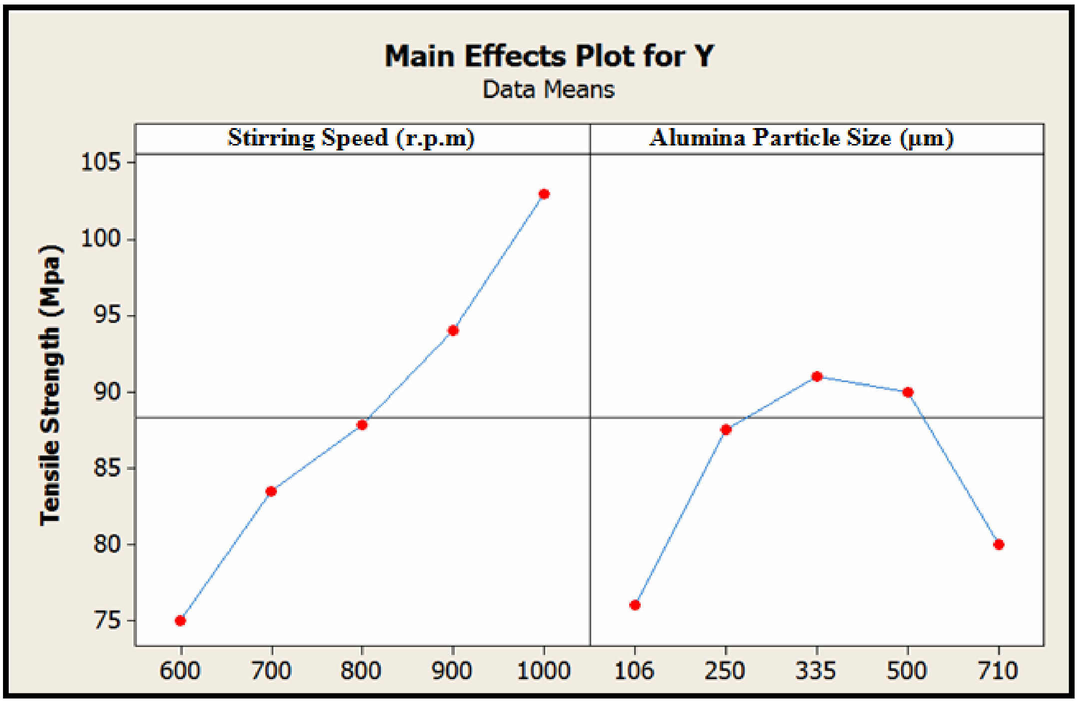

Fig. (5): Main effect plot to tensile strength

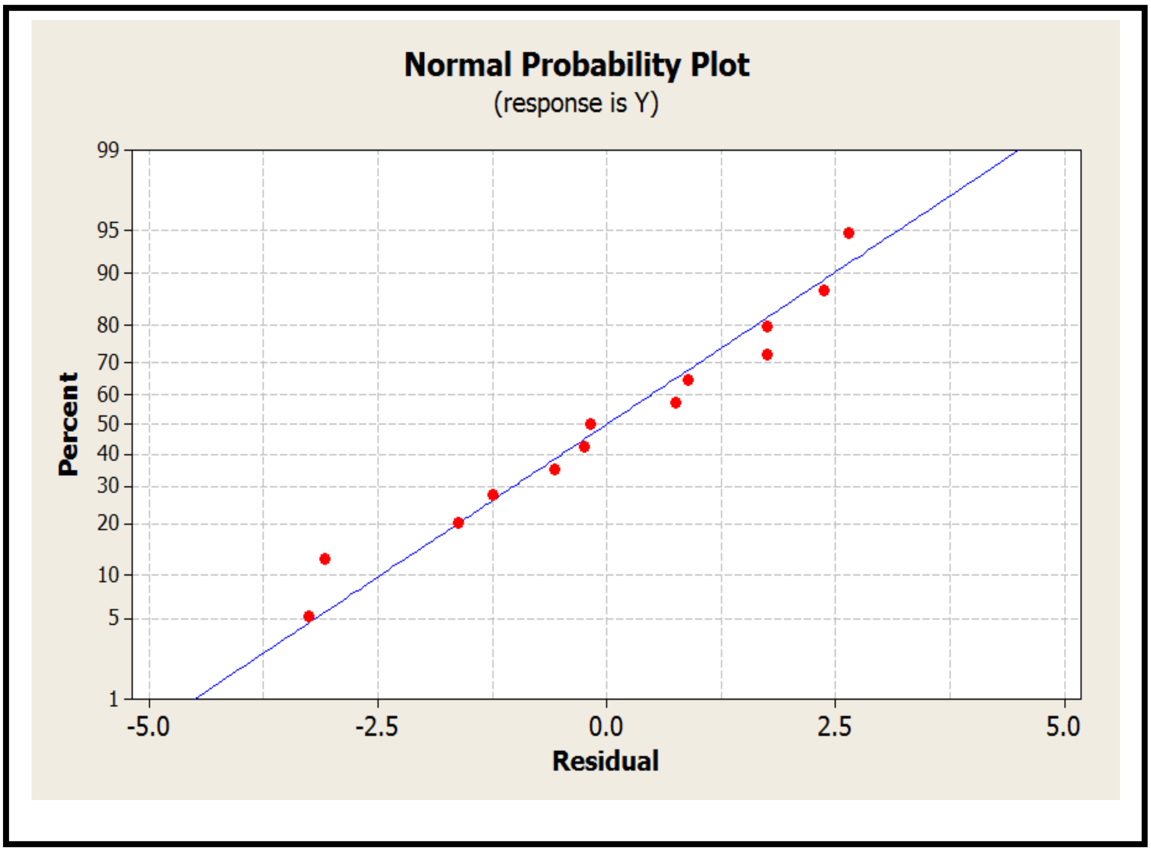

Fig. (6): Normal probability plot of residuals

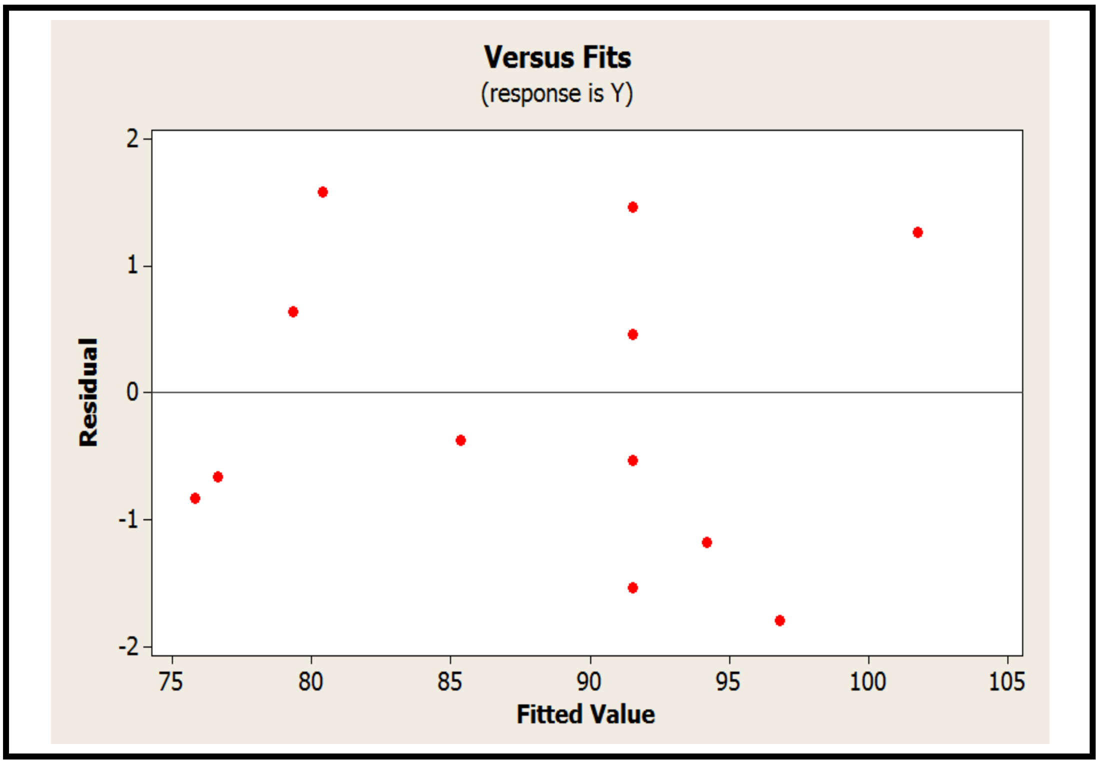

Fig. (7): Plot of residuals versus the fitted values.

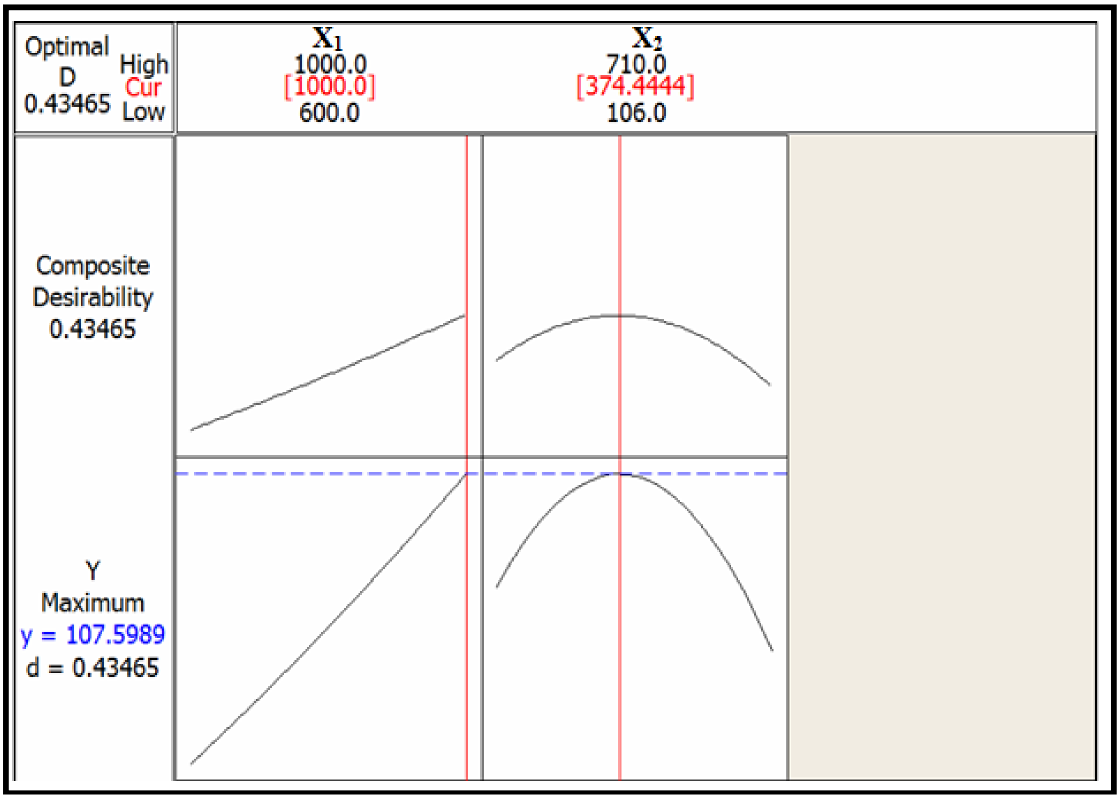

Fig. (8): Optimization chart for maximum tensile strength.

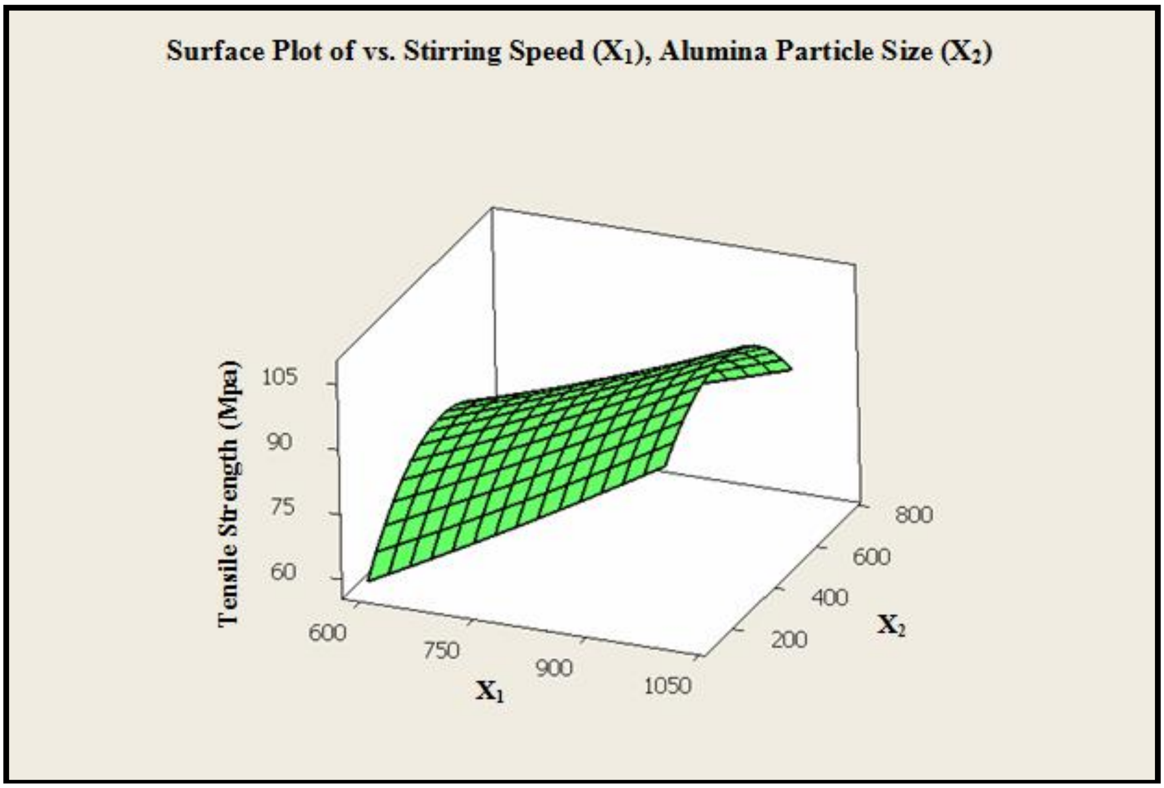

Fig. (9A): 3D Surface plots of tensile strength (Y).

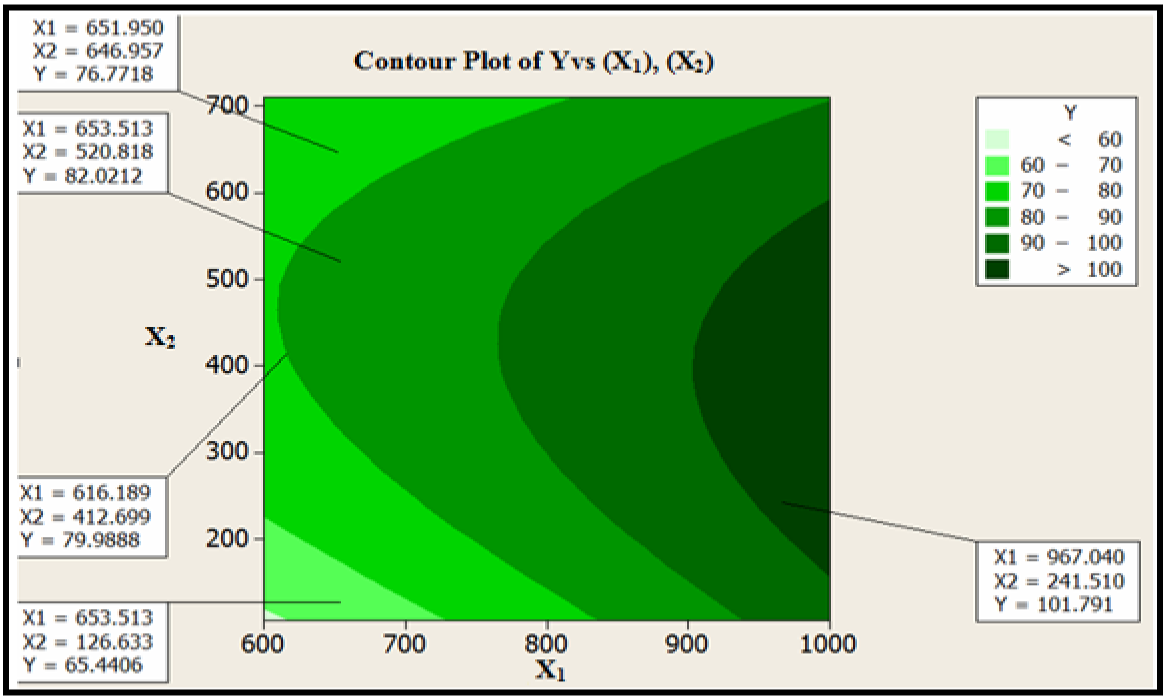

Fig. (9B): Contour plots of tensile strength (Y).

دراسة تأثير سرعة الخلط وحجم الدقائق على مقاومة الشد لمادة مركبة من الألمنيوم ($Al-6063-2wt\%Al_2O_3$)

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الخلاصة:

يتناول هذا البحث دراسة تأثير سرعة الخلط وحجم دقائق الالومينا المضافة على خاصية الشد لسبيكة Al-6063 باستخدام برنامج MINITAB 16 .تم أنتاج مادة متراكبة باستخدام طريقة السباكة بالخلط, حيث تم صهر السبيكة ومن ثم عمل دوامة داخل المنصهر باستخدام خلاط وبسرع مختلفة (1000,900,800,700,600) دورة\دقيقة ولفترة زمنية ثابتة (10 min.) ومن ثم تم إضافة دقائق الالومينا بنسبة وزنيه (2%wt) وبإحجام حبيبية مختلفة (700,500,355,250,106) مايكرون. تم استنتاج أن أفضل مقاومة شد (107.5989 Mpa) والتي يمكن الحصول عليها عندما تكون سرعة الخلط (X_1=1000rpm) وحجم حبيبي (X_2= 374.4µm), بعد الحصول على قيم سرع الخلط (X_1) و حجم دقائق الالومينا (X_2)، والتي تعطي أعلى قيمة لمقاومة الشد باستخدام برنامج (برنامج Minitab 16) ,تم استخدام هذه القيم عمليا وكانت قيمة مقاومة الشد الناتجة (109 Mpa) وبمقارنته مع نتيجة البرنامج كانت النتيجة مماثلة تقريبا. كذلك تبين من النتائج أن المتغيرات سرع الخلط والحجم الحبيبي لهما تأثير معنوي على مقاومة الشد بالإضافة إلى أن مقاومة الشد تزداد مع زيادة سرع الخلط أما بالنسبة إلى حجم دقائق الالومينا تزداد مقاومة الشد مع زيادة حجم الدقائق حتى الوصول إلى حجم دقائقي (335µm) وبعد ذلك تنخفض.