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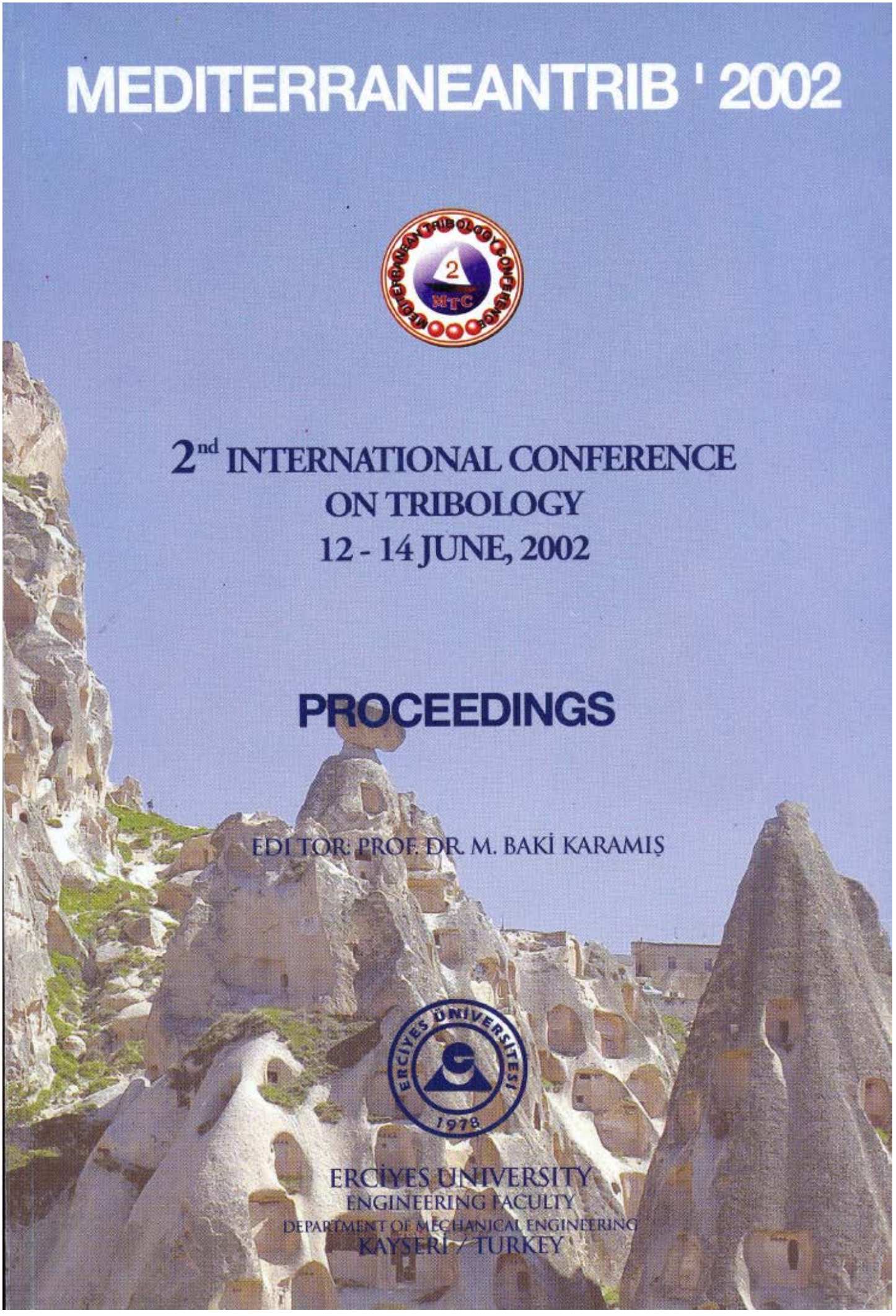

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THE NUMERICAL CALCULATIONS FOR THE RELATIONSHIPS BETWEEN THE SOLUTION - TREATING TEMPERATURE AND THE ABRASIVE WEAR BEHAVIOUR FOR 2014 AL ALLOY

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ABSTRACT

The aim of this work is to estimate the empirical relationships between the solution treating temperature and the abrasive wear parameters for 2014 Al alloy .The abrasive wear tests were conducted dry, at room temperature, under room humidity, for a speed of 0.18 m/s, a sliding distance of 11 m, a load of 5 N using 320 grit abrasive papers.For the numerical calculations between the solution treating temperature and abrasive wear behaviour, five functions of .the functions of polynomial, linear, logarithm, power and exponential were used to analyse the effects of the solution treating temperature on the wear volume, wear resistance and wear coefficient and the relationships between each others It has been found that the polynomial function has the best correlation for the relationships between the temperature and abrasive wear behaviour.Generally, experimantal and analytical results have showed good compatibility.

Keywords *:* The solution treating temperature, Abrasive wear, wear resistance.

1.INTRODUCTION

The best-known characteristic of Al is its ligth weight. Some Al alloys have been a better strength-to-weigth ratio than that of high strength steels. In addition, Aluminyum is suitable for casting and all machining and forming operations; it also has high corrosion resistance, and high electrical and termal conductivity. The excellent mechanical and tribological properties of Al alloys in engineering applications such as plain bearings, internal combustion engine pistons and clinder liners, aircraft constructions, heavy-duty forgings, and truck frames.

A great deal of research on the abrasive wear behaviour of Al alloys has been carried out experimentally [1-6]. Song et al. [1] studied changes in the abrasive wear resistance of aluminyum-based composites heat treated for different ageing conditions. They found that the the abrasive wear resistance increase with increasing the ageing temperature to 200 °C, but at 250 °C decrease due to the coarsening of intermetallic precipitates. In another study, ithas been shown that most composites exhibit better abrasive wear resistance than the unreinforced matrix alloys. And the impact-abrasive resistance increases with decreasing particle size and increasing volume [2]. Odabaş et al [3] studied changes in the reciprocating aand continous abrasive wear of solution-treated and age hardened 2014 Al alloy. They found that the values of average roughness of worn surfaces for the reciprocating wear higher than those for the continuous wear.

The aim of this work is to estimate the empirical relationships between the solution treating temperature and the abrasive wear behaviour for 2014 Al alloy because one of the main aims of wear investigations is to be to design mechanical components that will run under a given set of conditions with acceptable known values rate.

2. THE FUNCTIONS OF NUMERICAL CALCULATION

In this study, the mathematical functions were used for the numerical analysis of the relations the factors of abrasive wear as follows :

1-Linear function : $y = ax + b$

2-Power function : $y = ax^b$)

3-Polynomial function : $y = a_0 + a_1x + a_2x^2 + \ldots + a_nx^n$ (1)

4-Logarithmic function : $y = a\ln x + b$

5-Exponential function : $y = a\, e^{bx}$

The hardness (H) of test material can be written as a function of the solution-treating temperature (t)

$$H = f(t) \tag{2}$$

For the two-body abrasive wear, the worn volume V[m^3] is proportional to the load F [N] and the sliding distance L [m] , but inversely proportional to the hardness H [N/m^2] of the softer surface. Thus leads to the well-known expression for abrasive wear volume [4]

$$V = k_a F L / H = G / \gamma \qquad [m^3] \tag{3}$$

Where G [kg] is the weigth loss, and γ [kg/m^3] is the density of test material (for 2014 Al alloy, 2800 kg/m^3). The abrasive wear coefficient can be written as

$$k_a = V. H / F. L = G. H / F .L. \gamma \tag{4}$$

Abrasive wear coefficient is a function of V and t as follow :

$$k_a = f(V), \qquad k_a = f(t) \tag{5}$$

The wear volume V is written as a function of solution treating temperature (t)

$$V = f(t) \tag{6}$$

The wear resistance (ε) can be explained as

$$\varepsilon = L / V \qquad [m/m^3] \tag{7}$$

The wear resistance can be written as a function of t

$$\varepsilon = f(t) \tag{8}$$

2. EXPERIMENTAL DETAILS

2.1. Materials

In this study, 2014 Al alloy with higher Cu content was chosen as a test material. For this material, chemical analysis (wt %) was : Cu 4.18; Mn 0.72; Si 0.81; Fe 0.26; Zn 0.02 and Ti 0.0019. In Generally, this alloy is used for heavy-duty forgings, aircraft fittings and truck frames. After casting, the homogenizations heat treatment was applied to the alloy at 500 °C for 2 h and the hot-pressed billets with a 45 mm diameter were extruded at 450 °C into rods with a 16 mm diameter with an extruded ratio of 3:1.After then rods were left for cooling at the room temperature, they were straightened by a 3% plastic deformation.

The specimens to be used for the wear tests were cylinders with a 16 mm diameter and a length of 20 mm while those for the hardness tests were blocks 2.5x8x5 mm^3 in size.Before the wear tests, the specimens were solution treated in a muffle furnace and then quenched in cold water (16 °C). Later, the ageing treatment was carried out at 185 °C for 8 h in the furnace.T6 heat-treatment conditions (solution heat treated, artificially aged) and the hardness values are given in Table.1.

2.2. Test Methods

Abrasive wear tests were carried out using a grinding-polishing machine with the pin-on disc configuration under dry sliding conditions (Fig.1). The disc is 200 mm diameter. The dics speed of the electric motor is changed means of an A.C. speed-control converter. The waterproof SiC papers on the rotating disc were used an abrasive materials.The stationary pin specimen was mounted in a holder so that it could be removed for measurement and was rubbed against the surface of an SiC paper fixed to the flat surface of revolving disc.Wear was determined over a friction path of 11 m during the wear tests.

Tablo.1. The solution-treating temperature on the abrasive wear behaviour.

Temperature [°C]	Hardness HB30	Wear loss G [mg]	Wear volume V [m^3]x10^{10}	Wear coefficient k_ax10^2	Wear resistance [m/m^3]x10^{-8}	Wear rate k_a/H [m^3/Nm]x10^{11}
400	85	9.9	35.34	5.4	31.12	6.3
450	115	7.5	26.77	5.6	41.09	4.8
475	134	7	25	6.23	44	4.64
490	145	6.8	24.27	6.4	45.32	4.41
505	150	6.5	23.2	6.33	47.41	4.22
520	161	6.2	22.13	6.48	49.70	4.02

Before the wear tests, the contact surfaces of pins were polished with 500 grit size SiC paper and the initial average roughness was approximately Ra = 0.06 μm. Prior to testing, all the specimens were cleaned by rinsing in ethanol and dried in hot air. During the tests, the pin specimens were loaded with dead weights and tests were conducted dry, at room temperature and room humidity. The wear loss was measured by means of analytical balance with an accuracy of 0.1 mg.The wear tests were conducted dry, at room temperature, under room humidity, for a speed of 0.18 m/s, a sliding distance of 11 m, a load of 5 N using 320 grit abrasive papers.

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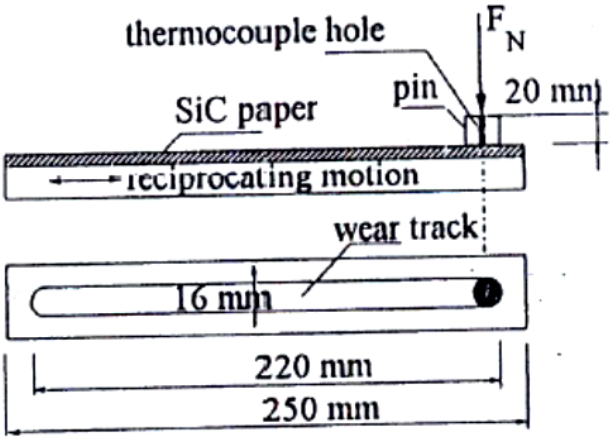

Fig.1. Schematic test rig and the dimensions of samples

3. THE RESULTS OF THE NUMERICAL CALCULATIONS

3.1. The Relationships Between The Hardness and Solution-Treating Temperature

The dependence of hardness on solution-treating temperature is shown in Table 1and Fig.2 . The hardness was increased by the increasing the temperature because the solubility of copper in Al increased markedly with temperature. The Al phase would contain Cu in a supersaturated solid solution at room temperature. During the ageing, the fine particles of $CuAl_2$ formed and precipitated. Thus the hardness of alloy increased by means of artificially age hardening.

As it is well known, the age hardenability of 2014 Al alloy is a function of solution-treating temperature. Therefore, numerous empirical correlations between the bulk hardness and temperature were established as shown in Fig.2. In this study, the five functions were used to give the relationships between hardness and temperature.For all functions, the correlation values changes between % 99.86 and % 99.36 and the characteristic of the curves has the same rule.As a result, it had better that the relationship between hardness and temperature is accepted as a polynomial function because of maximum correlation value as % 99.86 (Fig.2 c and f).The others functions can be used savety to propose the correlation between the hardness and temperature.

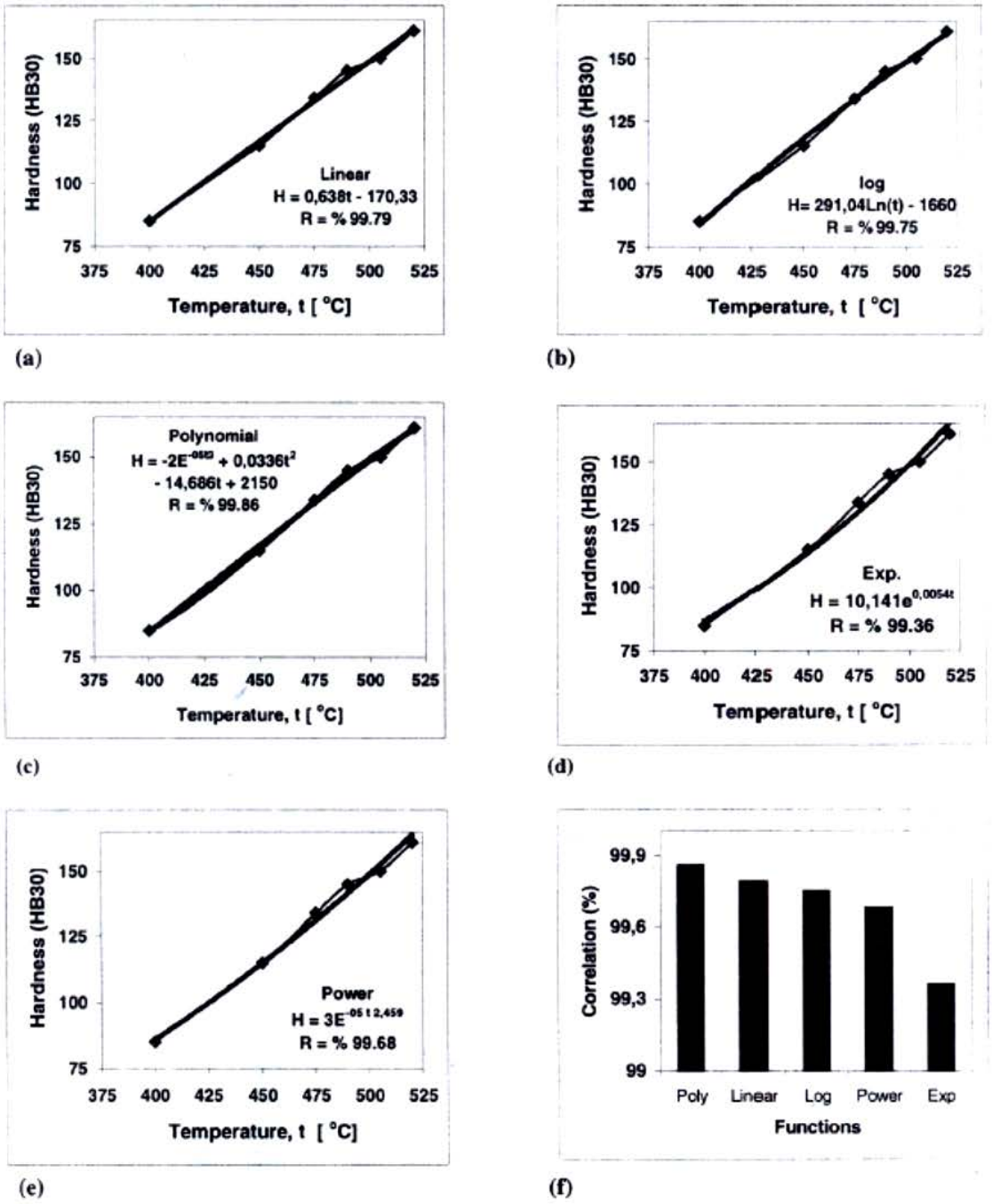

Figure.2. Diagrams showing relationships between the hardness and solution-treated temperature

3.2. The Relationships Between The Wear Volume and Solution-Treating Temperature

It can be seen from Fig.3 that the wear volume decreased with increasing the solution-treating temperature. The reason for this may be related to an increasing of the hardness by solution heat treatment.The hardening capability of 2014 Al alloy is a function of solution-treating temperature as shown in Fig.2.

In this study, numerous empirical correlations between the solution-treating temperature and wear volume have been established. Figure 3 (a-f) shows the correlation between the wear volume and solution-treating temperature for the 2014 Al alloy specimens used in the experiments. These data points came from all the

experimental data listed in Table 1. As it is shown in Fig.3c, the calculated values are in good agreement with experimental values given in Table 1.The mathematical functions were evaluated by the coefficient of correlation value as shown in Fig.3. The polynomial function has a correlation coefficient of R_{max} = % 100 and this correlation is certainly the best than the correlations obtained with the other four functions.

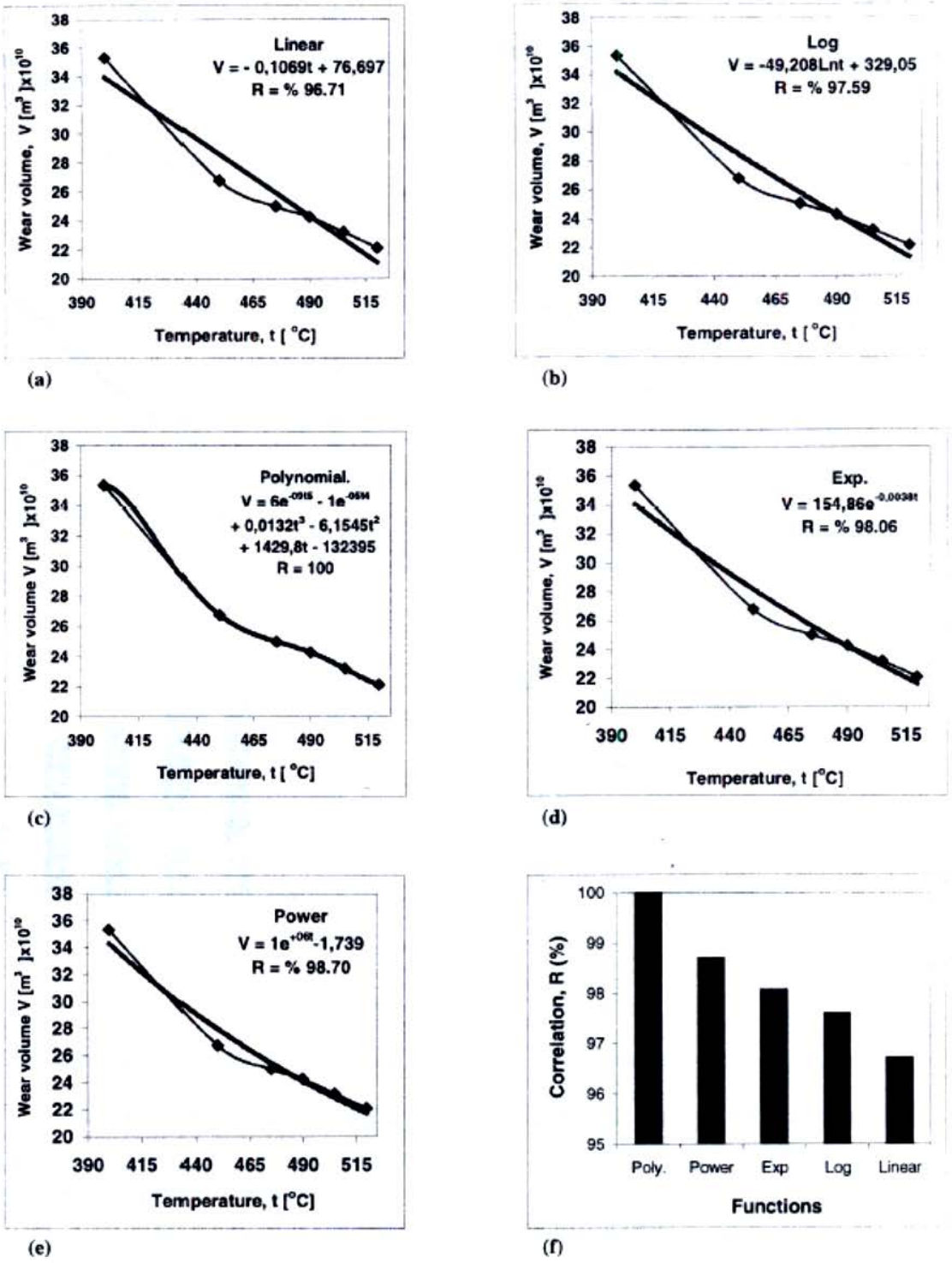

Figure.3. Diagrams showing relationships between wear volume and solution-treating temperature

3.3. The Relationships Between The Wear Resistance and Solution-Treating Temperature

As shown in Fig.4, the wear resistance increased with increasing solution-treating temperature. The reason for this may be related to an increasing of the hardness by solution heat treatment. In this study, five functions were used to analyse the relationships between the abrasive wear resistance and solution-treated temperature. It can be seen from the Fig.4 that there are not very different between the calculated values and the experimental values for the five functions. As shown in Fig.4 (d and f), the correlation values of exponential function is a R minimum of % 98.05. The other four functions could be used to propose the relationships between the wear resistance and temperature.There are a very good correlation between the wear resistance and temperature for polynomial function (Fig.4c). The polynomial function has a maximum values of correlation as R = % 99.98 as shown in Fig.4 (c and f). Also the logarithmic, linear and power functions can be used convenient to propose the relationships between wear resistance and temperature.

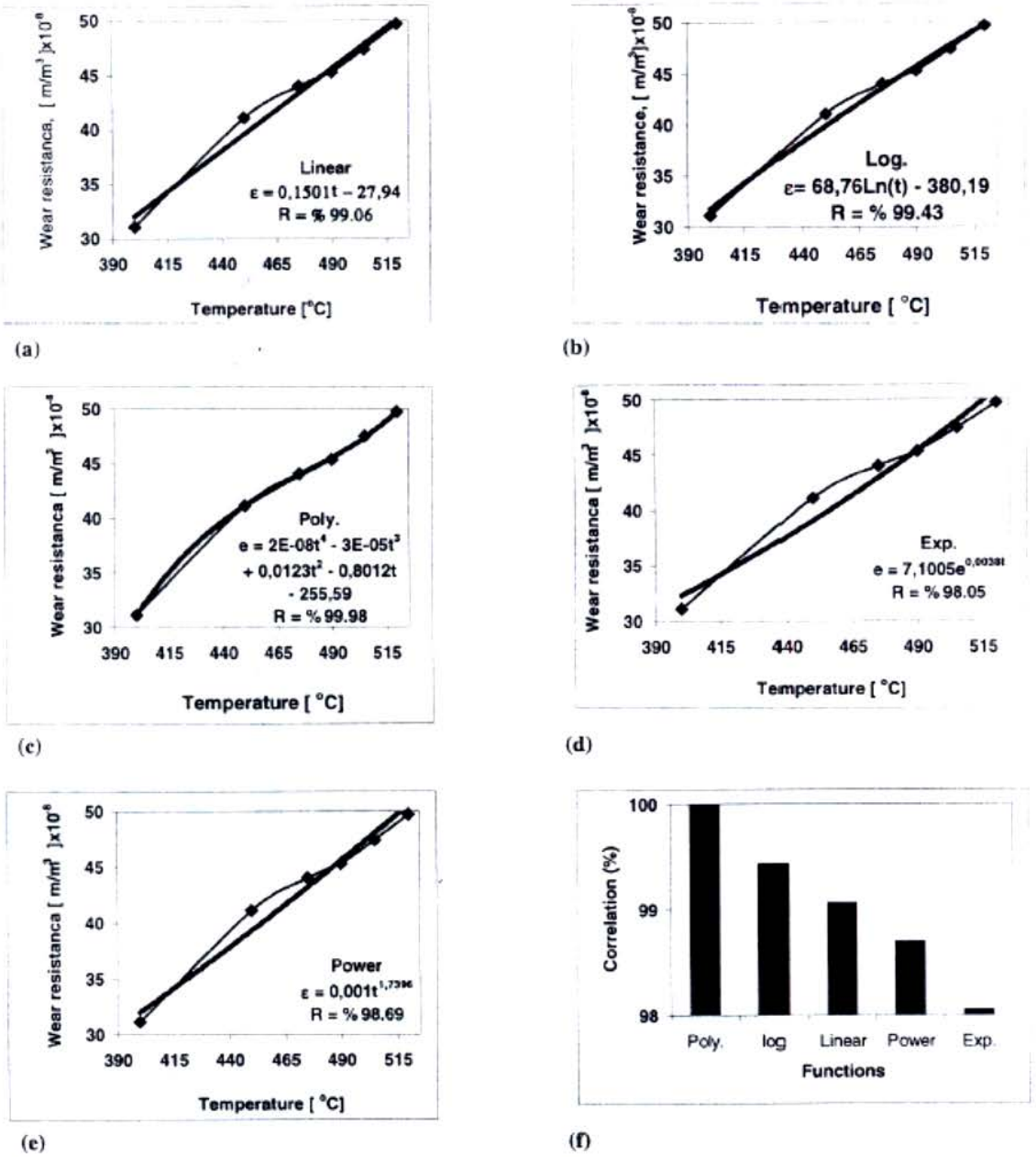

Figure.4. Diagrams showing relationships between wear resistance and solution-treating temperature

3.4. The Relationships Between The Wear Coefficient and Solution-Treated Temperature

In this study, it was determined that the wear coefficient increased with the increasing of the solution-treated temperature as shown in Fig.5.

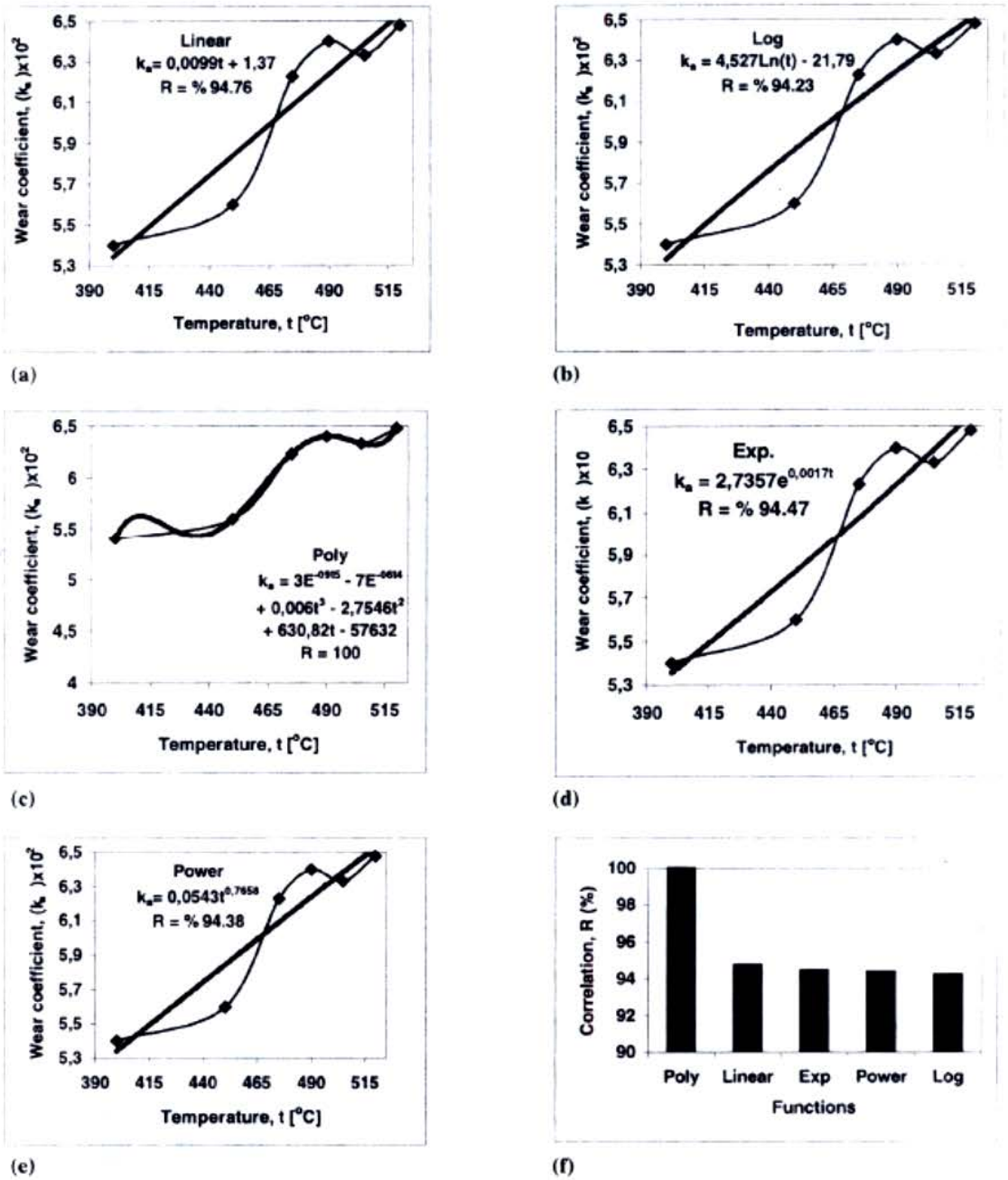

Figure.5. Diagrams showing relationships between wear coefficient and solution-treated temperature

The key factor for predicting abrasive wear volume is the abrasive wear coefficient k_a . It depends on the shape, size, type and distribution of the abrasive particles, on properties of the wearing material and on the mode interaction between abrasive particles and wearing material [4].It is accepted that the individual abrasive particles functions as cutting tools with a random distribution of the rake angle. Generally, the coefficient of wear k_a includes a probability factor allowing for a distribution of attack angles during abrasion by many contacting abrasive particles. It has proposed a simple expression for k_a during two-body

abrasion by a conical abrasive particle as $k_a = 2 \tan\alpha / \pi$. Where α is attack angle. When the hardness of material increases, the attack angle increases. So, abrasive wear coeffient increases with increaing the hardness of material.

In this study, the five functions were used to give the relationships between the wear coefficient and temperature. For all functions, the correlation values are between % 94.23 and % 100. And the characteristic of the four curves has the same rule as shown in Fig.5 (a, b and e). The polynomial function is the best function because of a maximum correlation value of % 100.The others functions can be used safely to propose the correlation between the abrasive wear coefficient and temperature

3.5. The Relatioships Between The Wear Coefficient and Wear Volume

In this study, it was determined that the wear cofficient decreased with the increasing of the wear volume as shown in Fig.6.

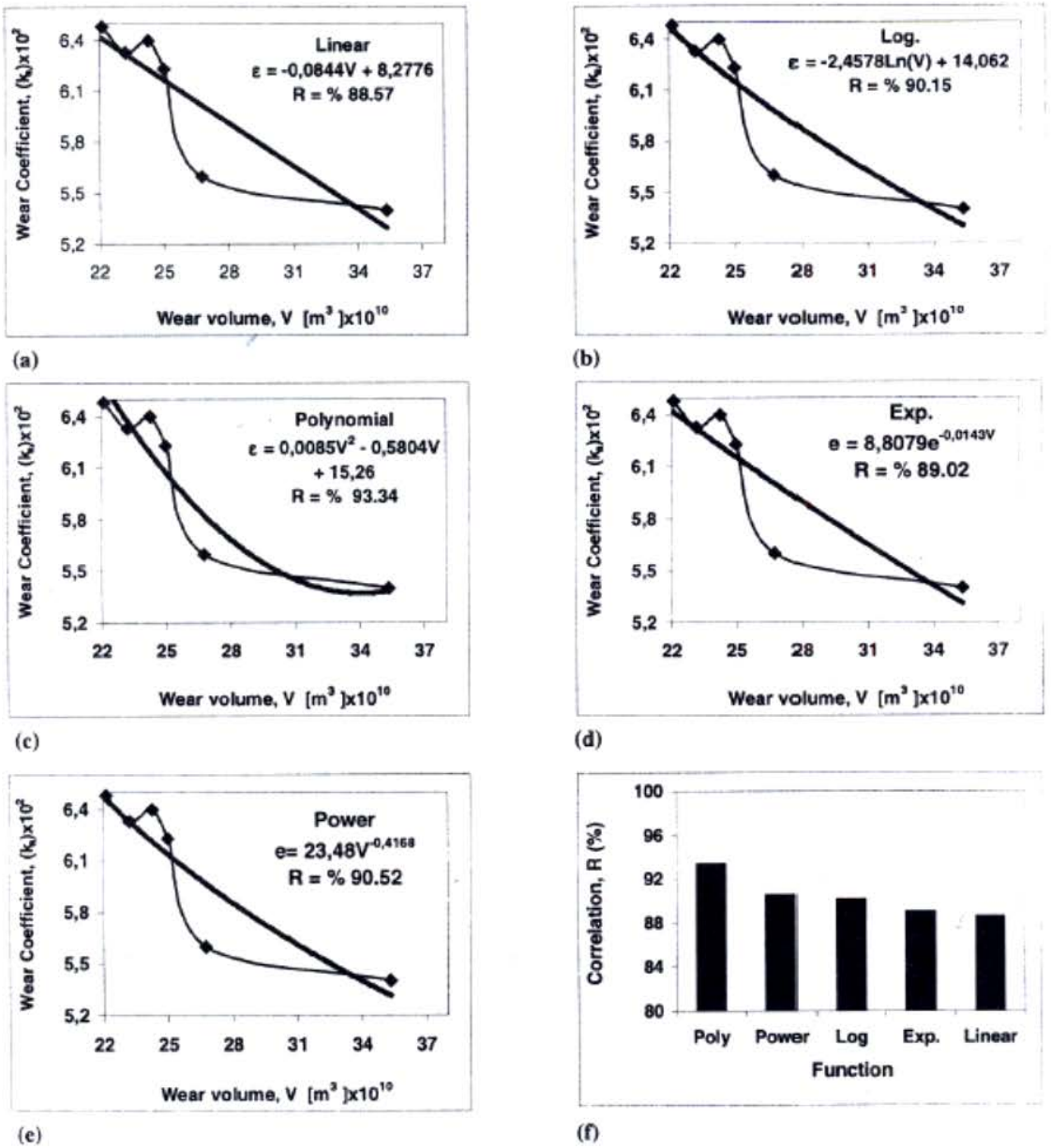

Figure 6. Diagrams showing relationships between wear coefficient and wear volume

The reason for this may be related to a decreasing of the hardness of tests material.If the hardness dcreases, the critical attack angle of the abrasive particles decreases.Figure 6 shows that the relationships between wear coefficient and wear volume is same tendency for five functions. The correlation value of polynomial function is a maximum of % 93.34 as shown in Fig.6 (c and f). All of the five functions can be used to analyse the relationships between the wear coefficient and wear volume because the correlation values of them are equal approximately each others.

4. CONCLUSIONS

The conclusions derived from the present work may be listed as follows

1- The hardness is increased by increasing temperature because the solubility of copper in Al increases markedly with temperature.
2- The five functions were used to give the relationships between hardness and temperature.For all functions, the correlation values are between % 99.86 and % 99.36 and the characteristic of the curves has the same rule.
3- The polynomial function has the maximum correlation value as % 99.86.The others functions can be used savety to propose the correlation between the hardness and temperature
4- The wear volume decreases with increasing the solution-treating temperature
5- For the relationships between the solution-treating temperature and wear volume, the polynomial function has a maximum correlation coefficient of % 100 and this correlation is certainly the best than the correlations obtained with the other four functions.
6- The wear resistance increases with increasing solution-treated temperature . The reason for this may be related to an increasing of the hardness by solution heat treatment.
7- In this study, five functions were used to analyse the relationships between the abrasive wear resistance and solution-treated temperature. The correlation values of Exponential function is a minimum of % 98.05.
8- There are a very good correlation between the wear resistance and temperature for polynomial function The polynomial function has a maximum values of correlation as R = % 99.98 .
9- Also the logarithmic, linear and power functions can be used convenient to proposed the relationships between wear resistance and temperature.
10- The wear cofficient increases with the increasing of the solution-treating temperature
11- The correlations between the wear coefficient and temperature, the polynomial function is the best function because of a maximum correlation value of % 100.The others functions can be used savety to propose the correlation between the abrasive wear coefficient and temperature
12- The wear cofficient decreases with increasing of the wear volume.
13- The relationships between wear coefficient and wear volume is same tendency for five different functions. The correlation value of polynomial function is a maximum of % 93.34. All of the five functions can be used to analyse the relationships between the wear coefficient and wear volume because the correlation values of them are equal approximately each others.

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