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Research Article

Experimental investigation of heat treated alloy for hardness using multiple linear regression model

M. Maruthi Rao[1]*, NVVS Sudheer[2]

[1]Department of Mechanical Engineering, ANU, Guntur, AP, India
[2]Department of Mechanical Engineering, RVR & JC College of Engineering, Guntur, AP, India

*Corresponding Author email: chella.maruthi@gmail.com

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ABSTRACT

Quenching media, temperature and time plays vital role to improve the mechanical properties of metal and alloys. Tap water blend with cow urine different compositions hot metal at different temperature interval and quenched the blend and find the hardness values Al 2585 alloy. Cow urine contains different ingredients to enhance the mechanical properties of the meal and alloy. Ingredients like sodium and silicon some other elements present homogeneously improve properties like tensile strength, yield strength and hardness. Sodium refine the micro structure and silicon interlocking the grain boundaries of the metal. The model defined the relationship existing between the two variables of % of blend and temperature of specimen and hardness value, the dependent variables. This was correlated with existing theories are the relationship between Hardness and two variables. A analytical model was developed for the fore casting of hardness, it was proved and certified to be a positive valuation tool for estimating the hardness on the heat treatment process.

Keywords: *Al Alloy; Ageing; Hardness; Regression; Quenching Media*

1. INTRODUCTION

A combination of heating & cooling operation timed & applied to a metal or alloy in the solid state in a way that will produce desired properties. Quenching is an essential element in developing the desired properties of many steel and aluminum alloys. The quenching media (1) (water + ice) and ageing period has significant effect of hardness of aluminum metal matrix composites and developed regression analysis and analysis of variance. Green permeability (2) depend on two variables that is clay and moisture content percentage. Mathematical model developed close estimation of green permeability in green sand mould model is therefore not a bad estimation tool for green permeability. Study the effect of age hardening on hardness values (3) Aluminum and its particulate composite carried out. Developed simple regression model are dependent (Hardness) and independent variable (ageing time) degree of correlation existing between the two variables. In age hardening finally (4) inter metallic compound formed and no phase transformation takes place precipitation formed it increase the hardness. It must be said that (5) several authors ageing time increase hardness increased it depends on many factors like, time, temperature, cooling rate etc; cooling media(6) normally used water with renewable bio mass with different composition different time and temperature found the mechanical

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properties and evaluated micro structure of Al 2585 alloy using the (7) eco friendly quench ants like water, distilled water, cow urine etc. as quenching medium found the heat transfer characteristics of the cooling media which is best media give the fast cooling rate high temperature and slow cooling rate at low temperature range investigated. Mechanical properties and micro structure (8) evaluated using sheep urine as quenching media blend with water hardness value increase up to 50% blend after that it was decrease. This result agrees with studies on the effect of these variables by other researchers (9) came up with a model equation for the prediction of green permeability as:

$$Y_{X1X2P} = 25.37 + 0.0114X_1 + 61.73X_2 \quad (1)$$

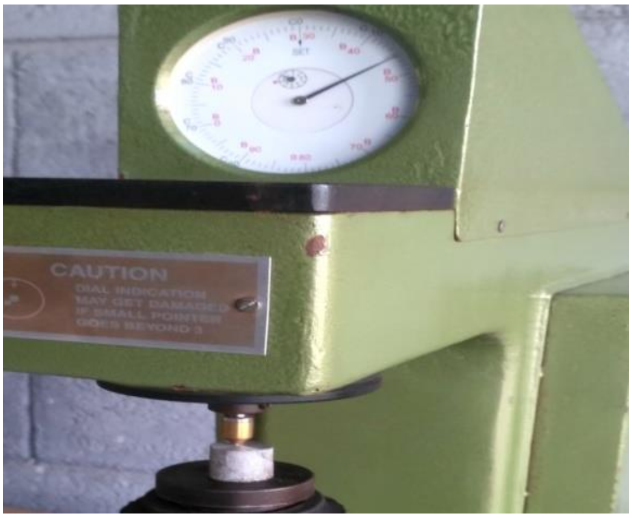

Fig. 1. Hardness Testing machine

Fig. 2. Cow urine blend with water

Table 1. Hardness values with variation in Blend and Temperature.

S.No	% X_1(Blend)	X_2(temp)	HBN(Y_H)
1	10	500	35
2	20	450	39
3	30	400	43
4	40	300	45
5	50	350	47
6	60	250	33
7	70	200	28

2. MATERIALS AND METHODS

The material used for this work Al2585 alloy purchased Fenfe metallurgical, India. Specimen cut with hack saw 15cmX15cm size heat treated with electric arc furnace up to 500^{0}C quenched the media soaking time is 15 min; nearly seven specimen tested (HBN) with different blends of quenching medium. Specimen at 500^{0}C, 0% water and a100% CU quenched the media after 15min; removed the specimen hardness test conducted. Similarly specimen at 450^{0}C 20% water and 80% cow urine (blend) quenched media after 15min removed the specimen Hardness tested. Repeat the above procedure 100% water 0% Cow urine blend.

3. MULTIPLE REGRESSION MODEL DEVELOPMENT

The basic two variable models (one dependent and one independent variable) is:

$$Y = a + bx \tag{2}$$

Which can be solved using the normal equations thus:

$$\sum Y = an + b\sum x \tag{3}$$

$$\sum XY = a\sum X + b\sum X^2 \tag{4}$$

From this can be developed models with more than two variables and this is illustrated below using a 3 variable model (one dependent and two independent variables, Y, X_1, and X_2):

$$Y = a + b_{1X_1} + \ b_{2X_2} \tag{5}$$

Which can be solved by the normal equations for a three variable model, as follows:

$$\sum Y_H = an + b_1\sum X_1 + \ b_2\sum X_2 \tag{6}$$

$$\sum X_1\, Y_H = a\sum X_1 + b_1\sum X_1^2 + b_2\sum X_1X_{\ 2} \tag{7}$$

$$\sum X_2Y_H = a\sum X_2 + b_1\sum X_1X_2 + b_2\sum X_2^2 \tag{8}$$

The line of best fit gives way to a plane of best fit, b_1 is the slope of the plane along the X_1 axis, b_2 is the slope along the X_2 axis and the plane cuts the Y axis at 'a'. The aim of adding to the simple two variable models is to improve the fit of the data. The closeness of fit is measured by the coefficient of multiple determination R^2 for which the general formula and a useful computational formula is given below:

$$R^2 = \frac{a\sum Y_H + b_1\sum X_{1Y_H} + b_2\sum X_{2Y_H} - \frac{(\sum X_H)^2}{n}}{\sum Y^2 - \frac{(\sum Y_H)^2}{n}} \tag{9}$$

For regression Y_P on X_1 (blend %)

$$b_{X1} = \frac{n\sum X_1Y_H - \sum X_1Y_H}{n\sum X_1^2 - (\sum X_1)^2} = \frac{7\times 10510 - 280\times 270}{7\times 14000 - (280)^2} = -0.0000014$$

$$a_{X1} = \frac{\sum Y_H}{n} - \frac{bX_1\sum X_1}{n} = \frac{270}{7} - \frac{-0.0000014\times 280}{7} = 39$$

The regression equation for the relationship of % of blend and Hardness value is:

$$Y_{X_1} = a_{X_1} + b_{X_1}X_1 = 39 + (-0.0000014X_1) = 39 - 0.0000014X_1$$

$$Y_{X_1} = 39 - 0.0000014X_1 \quad (10)$$

The coefficient of correlation for this relationship is:

$$r_{X_1} = \frac{n\sum X_1Y_H - \sum X_1 \sum Y_H}{\sqrt{n\sum X_1^2 - (\sum X_1)^2} \times \sqrt{n\sum Y_H^3 - (\sum Y_H)^2}} \quad (11)$$

Substituting the values in Table 2 in equation 11, we hav 0.0213, that is, coefficient of determination for $Y_H : X_1$

$$b_{X2} = \frac{n\sum X_2Y_H - \sum X_2Y_H}{n\sum X_2^2 - (\sum 2)^2} = \frac{7\times89050 - 2450\times270}{7\times602500 - (2450)^2} = 0.0213$$

$$a_{X2} = \frac{\sum Y_H}{n} - \frac{bX_2 \sum X_2}{n} = 38.571 - (0.0213 \times 2450) = -13.78$$

For regression of Y_H on X_2 (Temp)

The regression equation for the relationship of Temperature with Hardness value is:

$$Y_{HX_2} = a_{X_2} + b_{X_2}X_2 = -13.78 + (0.0213X_2) = -13.78 - 0.0213X_2 \quad (12)$$

The coefficient of correlation for this relationship is:

$$r_{X_2} = \frac{n\sum X_2Y_H - \sum X_2 \sum Y_H}{\sqrt{n\sum X_2^2 - (\sum X_2)^2} \times \sqrt{n\sum Y_H^3 - (\sum Y_H)^2}} = \frac{38150}{\sqrt{1785000}\times\sqrt{2014}} = 0.636$$

$r_{X_2}^2 = 0.4041$, *that is, coefficient of determination for YH : X2*

The multiple regression ($Y_H : X_1$ and X_2)

The multiple regression calculations are carried out using the three variable normal equations (6-7) with substitution with values from Table 2 and calculated values of a_{x1}, b_{x1}, a_{x2}, b_{x2} new set of equations are derived as follows:

$$270 = 7a + 280b1 + 2450b2 \quad (13)$$

$$10510 = 280a + 14000b1 + 84500b2 \quad (14)$$

$$89050 = 2450a + 84500b1 + 602500b2 \quad (15)$$

Solving these three equations simultaneously gave:

$a = 31.10$

$b_1 = -0.000418$

$b_2 = 0.021394$

Now substituting the model equation for three variables in equation 5 this new model equation is obtained:

$$Y_H = 31.10 - 0.000418X_1 + 0.02139X_2 \quad (16)$$

This model equation can be used to predict the Hardness value. For example what is the expected HBN with 20% blend and 450^0 C Temperature.

$$Y_H = 31.10 - 0.0000418 \times 20 + 0.02139 \times 450 = 40.72$$

When X_1 = 40, X_2 = 400, Y_H = 31.10 – 0.000418 X 40 + 0.02139 X 400 = 38

Coefficient of multiple determination, R^2

$$R^2 = \frac{(31.10 \times 270) + (-0.000418 \times 10510) + (0.021394 \times 89050) - \frac{(270)^2}{7}}{10702 - \frac{(270)^2}{7}} = -0.0109$$

4. RESULTS AND DISCUSSION

The developed model equation for the combined effect of % of blend and temperature variation on the HBN is:

$$Y_P = 31.10 - 0.000418X_1 + 0.0213X_2 \quad (17)$$

The various coefficient of correlations and coefficient of multiple determination can now be compile and made clear:

$$r_{x1} = -0.323$$
$$r_{x2} = 0.636$$
$$R^2 = -0.0109$$

r_{x1} indicates that about 32% of the variation in HBN is caused by variation in % blend (Cow urine+ water) this is not a major influence and the influence is negative which means that as the HBN is increasing the % blend up to (50% water + 50% cow urine) blend increased it showed that reduce HBN value, r_{x2} equal to 0.636 means that 63% of the variation in HBN are caused by change the temperature of the specimen. This is a great influence of the property of the metal at 350^{0}C it should maximum HBN (50% cow urine and % 50water). R^2 equals -0.0109 means that -10.9% is the combined influence of the two variables % blend and temperature of the specimen on the HBN and it is in the negative direction, quenching media, time and temperature decide the Hardness value of the alloy.

5. CONCLUSION

1. The developed analytical model feasible for a close estimation of HBN value in heat treatment process provided the s conditions (quenching time, temperature and media) are played vital role to decide the hardness of the alloy.
2. The correlation in the work made some good trailed in define the relationship between HBN and the variables % of blend and temperature of the specimen.
3. Existing theories on the relationship between HBN and the two variables of % blend and temperature of the specimen agree to a large intensity with the multiple linear regression model access used in the work.

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Conflict of Interest:

Authors No conflict of Interest

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