

MEASURING THE EFFECT OF ADDING COPPER ON THE QUALITY OF THE THERMAL CONDUCTIVITY OF PURE ALUMINUM

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ABSTRACT

In this research, an experimental work had been conducted to measure the effect of adding copper (Cu) with different percentages to the pure Aluminum (AL) and noise variables (error) on the quality of thermal conductivity (k). Alloys had been prepared by changing percentages addition of copper to pure Aluminum and the percentages were (5, 10, 15, 20&25%). The effect of an average deviation and variability on the thermal properties after an addition of copper through use of normal probability plot. The results shows as that copper percentage was increasing lead to increase thermal conductivity by (15.47%) and the property of thermal conductivity had goodness of fit test and percentages the effect of adding copper to pure Aluminium (AL) and error were (97%, 3%) respectively.

Keywords: Quality, Thermal Conductivity, Copper

INTRODUCTION

Aluminum divided by purity to Aluminum high-purity, where the proportion of Aluminum (99.999 % Al) and purity of commercial Aluminum (99 % Al), and Aluminum is characterized high resist corrosion by increase purity, also connected of high heat and electricity, an ability upon good formation, low resistance and does not heat treatment in the case of purity. The commercial Aluminum used to manufacture constructions and the parts are loaded (such as facilities on roofs of ships and electric wires, capacitors, structures of clocks, chips, exhibits art, doors, frames, and containers domestic). While, the aluminum of high purity is used to manufacture of chips products connected to the electricity and chemical industry (I.G. Brodova, 2002). Aluminum has the chemical symbol Al, atomic number 13, and atomic weight 26.98. The isotope with mass number 27 is the only stable isotope. It is a soft, light, gray metal that resists corrosion when pure in spite of its chemical activity because of a thin surface layer of oxide. It is nonmagnetic and no sparking. Its density is 2.6989 kg/cm³, melting point 669.7°C and boiling point 1800°C. Its electrical resistivity is 2.824 μΩ-cm at 20°C, with temperature coefficient 0.0039°C⁻¹, the same as coppers. Its thermal conductivity is 2.37 W/cm-K at 300K, and the linear coefficient of expansion is 23.86 x 10⁻⁶°C⁻¹ (R. Mathiesen, 2006).

In the design of experiments, a single experiments or a sequence of experiments is performed to test and quantify the effects of one or more input variables on one or more output variables of a process or a product. The design of experiments may be used to help improve the capability of a process by identifying the process and product variables that affect the mean and the variance of quality characteristic of the product (Robert L. Mason, 2003). Where the used symbols in mathematical equations can be summarized as shown in the table 1.

Table 1. Definitions of used symbols in mathematical equations [R. Mathiesen, 2006]

<i>Used Symbols</i>	<i>Definitions of used symbols</i>	<i>units</i>
A	Sectional area of the vertical section of the sample on the direction of heat transfer	m ²
d	diameter of, the sample	cm
k	Coefficient of thermal conductivity	W/m.°C
q	Power device fitted to the conductivity	Watt
T	Temperature	°C
x	length of the distance traveled by the heat (length of the sample)	cm

ACCOUNTS OF THERMAL CONDUCTIVITY

Heat form of energy transition, moving from the area with a high temperature to the region of low temperature in several images, namely, (conduction, convection, and radiation), and heat was transferred to one or more of these images. The transfer of heat conduction, has created the world Fourier law observed from which the heat transmitted through the middle of a directly proportional with temperature difference and the space perpendicular to the direction of heat flow (A), and inversely with the length of the distance traveled by the temperature [Y. Plevachuk,2008].

$$q \propto A \frac{\Delta T}{\Delta x} \quad (1)$$

And that the constant of proportionality is the thermal conductivity (k), which is a property of properties of the center carrier, indicates its ability to deliver heat (R. Mathiesen, 2006).

$$q = kA \frac{\Delta T}{\Delta x} \quad (2)$$

To calculate the value of the constant (k), we rearrange equation (2) to get the new formula, namely (F.P. Incropera, 2000).

$$k = \frac{q * \Delta x}{A * \Delta T} \quad (3)$$

Where: $A = \pi * d^2 / 4$

NORMAL PROBABILITY PLOT

A normal probability plot plots observed data value if the distribution of the random variable is normal. We will be content in reading normal probability plots constructed using the statistical software package, Minitab. In Minitab, if the points plotted lie within the bounds provided in the graph, then we have reason to believe that the sample data come from a population that is normally distributed. for each point obtain probability axis location using formula (4), where P_i is the percentile rank of the i th order statistic in a sample of size n (Steve,2005, Robert L.,2003).

$$P_i = \frac{i - 0.375}{n + 0.25} \quad (4)$$

SINGLE – FACTOR EXPERIMENTS

Analysis of variance (ANOVA) for a single – factor experiment, the factor is usually denoted by A (copper), and noise of variables (Error). Let the number of levels of factor A be a. then,

$$SST = \sum_{i=1}^a \sum_{j=1}^n y_{ij} - \frac{y^2}{an} \tag{5}$$

$$SSA = \frac{\sum_{i=1}^a y_i^2}{n} - \frac{y^2}{an} \tag{6}$$

$$SSE = SST - SSA \tag{7}$$

There is a total of (a × 1) combination in a full factorial design. If there are n replications, then there is a total of (n × a) observations .Simpler formulas for computing the sums of squares of factors are given below (Wu, C.F.J., 2000).

The degrees of freedom, mean squares and test statistics are summarized in table 2. Also values of tabulated F at the significant level (α = 0.05) are determining from

Table 2. Summary of test statistics (analysis of variance) [Robert L. Mason, 2003]

Source of variation	Sum of squares	Degrees of freedom (DF)	Mean square	Computed F and F From table at (α = 0.05)
% Cu (A)	SSA	a – 1	MSA = SSA/a – 1	MSA/MSE F _α [(a – 1), a(n – 1)]
error	SSE	(a – 1)(b – 1)	MSE = SSE/a(n – 1)	-----
Total	SST	an-1	-----	-----

Table 3. F distribution: 5 percent points [Salman Taghizadegan, 2006]

$\frac{v_1}{v_2}$	1	2	3	4	5
1	161.45	199.50	215.71	224.58	230.16
2	18.513	19.00	9.2766	19.247	19.296
3	10.128	9.5521	6.5914	9.1172	9.0135
4	7.7086	6.9443	6.5914	6.3883	6.2560
5	6.6079	5.7861	5.4095	5.1922	5.0503
6	5.9874	5.1433	4.7571	4.5337	4.3874
7	5.5914	4.7374	4.3468	4.1203	3.9715
8	5.3177	4.4590	4.0662	3.8378	3.6875
9	5.1174	4.2565	3.8626	3.6331	3.4817
10	4.9646	4.1028	3.7083	3.4780	3.3258

The following formulas are used for computing the approximate percentage contribution of each effect (main factor or error) to the variability of the response variable [Salman Taghizadegan, 2006].

$$\% \text{ contribution of } A = \frac{MSA - MSE}{SST} \times DF \times 100 \quad (8)$$

% contribution of error = 100 – (sum % A factor)

EXPERIMENTAL WORK

A Device for Measuring Thermal Conductivity

The device used to measure the thermal conductivity Consists of two pieces of copper placed inside two pieces of Teflon as a buffer. As well as an electric heater, be controlled by thermal regulator (thermostat), and the amount of heat transmitted from the heater to the alloy is placed between two pieces of copper can be controlled by the voltage regulator. We're using water to cool the end of the sample to ensure the heat transfer in one direction is the axis of the cylinder, and measured temperatures by eight thermocouples type (T), placed three of them before the sample and the other three after the sample and two on the sample surface after the hole on the Teflon insulation and the user, to ensure that thermal losses. As shown in Figure (1), which shows us a photograph of the user's device?

Testing Procedure Steps

Practical experiments were conducted to measure the heat conductivity as follows:

- I. Put the sample between the poles of copper and Teflon insulated material.
- II. Operation of the electrical heater, placed under a single polar copper and control electrical power within organized by the use of three voltages were (15, 25, 35 volt), to calculate the rate of thermal conductivity of the alloy accurately.
- III. Measurement the power entering the heater and the voltage and current by measurements placed in the device.
- IV. After the arrival of the electric heater to the required level and stability of temperatures after reaching the state of stability for the time period (30 minutes) take readings of the twin themes on the surface of the sample only, and is due not to our use of bisexual six placed before and after the sample is a different metal alloy being placed between two metal made of copper and thus a difference in thermal conductivity caused by an error in the measurements.

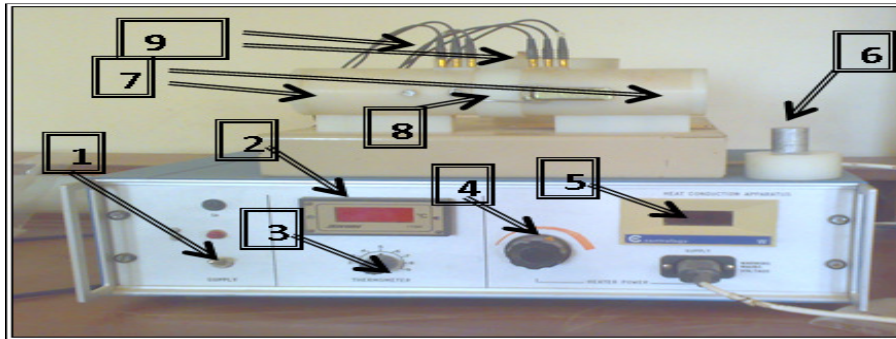


Figure 1. A photograph of the device for measuring thermal conductivity describes the used devices in the research: 1- Power key. 2- a digital scale with temperature. 3 - Control of the thermocouples. 4 - Voltage regulator. 5 - Measure of power. 6 - Test sample with Teflon. 7 - Teflon isolated copper electrodes. 8 - Place the test sample. 9 -Thermocouples.

RESULTS AND DISCUSSION

1. Thermal conductivity and specific heat was calculated of pure Aluminum as shown in table (1).
2. Percentage change was added from copper to Aluminum, five percentages 5%, 10%, 15%, 20% and 25% and calculated the thermal properties of each percentage as shown in table (1).
3. We noted that F from table (3) at ($\alpha = 0.05$) for main effect was smaller than F calculated, indicating that the percentages of copper had significantly effect upon thermal conductivity as shown in table (2).
4. Statistically, F-test provides a decision at some confidence as to whether these estimates are significantly different. Larger F-value indicates that the variation of the process parameter makes a big change on the performance as shown in table (2).
5. The characteristic of thermal conductivity had normal probability distribution (goodness fit) as shown in figure (1).
6. percentages an improvement according to additions of copper to pure Aluminum were (15.47%, 12.68%, 8.71, 6.66.6%, 2.79%) and an improvement probabilities were (33.4%, 27.4%, 18.8%, 14.4, 6%) as shown in figures (2,3).
7. According to this analysis, the most effective factors with respect to the two factors were copper (%Cu) and error. According to figure 4, the percentage contribution of copper was (97%) and the percentage contribution of error was (3%) as shown in figures (4).

CONCLUSIONS AND RECOMMENDATIONS

1. Values of thermal conductivity had goodness of fit test because of the statistic test was (0.154) and P value (89.9%) and that caused normal probability distribution.
2. The best an improvement was at addition (25%Cu) of copper to pure Aluminum.
3. A large percentage of contribution (total variations in values of thermal conductivity) by copper was (97%) because of linearity relationship between addition copper to pure Aluminum and thermal conductivity while a small percentage of contribution (small variations) by error was (3 %) for characteristic of thermal conductivity .
4. The factor copper had a big effect on the quality of thermal conductivity while the factor error had a small effect on the quality of thermal conductivity.
5. The effect of an interaction between main effects is not found.
6. Using another factors (two-factor experiments) with observing its effects on the multi properties from thermal properties with adding another elements to pure Aluminum by different percentages.

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APPENDIX

Table 4. Total of main factors and response thermal conductivity

<i>Pure-Al</i>	<i>K-for pure Aluminum is equal to 236 w/m.c</i>		<i>Row Total</i>
<i>Al-Cu</i>	<i>Replication2</i>	<i>Replication1</i>	
<i>Al-5%Cu</i>	244.21	240.94	485.15
<i>Al-10%Cu</i>	251.11	252.32	503.43
<i>Al-15%Cu</i>	257.98	255.12	513.10
<i>Al-20%Cu</i>	264.93	266.94	531.87
<i>Al-25%Cu</i>	274.13	270.88	545.01
	<i>Column Total</i>		2578.56

Table 5. Results of ANOVA of factors vs. response thermal conductivity

<i>Source of variation</i>	<i>Sum of squares</i>	<i>Degrees of freedom</i>	<i>Mean square</i>	<i>Computed F</i>	<i>F From table</i>
<i>%Cu</i>	1105.57984	4	276.395	79.105	5.1922
<i>error</i>	17.4696	5	3.494	-----	-----
<i>Total</i>	1123.04944	9	-----	-----	-----

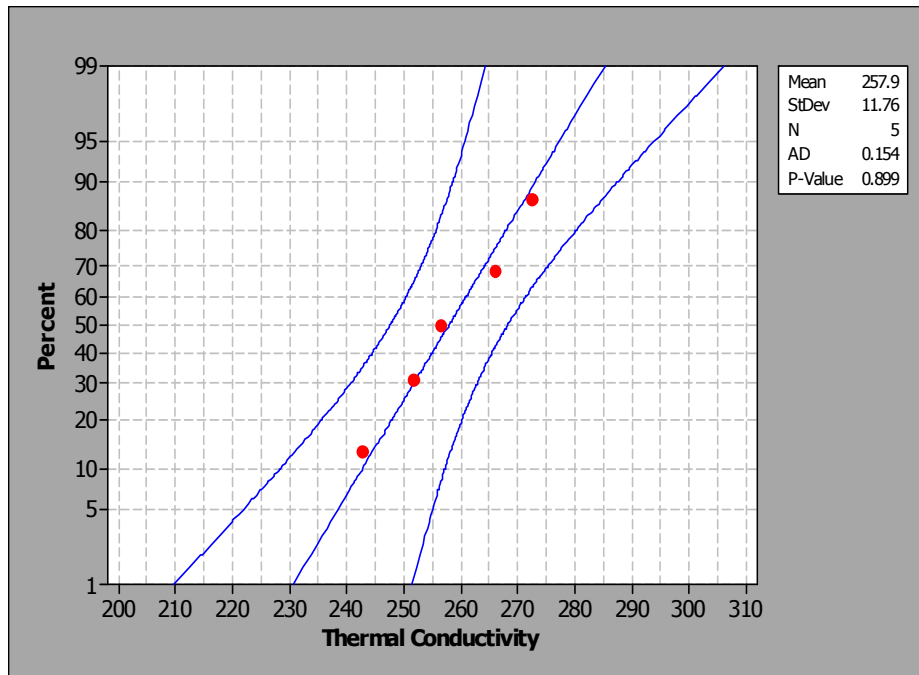


Figure 1. Normal probability plot of the thermal conductivity

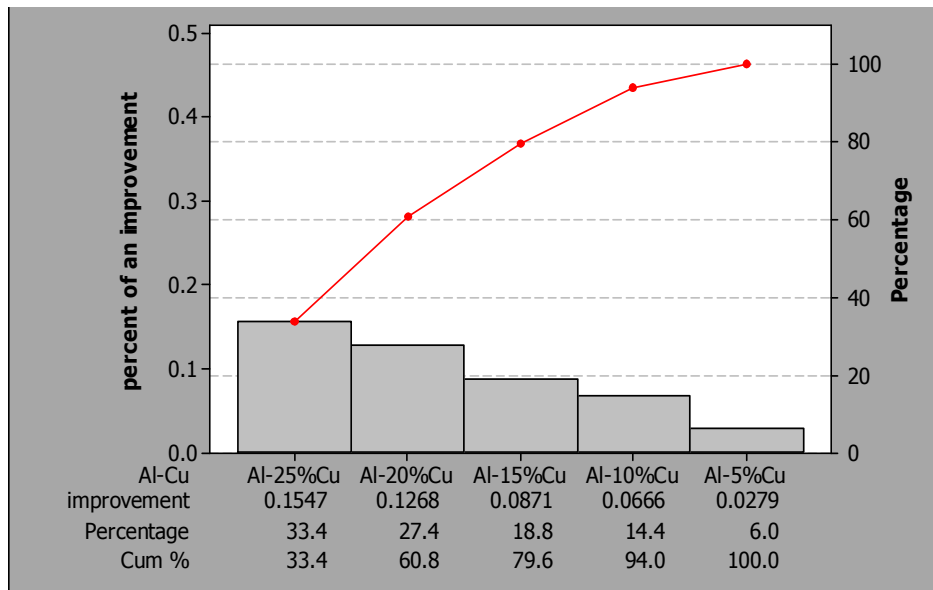


Figure 2. Pareto chart of an improvement factors vs. thermal conductivity

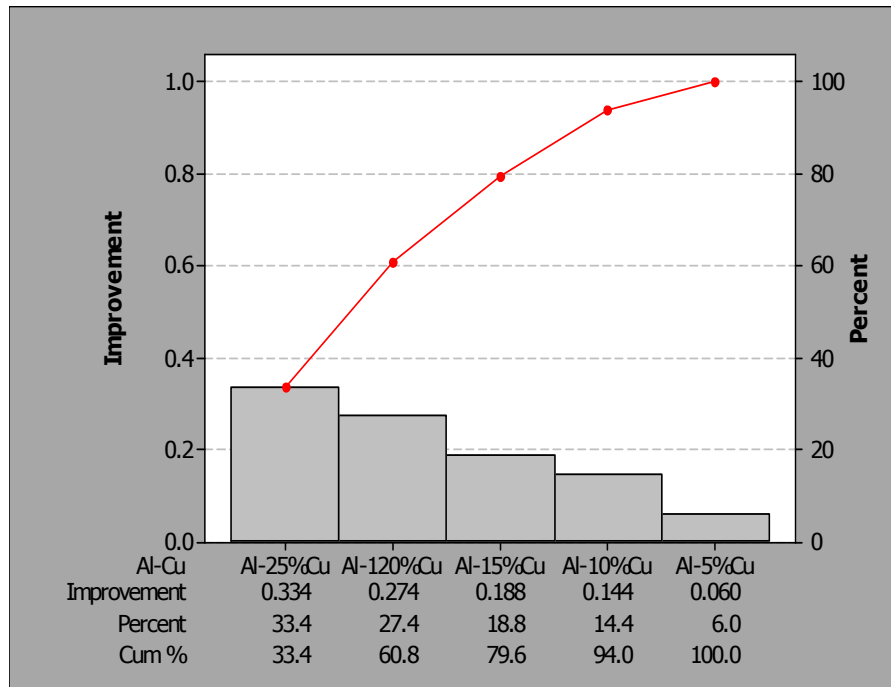


Figure 3. Pareto chart of improvement probabilities vs. thermal conductivity

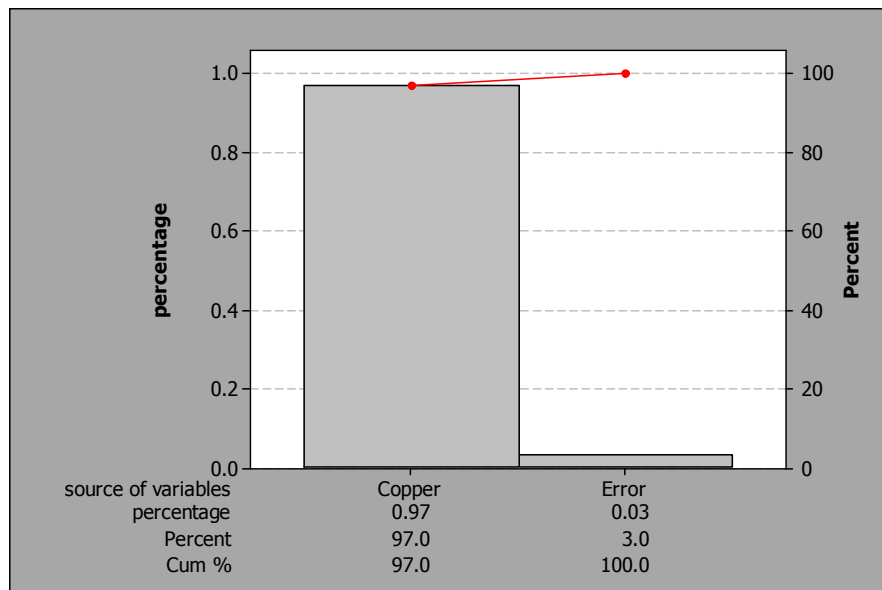


Figure 4. Pareto chart of contribution factors vs. thermal conductivity