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Development of Rice Husk Reinforced Aluminium Chips Based Composite by Direct Recycling of Hot Press Forging

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Abstract: The research investigates about the rice husk reinforced aluminium chips by direct recycling. It is significant to study which will affect the physical and mechanical properties of composite. Due to increasing of natural wastes, rice husk is developed in an alternative method of recycling it as reinforcement for aluminium chips-based composite. Major purposes of this research are to investigate the physical property of directly recycled aluminium alloy AA6061 reinforced by rice husk via density test and simulate the effect of process parameters namely operation forging temperature, holding time, and weight percentage (wt.%) of rice husk through DEFORM 3D software to reveal the optimum performance of the developed composite. The matrix composite used is recycled aluminium alloy AA6061 in chips with an average length of less than 4mm. The experiment is carried out by the hot press forging machine. The main parameters to be investigated are operation temperature (450°C, 500°C, 550°C), holding time (1, 2 and 3 hours) and weight percentage (wt%) of rice husk (5, 10, 15 wt%) burnt at different temperatures. (700°C, 900°C and 1100°C). The optimization of density will be done through the application of Design of Experiment (DOE) method by means of RSM. The AA6061 aluminium alloy as-received billet will be used as a reference for data comparison. Optimal results are obtained from ANOVA which parameters have the most significant effect to response of density. lower volume of fraction of RHA (<7%) and higher forging operation temperature (520-550°C). Experiments with wider setting of parameters for forging process could be conducted.

Keywords: Aluminium Alloy, Rice Husk Reinforcement, Hot Press Forging, Design Of Experiment, ANOVA, Density, DEFORM 3D

1. Introduction

Recycling is implementing and developing for improvement in every country nowadays. Recycling became such an effective program due to recycling help to decompose or handle the waste

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in a very thoughtful and effective way of waste management. Compared to the other way to manage wastes as open burning, littering, and it seems like recycling is the best way to handle trash. This research will mainly focus on hot press forging technique for recycling the chips. Hot press forging and hot extrusion are considered as solid-state recycling process, which are typical green-forming and environmental-friendly manufacturing process for aluminium alloy.

Conventional recycling created high amount of wastage and losses, thus replacement by conversion recycling is a great choice. Melting process in conventional recycling caused not only metal loss due to oxidation, but also costs labor and energy as well, which increasing the expenses. For the development of rice husk reinforced aluminium chips-based composite, the use of low-cost metal matrix composite is now rapidly increasing in various engineering fields due to having better mechanical properties. The effects of recycled aluminium chips with rice husk on physical properties were investigated by [1]. This was done by adjusting the mass fraction between rice husk and aluminium chips, which shows a change in density of metal matrix composite resulting in improvement of hardness and composition.

This study focuses on the development of rice husk reinforced aluminium chips matrix composite. The improvement of this proposed will enhances the use of rice husk and its sustainability. The enhancement by obtaining optimum and uniform results by minimum setting of operation temperature, holding time and weight percentage of rice husk that can result in an acceptable density will be revealed used as a guideline in direct chip recycling for low-cost composite development. This is a great improvement in the manufacturing sector and so facilitate the process of technology development.

2. Materials and Methods

The interactions of input parameters will be analyzed by implementing analysis of variance (ANOVA) to check the significant effects. The results from ANOVA in the fractional design give further details or insight into the experimental direction for process optimization.

For the experiment, aluminium chips will be first collected from the industry of manufacturing industry. Certain amount of aluminium chips can collect from manufacturing from milling and turning process of the industry. The next step after measuring is to remove the impurities that are attached on the chips. Purpose of cleaning with an ultrasonic bath is to remove the excessive impurities from the chips, which could affect the properties of chips and the final result. Therefore, the cleaning process is significant in the experiment to a better result. After the chips have been through the process of ultrasonic bath, the chips are in wet condition and required to be dried to proceed to the next step. Putting those dried chips in a drying oven to make sure the chips are totally dry.

The combustion will proceed with temperature 700, 900 & 1100°C for 6 hours respectively in a furnace. Rice husk ash (RHA) produced after combustion is rich with silica content. Burning of rice husk with different temperature, different appearance of product obtained. RHA will then grinded into fine powder form before mixed with aluminium chips. To produce composite which is a combination from two or more than two elements, mixing process is required for AA6061 aluminium chips and rice husk ash. About hot press forging, we first considered the parameters and levels that we are going to use to conduct the experiment. Total four parameters as RHA with different heating temperature, volume fraction, operation temperature and holding time. Comes up with an experimental design parameters and levels.

3. Results and Discussion

3.1 Analysis for density test

Density test was carried out is this research. Density test is From Archimedes's Principle, physical law of buoyancy, stating that any object partially or wholly submerged in the liquid is acted upon a buoyancy force in an upward direction, the magnitude of apparent weight of the object in the liquid is equal to the acted buoyancy force. The density test is carried out by using HR-250AZ-Compact Analytical Balance Density Determination Kit is show in figure. Distilled water was then added into the container in the density balance and fix the position of the temperature detector and the standard weigh for density balance to carry out the testing for 19 specimens. Density for 19 specimens is collected and calculated out by using the equation according to the Archimedes' principle. Three forging operation temperature (450, 500 and 550°C) were used in the preheating step as described before. The samples of a rectangular cross section after hot forging are in a dog bone shape from top view. 2mm is cut out from each sample to conduct with density test.

Table 1: Data of density in design of experiment (DOE) table.

Specimen	RHA.T (°C)	Operation. T (°C)	Holding. t (hour)	Volume fraction (%)	Unit or Dimension
1	700	450	1	5	2.516
2	1100	450	1	5	2.374
3	700	550	1	5	2.537
4	1100	550	1	5	2.518
5	700	450	3	5	2.39
6	1100	450	3	5	2.341
7	700	550	3	5	2.55
8	1100	550	3	5	2.582
9	700	450	1	15	2.133
10	1100	450	1	15	1.662
11	700	550	1	15	2.503
12	1100	550	1	15	2.468
13	700	450	3	15	2.283
14	1100	450	3	15	1.968
15	700	550	3	15	2.473
16	1100	550	3	15	2.525
17	900	500	2	10	2.52
18	900	500	2	10	2.531
19	900	500	2	10	2.482

3.2 ANOVA of density result

3.2.1 Analysis for pareto chart

By using software Minitab 19 full factorial design is analyzed out and shows no unusual observation, which means the Pareto chart consider as a combination of a line graph and bar graph. A DOE pareto chart shows the standardized effects from 4 significant process parameters. A, B, C and D represented 4 process parameters. Each bar represents a standardized effect by each factor. A as RHA burnt with different temperature, B, forging operation temperature, C, holding time of forging operation and D, volume fraction of the RHA. The process varied from lower to higher level proves that the factors have a standardized effect. Investigated model are considered statistically significant if all factors across 4.30, the level of reference line, which displayed in red color dot line.

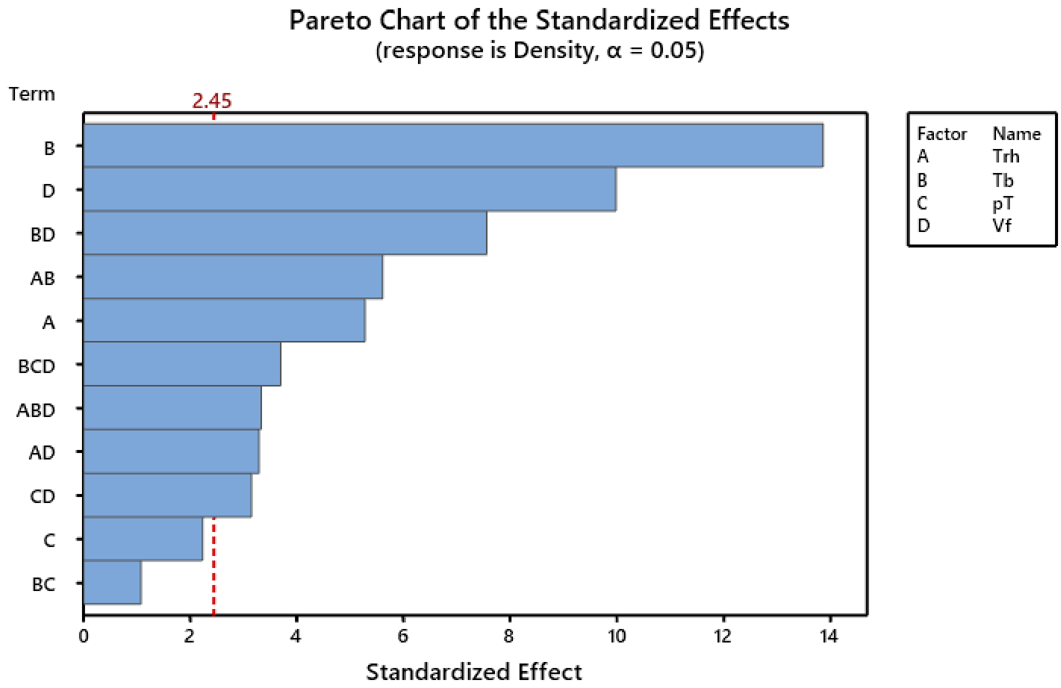

Figure 1: Pareto chart of the standardized effects after eliminated insignificant factors.

3.2.2 Analysis for regression result

From the model summary shown in table, showing that a strong determination of R^2=98.78%, which representing a very strong determination and a great regression model that matched with the research objective. Other than R^2, values for R^2 (adj) and R^2 (pred) both show a good regression result, 96.34% and 82.33%. The lower the value of R^2, the higher chance to get standard error. If higher value of R^2 indicate that the experimental relationships are acceptable to estimate the responses without considerable error. R^2 is referred to avoid the mathematical model from overfitting. A mathematic model according to factorial regression model by analysis of variance (ANOVA), quadratic model tells the effect of factors on the model to investigate the density of the composite material. A mathematic model defines by a quadratic equation. Overall model quality can be assessed based on the model summary.

Table 2: Model summary

S	R^2	R^2 (adj)	R^2 (pred)
0.0449273	98.78%	96.34%	82.33%

Table 3: Model summary

Density	=	3.64 + 0.00067 Trh - 0.00205 Tb - 0.756 pT - 0.002 Vf - 0.000001 Trh*Tb - 0.000411 Trh*Vf + 0.001421 Tb*pT - 0.000002 Tb*Vf + 0.0902 pT*Vf + 0.000001 Trh*Tb*Vf - 0.000166 Tb*pT*Vf + 0.1471 Ct Pt

P-value in table, represented the probability values, which could tell the data occurred or not under the null hypothesis. From observation for table of analysis of variances for density shows that all the P-values having very small in value approximate to zero. P-value less than 0.05 indicate that the model terms were significant. Linear models that are significant such as RHA temperature (Trh), forging operation temperature (Tb), and volume fraction (Vf) have P-value less than 0.05.

Table 4: ANOVA analysis for density

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	12	0.981504	0.081792	40.52	0.000
Linear	4	0.654224	0.163556	81.03	0.000
Trh	1	0.056051	0.056051	27.77	0.002
Tb	1	0.387195	0.387195	191.83	0.000
pT	1	0.010050	0.010050	4.98	0.067
Vf	1	0.200928	0.200928	99.55	0.000
2-Way Interactions	5	0.222578	0.044516	22.05	0.001
Trh*Tb	1	0.063378	0.063378	31.40	0.001
Trh*Vf	1	0.021830	0.021830	10.82	0.017
Tb*pT	1	0.002328	0.002328	1.15	0.324
Tb*Vf	1	0.115091	0.115091	57.02	0.000
pT*Vf	1	0.019952	0.019952	9.88	0.020
3-Way Interactions	2	0.050064	0.025032	12.40	0.007
Trh*Tb*Vf	1	0.022425	0.022425	11.11	0.016
Tb*pT*Vf	1	0.027639	0.027639	13.69	0.010
Curvature	1	0.054638	0.054638	27.07	0.002
Error	6	0.012111	0.002018		
Lack-of-Fit	4	0.010789	0.002697	4.08	0.206
Pure Error	2	0.001322	0.000661		
Total	18	0.993615			

3.2.3 Analysis for residual, main effect and interactions for density

To verify the assumption made from the R^2, residual plots have to be checked as a verification. A residual value is necessary for knowing the measure of how much a regression line misses the data point. By taking line as average, a few of point will fit right on the line and some will miss and pointed somewhere around the line. The regression line is the best fit of the data. Figure below shows 4 residual plots for density. Normal probability plot having percent as vertical axis and residual as horizontal axis. A linear plot is shown as the dots are positioned close enough to the regression line.

Main effect plots for density shows the mean outcome for 4 process parameters as independent variable values and combining effects of the other variables. 4 quadratic graphs are shown with different gradient of plots. Y-axis, represented the mean outcome, which is the value of density and x-axis are represented by four independent process parameters respectively. The first plots with density versus temperature of RHA (Trh) plots a line with moderate gradient. The first plots show the mean of density versus temperature of RHA and it shows a negative gradient, which means the density is decreasing if the temperature increase. For 700°C of RHA, it has more than 2.40 outcome of mean of density, while 1100°C of RHA has only 2.30 mean of density. However, there are a clear gradient shows in the graph, RHA is a factor that will have significant effect to the outcome of mean of density.

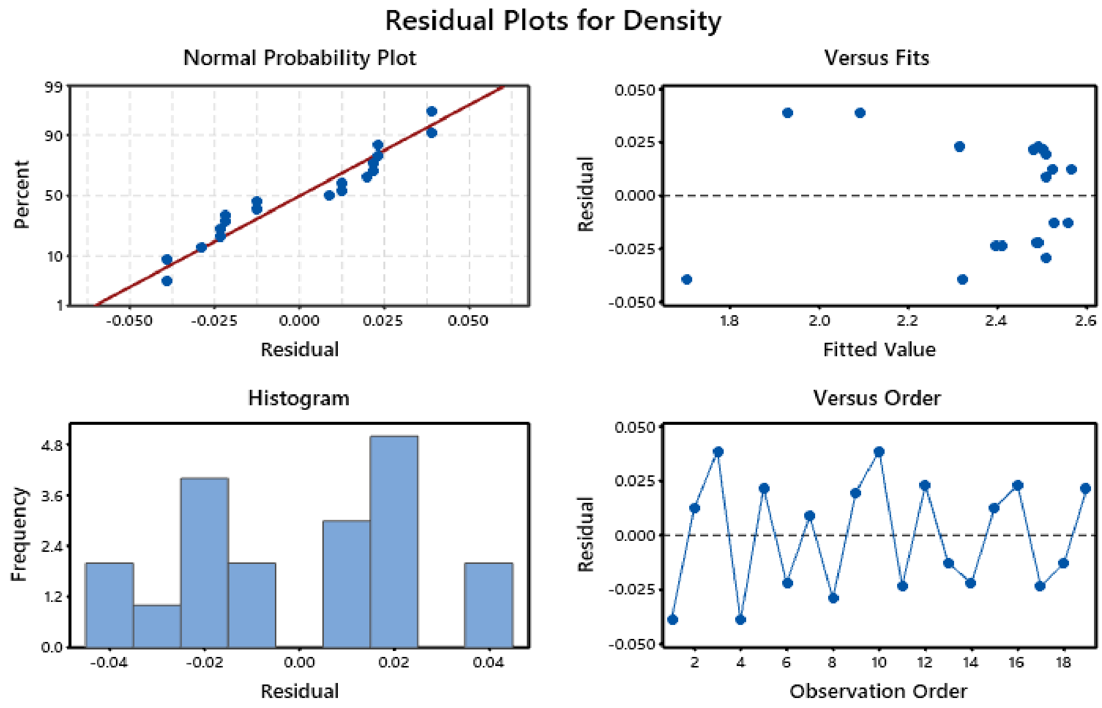

Figure 2: Residual plot for density.

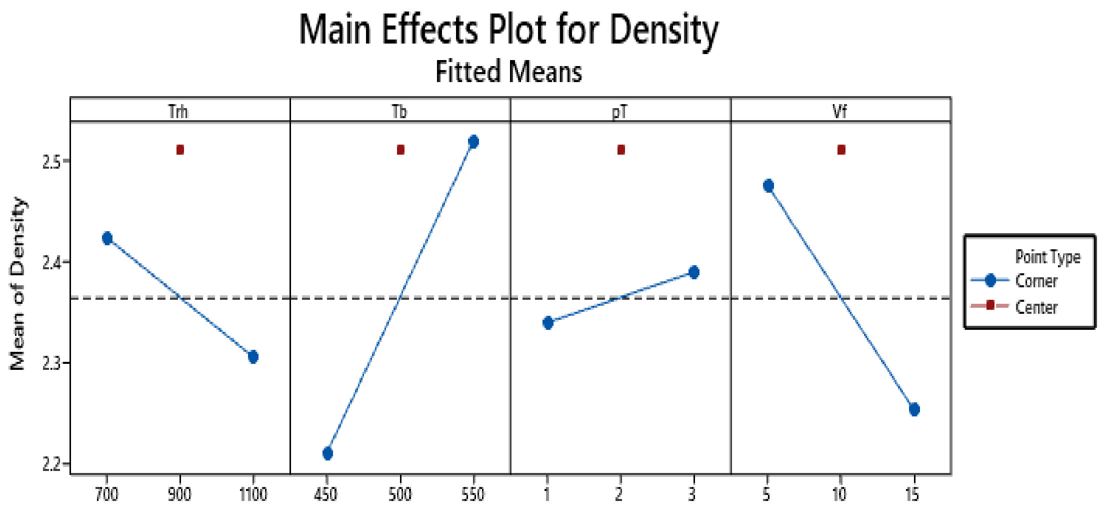

Figure 3: Main effect plot for density.

For interaction plot of density with fitted means, four of the independent variables are affecting the dependent variables and the independent variables will not affecting each other but putting them together will having a different result. By eyeballing the figure below, none of the plots have an interaction. Without an interaction that defines the 4 independent variables are not combining in such a way to give a different specific effect. Hence, 4 independent variables in this research are all have main effect to the result. The plots with independent variables forging operation temperature (Tb) and volume fraction (Vf) showing a significant effect besides the interaction plots with independent variables holding time (pT). The lines are almost parallel signify that have no significant effect. Variables with 5% of volume fraction of RHA and 550°C of forging operation temperature will give the optimum result for this research.

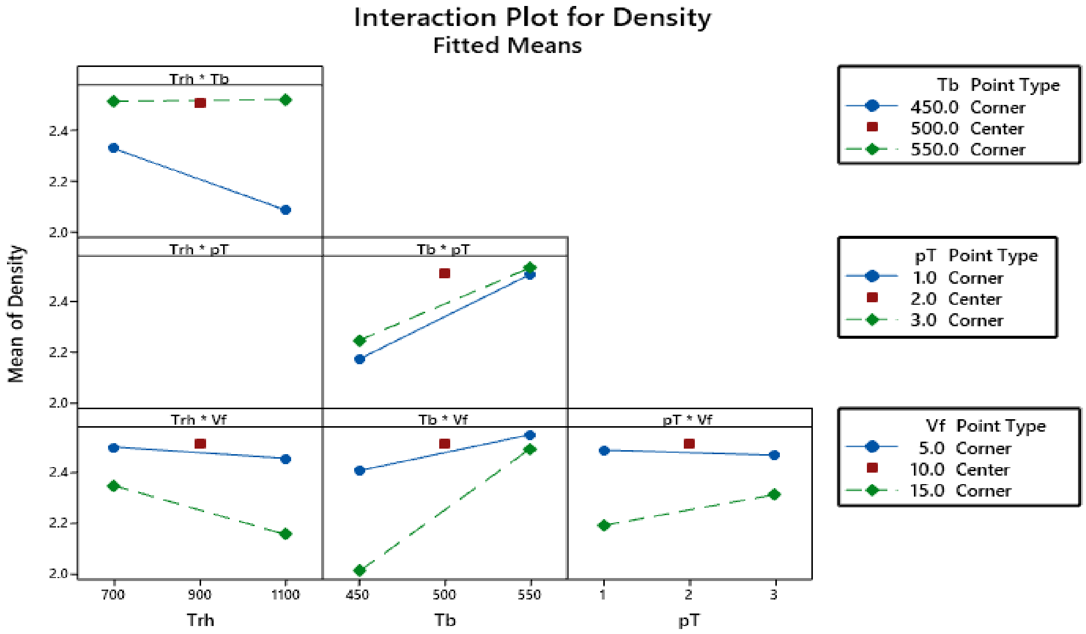

Figure 4: Interaction plot for density.

3.2.4 Analysis for contour plot

Fitted response contour plots were generated to see how a density response relates to two continuous variables such as RHA temperature (Trh) and forging operation temperature (Tb) in figure below. The darker region indicates higher of z-values which means density. All combination revealed a high value of density (2.40-2.55) and covered most of the space in contour plots. There are only two contour plots show a very small area of blue color region.

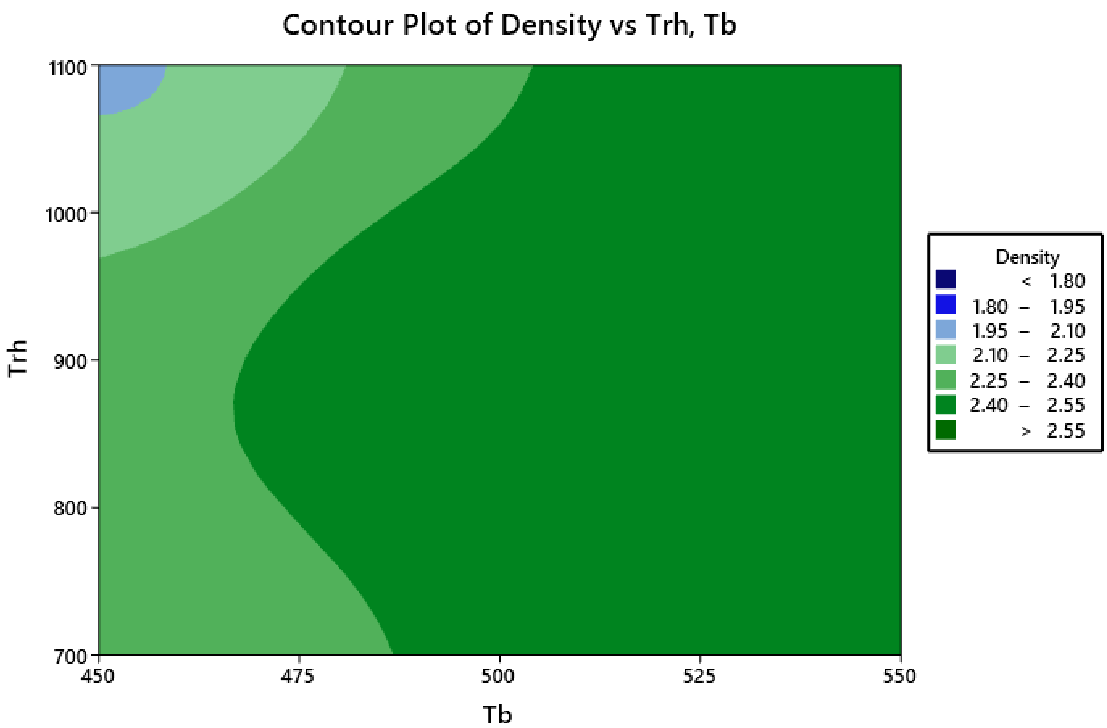

Figure 5: Response contour plot of density by temperature of RHA vs forging operation temperature.

3.2.5 Optimization response of density

The purpose of this investigation was to determine which parameters that are optimum for this direct conversion process. The best parameters to get the highest value of density. Figure below shows the suggested best parameters for the hot press forging process by ANOVA. The suggested optimal parameters are analogous with the results from the analysis mentioned in previous chapter which are highest forging operation temperature (550°C) and least volume fraction of RHA (5%).

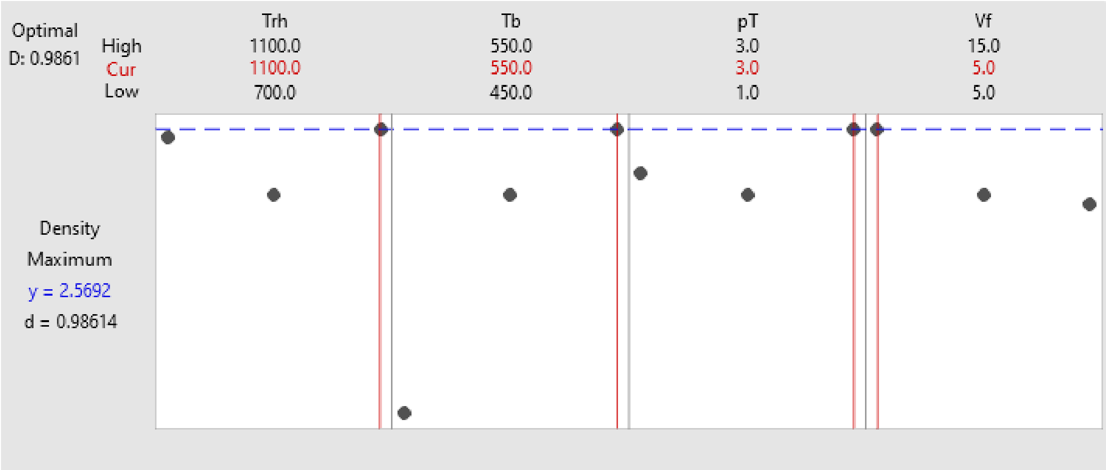

Figure 6: Optimal result of density from ANOVA.

3.3 Analysis of DEFORM 3D

3.3.1 Analysis for stress, strain and temperature

Stress and strain experienced by workpiece only when it has contact with the top die. Noted that there was always zero value for either stress or strain when the plunger is at holding mode. Stress applied on a material is the force divided by unit area of the surface of the material. Force will be uniformly distributed to the acting area. Larger the surface area, lower the stress, thus smaller area results in increase of stress. The edges of the workpiece have the smallest in surface are, thus higher stress was experienced.

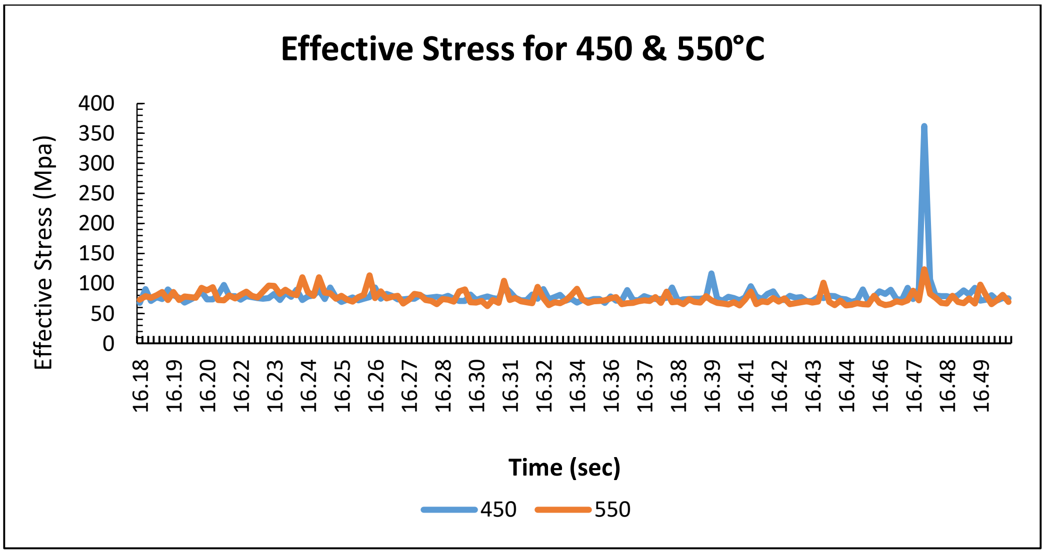

Figure 7: Line graph of effective stress.

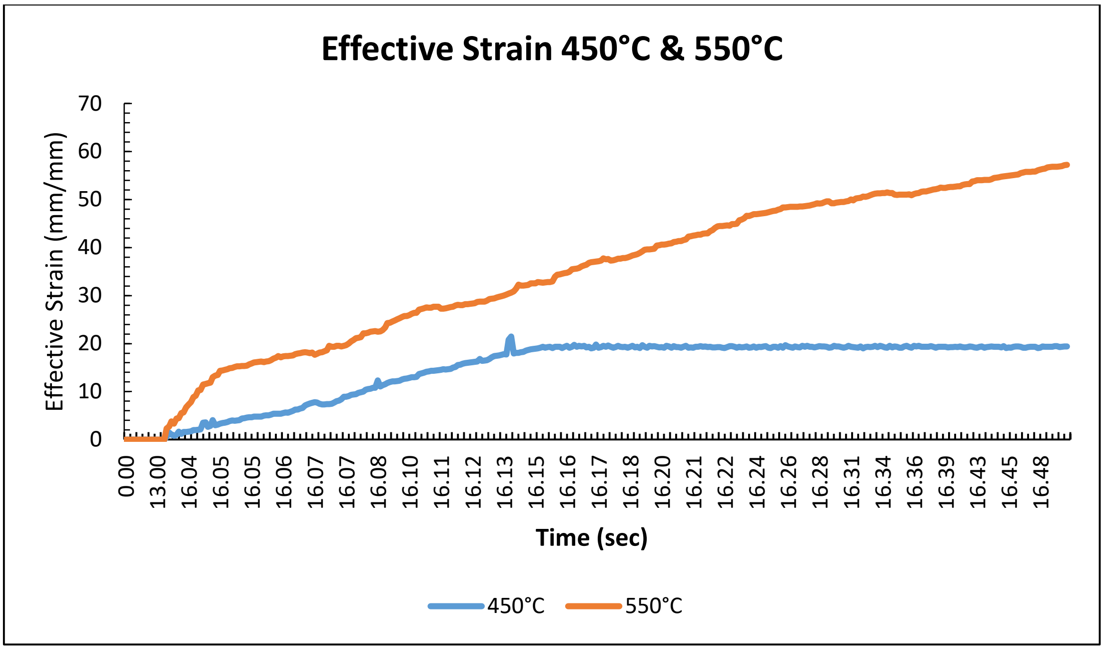

Figure 8: Line graph of effective strain.

4. Conclusion

From the research findings, the result of density value showed a linear trend in graph and consistent in value. There lowest value of density was observed at 1100°C of RHA, 450°C of forging operation temperature, 1 hour of holding time, and 15% of volume fraction of RHA is 1.662 g/cm3. From discussion of ANOVA analysis in chapter 4, samples with minimum forging operation temperature (450°C) and maximum percentages of RHA (15%) showed the minimum value of density. On the contrary, the maximum value of density was observed at 1100°C of RHA temperature, 550°C of forging operation temperature, 3 hours of holding time, and 5% of volume fraction of RHA is 2.582 g/cm3. Sample having the maximum value of the density value has maximum in forging operation temperature (550°C) and minimum in RHA volume fraction (5%). Both of these statements revealed that the temperature of RHA and holding time is not a significant factor which bring not much effect to the outcome.

Analysis from DEFORM 3D software is done to support the results from ANOVA study. Effective of stress and strain results have determined that the significance of the forging operation temperature. Higher the forging operation will have a greater result of specimen even if the lower effective stress generated.

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