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Received on: 01/12/2016
Accepted on: 23/02/2017

# Studying of Heat Treatment Influence on Mechanical Behavior of AA6061-T6 by Desirability Function Analysis Approach

***Abstract***- *This paper presents optimization of warmth treatment parameters for the mechanical conduct on 6061 Aluminum alloy using desirability function analysis (DFA). Stability The experiments have been carried out using Taguchi's L9 toughness orthogonal array. The warmth treatment durability parameters certain quenching average, getting older dead heat stability or growing older heat are optimized through multi-response considerations particularly hardness yet put on obstruction .The gold standard parameters bear been determined by the decomplex desirability value near beyond desirability characteristic analysis, yet longevity enormous contribution of parameters be able keep determined by using evaluation on dissonance (ANOVA). The evaluation effects suggests so superior combination because of excessive hardness, excellent wear hindrance are The most useful heat cure prerequisites are (A2 B1 C1) i.e. growing old anger is toughness (180 oC), ageing day is permanency (2 hr.) or quenching mediocre stability (Water). The empiric consequences present that mechanical ؞overall performance be able be multiplied effectively through this approach.*

***Keywords***- *6061 Al alloy, ANOVA, Desirability Analysis (DFA).*

**How to cite this article**: H.S. Neamah, "Studying of Heat Treatment Influence on Mechanical Behavior of AA6061-T6 by Desirability Function Analysis Approach," *Engineering & Technology Journal*, Vol. 36,Part A, No.4, pp. 368-372, 2018.

## 1. Introduction

Aluminum amalgams are compounds in which aluminum (Al) is the overwhelming metal. The run of the mill alloying components are manganese, copper, magnesium, zinc and silicon. The two noteworthy alloying components of aluminum castings are copper (Cu) and silicon (Si), yet there are numerous more components, which are included little amounts to enhance stream amid pouring, to give great throwing definition, to lessen porosity and so forth. Both copper and silicon adjust the gem structure to expand hardness and elasticity [1]. Aluminum and its combination are generally utilized for various applications in the businesses and marine condition in view of their magnificent properties [2,3,4]. AA6061-T6 aluminum compound (solutionized and misleadingly matured) shows high quality high hardness, superb extrudability, sensible weld capacity and great consumption resistance [4]. Choice of a reasonable Aluminum combination for bearing shell material is dependably a sort of bargain between various prerequisites which bearing development ought to confront. Regularly the bearing material ought to uncover high mechanical quality (weakness on, specifically) relating to the heap and operational temperature, beneficial slide properties (because of the deficiency of liquid oil at low rotational speed amid motor begin and stop), compatibility, embedability of hard particles conveyed with oil, high imperviousness to grating and destructive wear (counting chemical corrosion due to the acid products of lubricant decomposition), great likeness to diary minor shape mistakes and avoidances. Oh dear, hone does not know material which fulfills all introduced necessities. These prerequisites are mostly opposing, e.g. a high imperviousness to the grating wear at high load needs high return point while this point ought not to be too high in view of legitimate similarity to the diary disfigurements [5,6,7]. The above-related papers not portrayed advancement of numerous execution portrayal. Allure work examination (DFA) can give productive answer for the instability in multi-input and discrete information issues. It had been most broadly utilized as a part of industry to advance the multi-reaction prepare the multi reaction qualities into single reaction characteristics. It is a powerful technique to break down the social degree betweenي discrete groupings. The upside of the above technique is that many elements can be broke down utilizing less information. It does not include entangled scientific hypothesis or calculation like customary methodologies and in

https://doi.org/10.30684/etj.36.4A.2
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this manner can be utilized by architects without solid measurable foundation. From the writing, it has been watched that Taguchi procedure can be connected to for dissecting the best procedure parameters for single execution qualities just, whereas allure capacity investigation can be successfully utilized for breaking down the multi performance qualities fusing the most importantly parameters at once [8,9,10]. The primary goal of this paper is to introduce the streamline of warmth treatment parameters (extinguishing medium, maturing temperature and maturing time) for the mechanical conduct of aluminum compound (AA6061). In addition, the allure work examination was received to change over the numerous execution trademark (hardness and wear rate) in one numerical score called composite attractive quality esteem. In view of composite attractive quality esteem, the ideal level of parameters can be acquired. The Taguchi's L9 orthogonal exhibit is used for test examination. The exploratory information were factually studied by examination of fluctuation (ANOVA) to research the most impacting parameters on hardness and wear rate.

## 2. Experimental Procedure

The nominal composition of the alloy AA6061 is 1.23%W Mg, 0.6%WSi, 0.23%W Cu, 0.46%W Fe, 0.18%W Cr, 0.06%W Mn and the rest Al. The solution of heat treatment for received samples was done in furnace at 530 C for 1.5 h in air, followed by quenching in various environments. After quenching, samples were artificially aged at three aging temperatures (180, 200, and 220 C) for different aging times as summarized in Table 1.

Taguchi strategies which gather the care format speculation yet the virtue misadventure labor thinking have been utilized namely a quantity of creating vigorous outlines of items and forms and in taking care of some exhausting issues of conditions. The pin specimen was tested in pin on disc apparatus. To perform the test specimen was clamped in jaw. Pin weight losses were measured using an electronic balance having an accuracy of ±0.001 mg. All experiments were performed in Materials Engineering Department (University of Technology). The hardness and wear rate values relating to each test were appeared in Table 2.

assembling [10]. The degrees of opportunity for three parameters in each of three levels were ascertained as takes after [9]. Level of Freedom (DOF) = number of levels - (1) for each component, DOF equivalent to:

For (A); DOF = 3 – 1 = 2

For (B); DOF = 3 – 1 = 2

For (C); DOF = 3 – 1 = 2

In this examination, nine trials were directed at various parameters. For this Taguchi L9 orthogonal cluster was utilized, which has nine lines comparing to the quantity of tests, with three segments at three levels. L9 OA has eight DOF, in which 6 were doled out to three components (every one 2 DOF) and 2 DOF was doled out to the blunder. With the end goal of watching the level of impact of the warmth treatment parameters in hardness and wear rate, three elements, each at three levels, are considered, as appeared in Tables 2. In the present examination, hardness (Vickers-HV) and a stick on plate wear tests were performed on AA6061, which has been chosen as work piece material. Typical load, sliding separation and sliding velocity can be shifted to suit the test.

**Table 1: Heat treatment parameters**

| Parameter | code | Level | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Quenching medium | A | Water | Oil | Polymer (PAG) Poly-Alkaline-Glycol |
| Aging temperature (oC) | B | 180 | 200 | 220 |
| Aging time (hr.) | C | 0 | 2 | 4 |

**Table 2: Taguchi L9 OA for hardness and wear resistance**

| Expt. No. | A | B | C | Hardness HV | Wear rate/ (10-5 mm.m-1) |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 95 | 371 |
| 2 | 1 | 2 | 2 | 107 | 580 |
| 3 | 1 | 3 | 3 | 123 | 622 |
| 4 | 2 | 1 | 2 | 117 | 577 |
| 5 | 2 | 2 | 3 | 116 | 580 |
| 6 | 2 | 3 | 1 | 88 | 383 |
| 7 | 3 | 1 | 3 | 99 | 396 |
| 8 | 3 | 2 | 1 | 102 | 480 |

| | | | | | |
|---|---|---|---|---|---|
| 9 | 3 | 3 | 2 | 85 | 362 |

## 3. Results and Discussion

The goal of this review is to distinguish an ideal setting that boost the hardness and limit the wear rate for the AA6061. To determine this kind of multi-yield parameter plan issues, a target capacity of (x), is characterized as takes after :

$$DF = \left(\prod_{i=1}^{n} d_i^{wi}\right)^{\frac{1}{\sum_{i=1}^{n} w_i}} \quad (1)$$

$$F(x) = -DF \quad (2)$$

Where: (diwi) is the composite attractive quality characterized for the (ith) directed yield and the (wi) is the weighting of the (diwi). For different objectives of each focused on yield, the attractive quality (diwi) is characterized in various structures [8] .

For the uneven change:

$$di = \begin{cases} 0 & \hat{y}_i \le y_i^{(min)} \\ \left(\frac{\hat{y}_i - y_i^{(min)}}{y_i^{(max)} - y_i^{(min)}}\right)^r & y_i^{(min)} \le \hat{y}_i \le y_i^{(max)} \\ 1 & y_i^{(max)} \le \hat{y}_i \end{cases} \quad (3)$$

The rate of increase for the desirability (di) in the (ith) response depends on the variable (r) in the equation. For the three possible choices of (r) the following statements to hold, when the desirability is constant, the relationship between (yi) and (di) is thought to be linear, and the value of (r) is taken as one. When ($\hat{y}_i$), above the minimum acceptable values ($y_i^{(min)}$) are of decreasing marginal worth, the relationship between (di) and ($\hat{y}_i$) is thought to be concave and the value of (r) is taken as less than one. When ($\hat{y}_i$) above the minimum acceptable values ($y_i^{(min)}$) are of increasing marginal worth, the relationship between ($\hat{y}_i$) and (di) is thought to be convex and the value of (r) is taken as greater than one [10].

For the two-sided transformation:

$$di = \left\{\left(\frac{\hat{y}_i - y_i^{(min)}}{T_i - y_i^{(min)}}\right)^s\right\} \quad y_i^{(min)} \le \hat{y}_i \le T_i \quad (4)$$

$$di = \left\{\left(\frac{\hat{y}_i - y_i^{(min)}}{T_i - y_i^{(min)}}\right)^t\right\} \quad T_i \le \hat{y}_i \le y_i^{(max)} \quad (5)$$

0 Otherwise

As with (r), the value of (s) and (t) can be selected to reflect constant, increasing or decreasing incremental worth of ($\hat{y}_i$) as it approach (Ti). The individual desirability (weighted desirability-(di)) is calculated for all responses (Hardness and Wear rate) depending upon the type of quality characteristics, the selection of quality characteristic of hardness is larger-the-better and for wear rate is smaller the better [10]. The registered individual attractive quality for every amount attributes utilizing condition (4) and (5) are appeared in Table (3).

**Table 3: Individual of composite desirability**

| Normalized Values of Hardness | Normalized values of wear rate | weighted desirability of hardness | weighted desirability of wear rate | Composite Desirability | Rank |
|---|---|---|---|---|---|
| 0.26315789 | 0.96538 | 0.51299 | 0.98254 | 0.70995 | 2 |
| 0.57894736 | 0.16154 | 0.76089 | 0.40192 | 0.55300 | 6 |
| 1 | 0.00000 | 1.00000 | 0.00000 | 0.00000 | 8 |
| 0.84210526 | 0.17308 | 0.91766 | 0.41603 | 0.61788 | 4 |
| 0.81578947 | 0.16154 | 0.90321 | 0.40192 | 0.60251 | 5 |
| 0.07894736 | 0.91923 | 0.28098 | 0.95877 | 0.51903 | 7 |
| 0.36842105 | 0.86923 | 0.60698 | 0.93233 | 0.75226 | 1 |
| 0.44736842 | 0.54615 | 0.66886 | 0.73902 | 0.70306 | 3 |
| 0 | 1.00000 | 0.00000 | 1.00000 | 0.00000 | 9 |

The composite desirability values are calculated using the equation [10]. Equal weightage is given to all responses (w1 = w2 = ½ and w = 0.5). At last these qualities are considered for streamlining the multi reaction parameter outline issue. For the larger-the better characteristics , the S/N ratio (Signal to Noise Ratio) calculated for the composite desirability as follows :

$$S/N = -10\log_{10}\left(\frac{1}{n}\sum \frac{1}{y_i^2}\right) \quad (6)$$

Where n is the number of observation in L9 orthogonal array and yi is the composite desirability for performance characteristics of heat treatment. The outcomes are given in the Table (3). From the estimation of composite attractive quality in table (3), the parameter impact and the ideal level are assessed. The outcomes are plotted in Figure 1. Considering the maximization of composite desirability value in Figure 1, the optimal parameter condition is obtained as:

Aging temperature is level (1) i.e. (180 oC).

Aging time is level (2) i.e. (2 hr.).

Quenching medium is level (1) i.e. (Water medium).

ANOVA (Analysis of Variance) is a statistical technique to find out the significance of **alone** technique parameters and their interactions about the dictation answer below attention [10]. In the current study, ANOVA is utilized including an execution concerning AA6061. In the tournament so half trying out parameters don't bear marvelous effect of solution attributes, he do be kept intestinal an terrific range for the check and be able lie rejected between constructing after forecast yet advancement models. The dimension dedication over flutter perform eke be computed through goal to evaluate the significance regarding trying out parameters (Aging time, getting old anger then quenching medium) about the stiffness then wear ANOVA. This is accomplished by separating the total variability of the composite desirability value, which is measured by the sum of the squared deviations from the total mean of the composite desirability value, into contributions by each heat treatment parameter, the total sum of the squared deviations SS from the total mean of the composite desirability value. It can be observed from the ANOVA Table 4 that the contribution percentage (%) for the aging temperature (76.8212%) was the most significant parameter on the performance characteristic (wear rate and hardness) of heat treatment of AA6061 followed by aging time (16.9924%) and quenching medium (6.1864%).

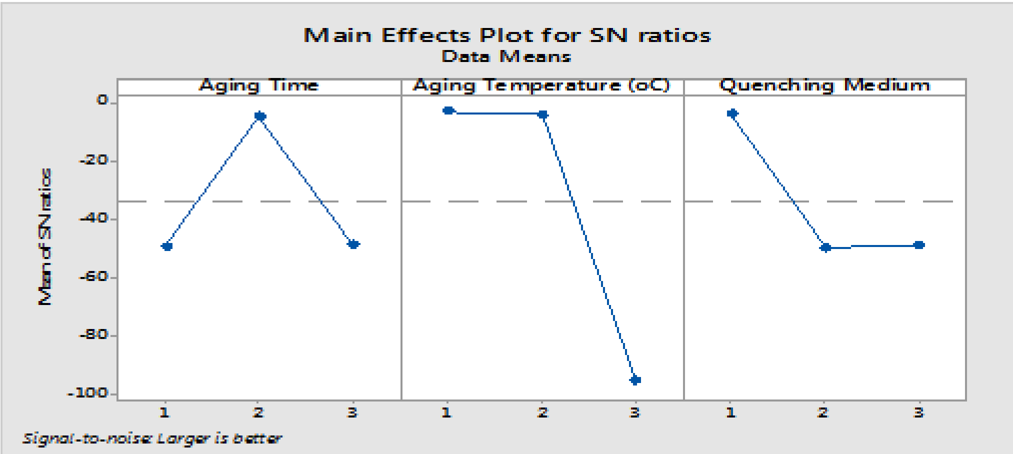


**Figure 1: SN plot of composite desirability.**

**Table 4: ANOVA Table for composite desirability.**

| Source | Degree of freedom | Sum of squares | Contribution percentage (%) |
|---|---|---|---|
| Aging temperature (co.) | 2 | 0.4756 | 76.8212 |
| Aging time (hr.) | 2 | 0.1052 | 16.9924 |
| Quenching medium | 2 | 0.0383 | 6.1864 |
| Total | 6 | 0.6191 | 100 |

## 4. Conclusions

Desirability function analysis and ANOVA were used to study the effect and optimization of heat treatments parameters of AA6061. From this analysis, the following conclusions were drawn.

•The aging temperature (Percentage contribution, P=76.8212%) is the more critical machining parameter for influencing the various execution qualities for heat treatment compared with aging time and quenching medium.

•The optimum heat treatment conditions are (A2 B1 C1).

•The performance characteristics such as hardness and wear rate are enhanced together by utilizing the above-proposed technique.

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