OPTIMIZATION OF EFFECT OF PRODUCTION PARAMETERS ON WEAR RESISTANCE OF COATED LAYER ON THE SURFACE OF COPPER ALLOY BY TAGUCHI METHOD

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ABSTRACT

In this study, a coated layer with ferromanganese is obtained with using the tungsten inert gas (TIG) method on the copper alloy surface. And, this layer is subjected to a wear test. Statistical analysis of wear test results are performed using ANOVA and Taguchi methods The samples are subjected to a surface layer using different current levels of 115 A, 125 A and 140 A. Adherent wear test is carried out under dry conditions of the coated samples under the force of 20N, 40N and 60N and at different sliding distance of 100 m to 500 m. In addition, experimental design is carried out with L_{27} (3^3) Taguchi orthogonal array. ANOVA and F-test are applied from the statistical methods to determine the level of importance of the experimental parameters (force, current and sliding distance) over the wear amount. The statistical results show that the wear amount is decreased with increasing current level, and the wear amount is increased with increasing slip distance and the force in adhesive wear test.

Keyword: *Cu alloy, Surface coating, Adhesive wear, Taguchi, ANOVA*

1. INDRODUCTION

Surface hardening process is to create a layer with excellent corrosion and oxidation resistance on the surface of a substrate, and to improve the surface properties of the metal with the current agglomeration. High production quality, long life materials and low cost are targeted based on the prolongation of the wear life of parts exposed to wear environments. Evaluation of surface coated and uncoated specimens under dry weather conditions by wear test laboratory experiments has shown that coated specimens have shown significant improvements in wear behaviors [1].

Various coating processes are applied to some materials used in the industry in order to provide properties such as corrosion resistance, wear resistance, thermal and electrical conductivity [2]. Coating or alloying of ceramic or metal materials to different sub-material surfaces is possible with today's coating and surface alloying techniques (such as chemical vapor deposition (CVD), physical vapor deposition (PVD), plasma nitriding, plasma spraying (PS), laser beam coating, electron beam, gas tungsten arc (GTA) and plasma transfer arc (PTA) techniques [3-6].

The Taguchi design of experiment method emerges as a successful method of solving optimization problems by increasing processing performance with a fewer experiments and less cost. Taguchi significantly reduces the number of experiments, thereby preventing the loss of time and cost with developing the vertical indexes. The great advantage of the Taguchi method is that it can predict the results. The Taguchi method not only ensures that the solution is achieved with only a few experiments, it also supports high quality process and product development from every angle. It shows the minimum sensitivity to the production conditions of the process or product and to uncontrollable factors. Both the necessary tolerances are provided at the lowest cost and the Taguchi loss function develop a new sense of quality cost [7].

In this study, the effect of ferromanganese coating of copper alloy surface on wear resistance is studied, and the parameters force, current and sliding distances are investigated experimentally and statistically.

2. MATERIALS AND METHOD

2.1 Coating Method and Microstructural Analysis

In this study, copper alloy is obtained with adding Al, Zn and Sn elements by casting. Specimens of dimensions of 100 x 20 x 15 mm are removed from this alloy. Ferromanganese alloy powder placed on the surface of the samples is coated with tungsten inert gas (TIG) method to form a top layer (Figure 1). Surface coating is carried out using TIG method at 115A, 125A and 140A currents. The chemical compositions of the samples used as base materials and the ferromanganese alloy powder are given in Table 1.

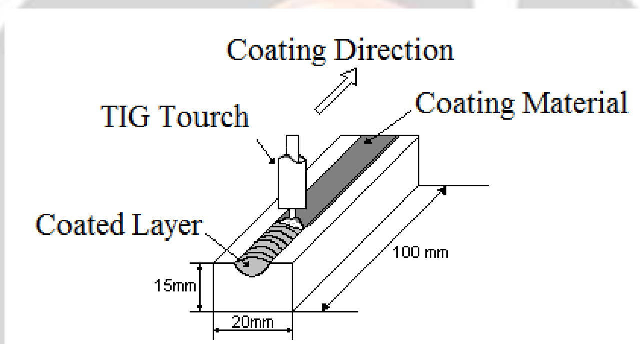


Fig -1: Schematic representation of surface coating by TIG method

Table -1: Chemical composition of copper alloy and ferromanganese alloy powder by % weight

Alloy Elements (% Weight)									
Alloy Elements	**Cu**	**Al**	**Zn**	**Sn**	**Fe**	**Mn**	**Ni**	**C**	**Si**
Cu-alloy	**rest**	**7,00**	**7,00**	**4,50**	**1,50**	**1,00**	**1,00**	**-**	**0,38**
(Fe,Mn) powder	**-**	**-**	**-**	**-**	**83,40**	**13**	**2,80**	**0,70**	**0,10**

Scanning electron microscopy (SEM) is used for microstructure studies of the samples, and energy distribution analysis (EDS) point analyses are used to determine the phases formed in the structure. The wear test is performed on a block-on-ring model. Experiments are carried out with a diameter of 9.5 mm AlSl 9840 steel abrasive at different durations, at different sliding distances of 100, 250 and 500 m at three different loads of 20, 40 and 60 N, and at a shear rate of 0.0079 m/s. Wearing amount is weighed with an electronic balance sensitive to 10^{-5} g weight before and after wearing, and mass loss is determined.

2.2 Statistical Method

research. Taguchi method is a powerful tool to develop the design of experiments and to determine the optimum parameters to have minimum wearing rate. In the analysis, signal-to-noise (S/N) ratios are very important to find response of the experimental trials. There are three concepts to analyze the data, the concepts are;

- Higher the better,
- Nominal to better,
- Lower the better,

Analysis of variance (ANOVA) gives the information of the each parameter.

A robust design of the L_{27} orthogonal array is used for experimentation [8]. Force, current, sliding distance are the parameters expected to influence the wearing amount. These parameters have 3 different levels. For example,; 115 A, 125 A and 140 A current levels; 20 N, 40 N and 60 N forces, and 100 m, 250 m and 500 sliding distances are given in Table 2.

Table -2: Factors and levels

Factors	**Level 1**	**Level 2**	**Level 3**
A: Load (N)	20	40	60
B: Current level (A)	115	125	140
C: Sliding distance (m)	100	250	500

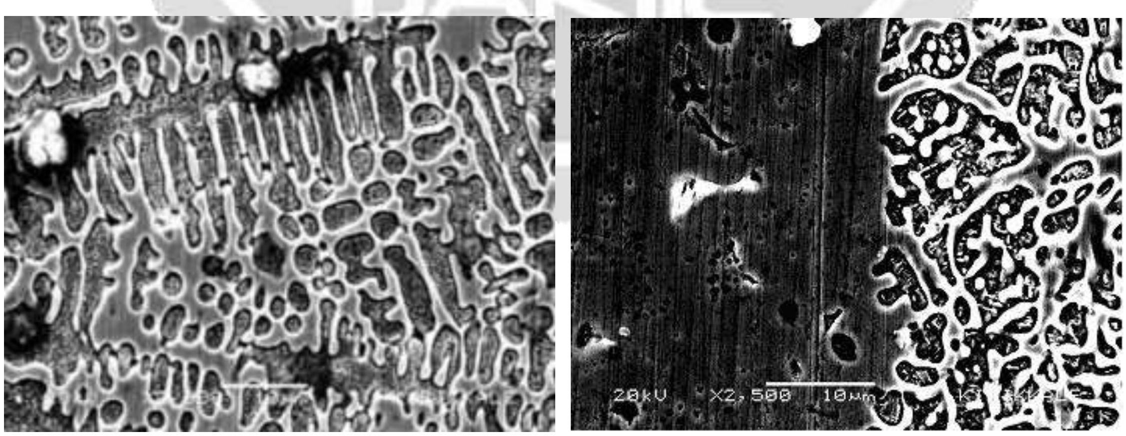
In our experiments, smaller the better model is used. Because, the main goal of the research is to have a minimum wear resistance. Signal to Noise ratio (S/N) can be found from below equation;

$$\text{Lower the better S/N} = -10 \times \log 10 \left(\frac{1}{n}\sum_{i-1}^{n} Y_i^2\right)$$

Where *Yi* = the result of the each experiment, i = number of repetitions

3. RESULTS AND DISCUSSIONS

3.1 Microstructural Characteristics of Coated Layer



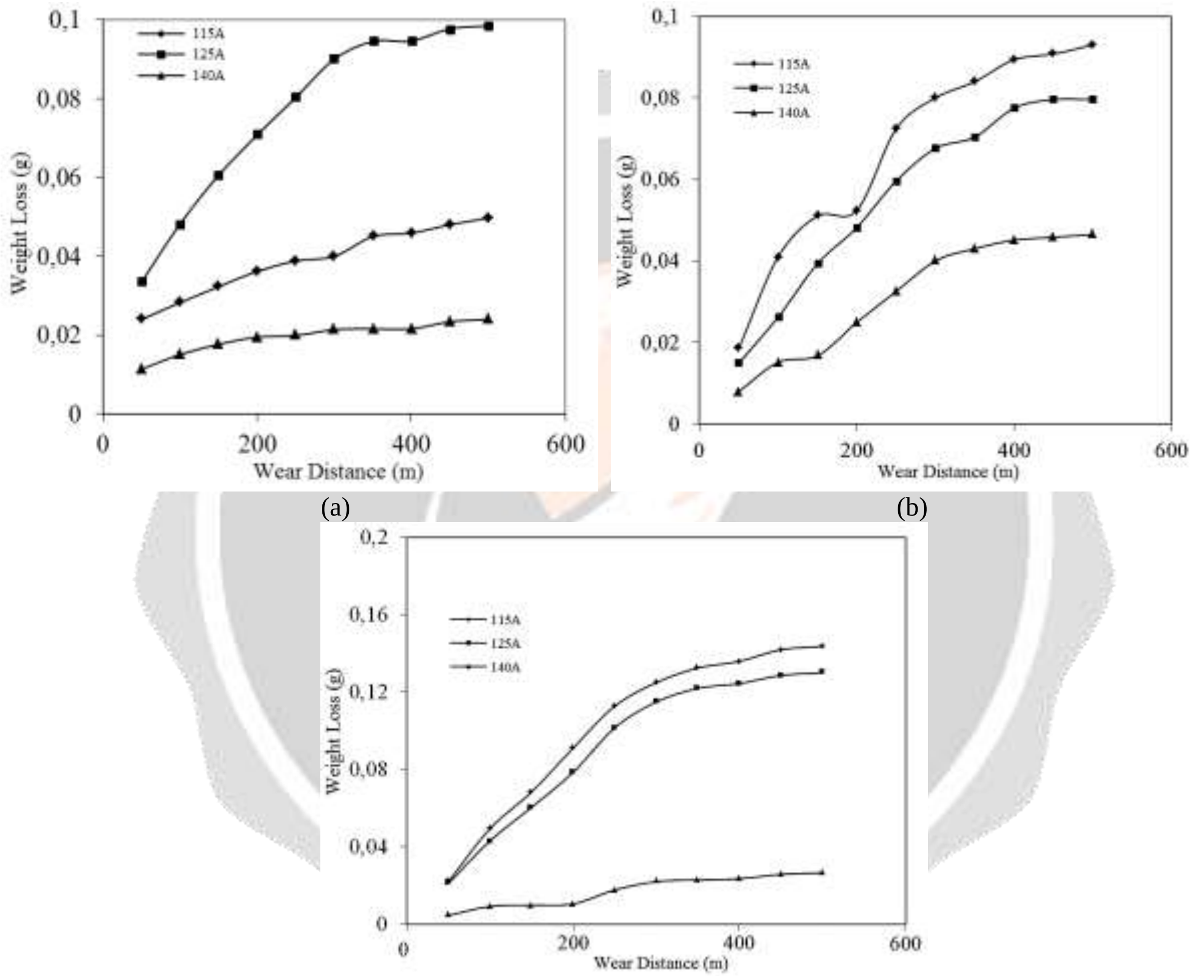
(a) (b)

Fig -2: (a) Surface layer of the coated sample and (b) SEM photo of interface with coated layer, at 140 A.

The SEM microstructure photographs taken from the surface of the coated sample at 140 A are shown in Figure 2. In these photographs, it is seen that there is a completely dendritic structure in the coating region (Figure 2-a) and a good transition between the coated layer and the main material (Figure 2-b). In the interface regions; cracks, pores, undesired residues, etc. The absence of their presence proves to be a good match between the coated layer and the substrate material. With increasing current value, the amount of energy given to the sample increased and different microstructures are obtained.

3.2 Wear Test Results

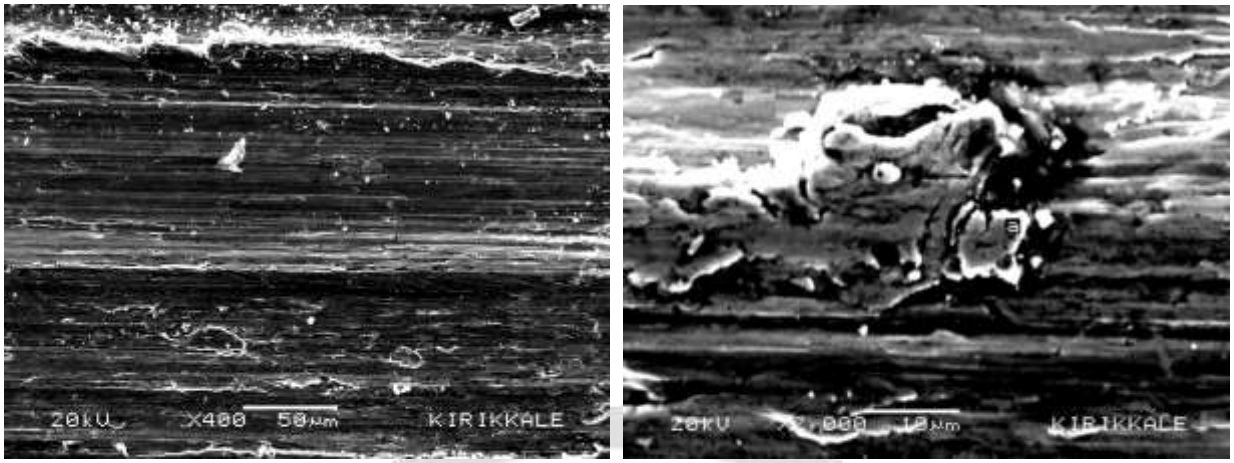
The values of wear amount under load of 20N, 40N and 60N are shown in Figure 3. By increasing the applied load from 20 N to 40 N and 60 N, the abrasive effect at the interface is increased and this caused an increased on wear.



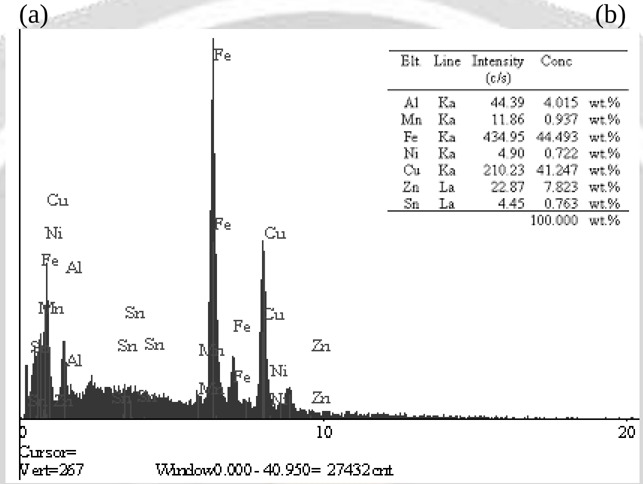
(c)

Fig -3: Wear amount of the specimens at (a) 20 N, (b) 40N and (c) 60N load

As the energy input to the sample increases during surface coating, it makes the distribution of the ferromanganese powder in the layer easier and allows the dendrites to grow. This change in the dendritic structure has caused the wear resistance to decrease.



(a) (b)



(c)

Figure 4. (a) SEM photo of worn surface, (b) SEM photo of EDS points of the worn surface, (c) EDS analyzes of point a, taken from the of coated sample with 125 A.

The SEM photo taken from the worn surface is shown in Figure 4-a. The EDS analyses taken from the points indicated on these SEM photographs (Figure 4-b) gives that in point a, this region is rich in Fe and contains 44.493% Fe, 41.247% Cu (Figure 4-c). When we look at the EDS analysis shown on the wear surface photograph, it is seen that the areas where the ruptures occur are rich in Fe. EDS analysis of the point a is pointing to the intensification of Fe, Zn, and Al elements in Cu matris.

3.3 Statistical Results

The S/N ratios calculated for the experimental control parameters specified in Section 2 are given in Table 3. In this table, the values that maximize the results under the influence of the test parameters are marked. Moreover, for better interpretation of the results, these values are used to plot the effect of the wear loss feature of the parameters of force, current and sliding distance in Figure 5. Experimental study findings are verified by statistically revealing that the characteristics of the powder alloy are influenced by different current levels and the amounts of wear are affected by the applied force and the sliding distances, as shown in Figure 3 and the analysis of variance (Table 4) based on means. An increase in wearing amount is an expected result with an increase in sliding distance (an increase of 100 m to 500 m). In addition, it is seen with the statistical results that the differences in force and current are affecting wear amount, and force and current are two independent parameters in experiments too. When the ANOVA table is examined, the differences in force has an important effect on the wear amount even though it is not as good as current level and sliding distance.

Table -3: S/N ratios of factor levels

	Wearing amount		
	Level 1	**Level 2**	**Level 3**
Force	28,50	26,90*	26,01
Current	24,26	23,49	33,66*
Sliding Distance	31,52*	26,12	23,78

* Levels that maximize test results

Table -4: Analysis of variance analysis (ANOVA) for wear amount

Source	DF	Seq SS	MS	F	P
Force	2	0,003171	0,001585	3,57	0,047
Current	2	0,014523	0,007261	16,34	0,000
Sliding Distance	2	0,009797	0,004898	11,03	0,001
Error	20	0,008886	0,000444	-	-
Total	26	0,036376	-	-	-

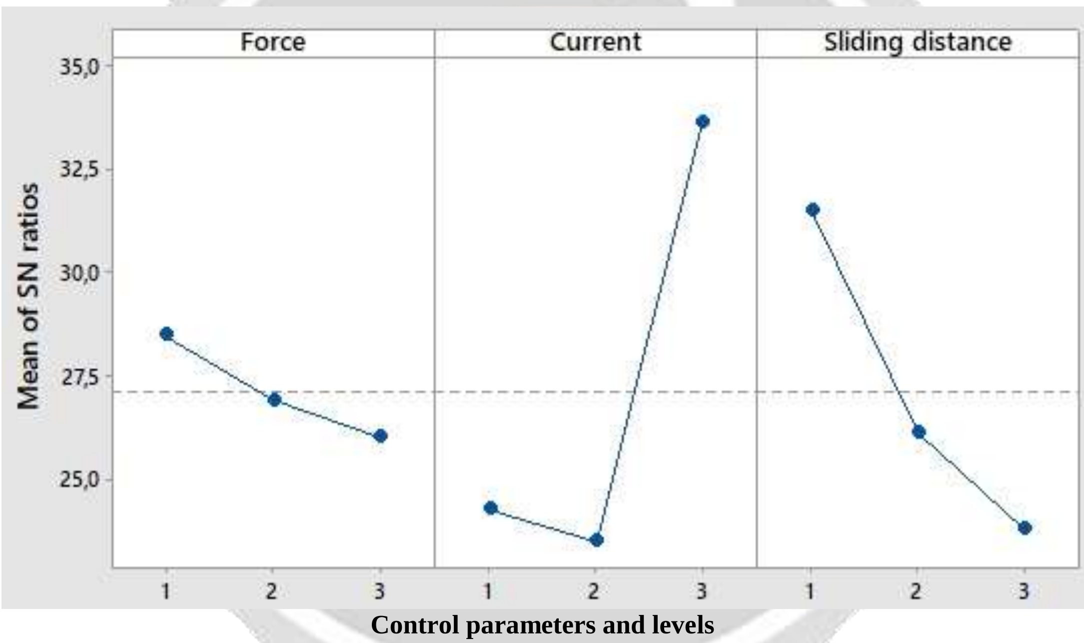


Fig -5: S/N ratio graph of experimental parameters for wear amount

When Figure 5 is examined, it is seen that the slope decreases with the increase of the force and sliding distance, and the slope increases with the increase of the current. This effect graph, which is calculated according to the calculated S/N ratio values, shows that increasing the current level causes the minimization of wear amount, which is a characteristic feature of the dust alloy; increasing sliding distance causes the maximization of wear amount (increase of wear amount). Since S/N ratio is highest, the sample with 140 A current has the least amount wear.

4. CONCLUSIONS

- Dendritic microstructure formed throughout the coating layers. It is determined with EDS analysis that regions at dendrites are rich in Fe and regions between dendrites are rich in Cu.
- It has been determined that the least wear amount is achieved with the sample at 140 A current level under the loads of 20N, 40N, and 60N.
- The statistical study results supports the experimental study results.

- As a result of the statistical study, it is found that increasing the current level reduce the wear loss of the powder alloy even though the wear loss is increased at 125 A current level.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1]. Özel S., Turhan H., and Somunkıran İ. "The Investigation of effect on Wear Resistance of Production Parameters and Ferromanganese Alloyed on Surface of Cu Alloy By Using Tig Process." International Congress of Vocational and Technical Education Technologies, 3. 1444-1450, 2005.
[2]. Molleda F., Mora J., Molleda F. J., Mora E., Carrillo E., and Mellor, B. G. "A study of the solid–liquid interface in cobalt base alloy (Stellite) coatings deposited by fusion welding (TIG)." Materials characterization, 57.4, 227-231, 2006.
[3]. Zhang S., Jiang F., and Ding W. "Microstructure and mechanical performance of pulsed current gas tungsten arc surface engineered composite coatings on Mg alloy reinforced by SiCp." Materials Science and Engineering:A, 490.1, 208-220, 2008.
[4]. Garces G., Cristina M. C., Torralba M., and Adeva P. "Texture of magnesium alloy films growth by physical vapour deposition (PVD)". Journal of alloys and compounds, 309(1), 229-238, 2000.
[5]. Eroğlu M., and Özdemir N. "Tungsten-inert gas surface alloying of a low carbon steel." Surface and Coatings Technology, 154(2), 209-217, 2002.
[6]. Ozel S., Kurt B., Somunkiran I., and Orhan, N. "Microstructural characteristic of NiTi coating on stainless steel by plasma transferred arc process." Surface and Coatings Technology, 202(15), 3633-3637, 2008
[7]. Şirin E., Şirin Ş., Turgut Y., and Korkut İ. "Optimization of Surface Roughness Using the Taguchi Method in Milling of AISI D2 Cold Work Tool Steel". Düzce University Journal of Science and Technology, 3(1), 2015.
[8]. Montgomery, D. C. "Design and analysis of experiments." John Wiley & Sons. 7th Edition, 730 Arizona State University, USA, 978-0-470-45687-3, 2009.