EFFECT OF DEZINCIFICATION PROCESS OF A-BRASS ALLOYS ON THE WEARING RESISTANCE[+]

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Abstract:

The aim of this paper is to study the effect of dezincification process of brass alloys which contains different percentages of zinc 5, 10, 20 & 30 % on the wearing resistance. Dezincification process was carried out in electrical furnace under a protective atmosphere at different temperatures750, 850 & 950 ^{o}C for different periods of time 10,20,40,80 &120 hrs. The weight loss was measured before and after dezincification process. A relationship has been achieved between the weight loss per unit area ($\Delta W/A$) and the dezincification time at different temperatures and zinc concentration. The results show that the dezincification process is diffusion controlled. A mathematical relationship between zinc concentration and dezincification constant (D) was also achieved. It was found that the dezincification constant values are concentration and temperature dependent. Also the activation energy (Q) for dezincification process increases with increasing zinc concentration.

المستخلص:

يهدف البحث الى دراسة تاثير ازالة الخارصين من سبائك البراص والحاوية على نسب مختلفة من الخارصين (٥، ١٠، ٢٠، ٣٠) % على مقاومة البليان. تم أجراء عملية ازالة الخارصين باستخدام الفرن الكهربائي تحت جو محمي عند درجات حرارة مختلفة (٧٥٠، ٨٥٠، ٩٥٠) ^{o}م ولأوقات مختلفة (١٠، ٢٠، ٤٠، ٨٠، ١٢٠) ساعة. تم قياس وزن العينة قبل أجراء عملية ازالة الخارصين وبعدها لمعرفة الفقدان في الوزن. أستخدمت علاقة رياضية تربط بين الفقدان بالوزن لوحدة المساحة ($\Delta W/A$) مع زمن عملية ازالة الخارصين عند نسب خارصين ودرجات حرارة مختلفة.أشارت النتائج الى ان عملية ازالة الخارصين هي عملية انتشارية. كما استخدمت علاقة رياضية تربط بين تركيز الخارصين وثابت الازالة (D)، و ظهر أن قيمة ثابت الازالة يعتمد على تركيز الخارصين ودرجة الحرارة. تم حساب طاقة التنشيط (Q) لعملية ازالة الخارصين ولوحظ أنها تزداد مع زيادة نسبة الخارصين.

1. Introduction:

Dezincification selectively removes zinc from the brass, leaving behind a porous and copper rich structure. Balluffi and Alexander studied the porosity formation after dezincified a brass sheet which consist of 30% Zn in vacuum at 700, 800 & 900 ^{o}C for various times. The weight loss from α-brass was measured as function of time at three different temperatures. As diffusion proceeds, the zinc which diffuses out of the α-brass leaves vacancies behind which may precipitate in the form of pores [1].

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Wear may be defined as loss of material from the interface of two bodies when subjected to relative motion under load. When the applied load is small, a weak contact occurs at the tip surface asperities only. During sliding this weak contact forms a thin oxide layer which acts as a protective surface film that covers the sliding surfaces and also protects direct metal contact between surface asperities. The required force to shear and separate the connection among surface asperities is lower than the bonding force between metal atoms, yielding a lower wear rate [2]. When the applied load increases, fraction of the surface oxide layer may be detached, because of its brittleness it will extruded outside the sliding surface of the specimen and disc during the sliding process. This produces metallic junction between the mating surfaces. The required shear force to shear the connected asperities is higher than the bonding force among the metal atoms themselves, this will lead to metallic particles separation from metal surface and finally increases in the wear rate [3].

Friction is the resistance to motion. It exists when a solid object is moved tangentially with respect to another surface or when an attempt is made to produce such a motion. The resistive force which is parallel to the direction of motion is called the friction force. If the solid bodies are loaded together and tangential force is applied, then the value of the tangential force which is required to initial sliding is called the static friction force. The tangential force which is required to maintain sliding is called the dynamic friction force which is lower than the static friction force [4, 5].

2. Material Selections & Experimental Work:

2.1 The specimens:

A rectangular sheet of brass specimens with different zinc concentration of 5, 10, and 20% Zn, with the following dimensions 25×15 ×0.15 cm, 25×15×0.2 cm, 25×15×0.3 cm respectively. These sheets were obtained after cold rolling and annealing at 600 ^{o}C for two hours. The brass alloy containing 30% Zn was supplied as circular rods of 20 mm diameter and 250mm length. The specimen was ground with 120, 220, 320, 400, 600, 800,1000 grades of silicon carbide paper, and polished with 5μm and 0.03 μm alumina slurry. Then the specimens were etched with alcoholic ferric chloride solution (2ml HCl, 5 gm$FeCl_3$, 96 ml alcohol) [6].

Wear test specimens containing 30% Zn, they were cut circular rod specimen of 20mm diameter and 25 mm length. The two end surface of each specimen were ground with 120, 220, 320, 400, 600, 800, 1000 grades silicon carbide paper, polished with 5 μm and 0.03 μm alumina slurry respectively. Table (1) shows the chemical compositions of these alloys were carried out by the Central System for Standardization and the Quality Control.

Table (1) Chemical composition of the brass alloys used.

Specimen	**Composition wt %**									
Materials	**Zn**	**Fe**	**Si**	**Mn**	**As**	**Al**	**Ni**	**Sb**	**S**	**Cu**
Brass Alloys	٣٠	.009	.0043	.0077	.007	.014	.0005	.0077	.0029	Rem.
	20	.015	.004	.006	.006	.007	.0007	.009	.003	Rem.
	١٠	.009	.006	.006	.003	.008	.0006	.008	.003	Rem.
	٥	.028	.004	.008	.005	.009	.0006	.007	.007	Rem.

2.2 Dezincification process:

2.3

Dezincification process of the specimens was carried out in a container made of stainless steel. Dezincification process began after evacuation of the vacuum chamber from air. After the vacuum pressure had reached 0.01mm Hg the chamber was flushed with argon for 20 minuets to prevent any oxidation process. The temperature indicator was set on at the required temperature. The temperature range for dezincification is750-950 ^{o}C.This range is chosen based on the fact that diffusion process is faster at temperature > 0.7 Tm (Tm is melting temperature). The time was taken to be 10 –120 hrs, because the weight loss is so little with short time. The amount of zinc lost from dezincified brass is calculated by measuring the specimen weight before and after dezincification process as follows:

$$\Delta W = W_1 - W_2 \qquad \text{-------------} \ (1)$$

Where:

ΔW: Weight loss (gm).
W1: Specimen weight before dezincification (gm).
W2: Specimen weight after dezincification (gm).

2.3 Wear test:

Figure (1) shows a schematic diagram of the pin–on–disc machine. A carbon steel disc was used as a counter face with hardness and surface roughness values of 430 Hv, 0.2 µm respectively. Table (2) shows the chemical composition of the disc. Dry and wet sliding wear test were conducted.

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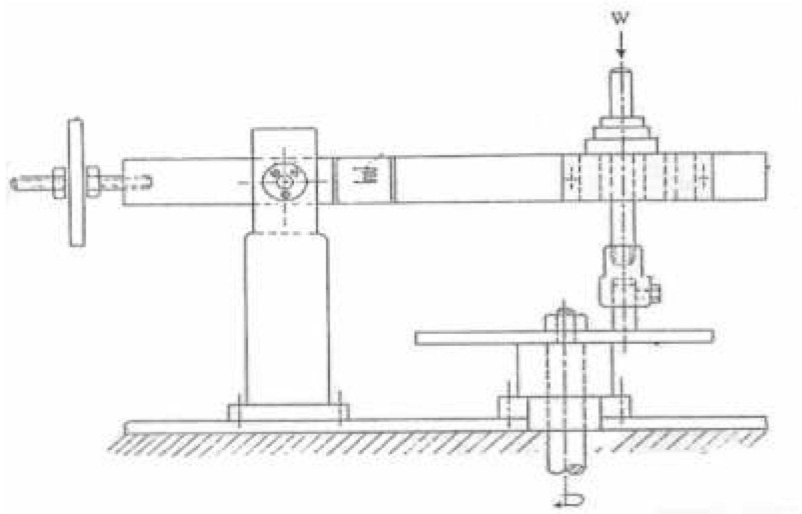

Figure (1) a schematic diagram of the pin–on–disc machine.

Table (2) Chemical composition of the disc used in wear test.

Disc Materials	Composition wt %										
	C	Si	P	S	Cr	Mo	Ni	Mn	Cu	V	Fe
DIN Ck 65	.650	.260	.015	.030	.115	.008	.053	.947	.037	.004	Rem.

2.4 Wear rate:

Wear rate was calculated from weight loss measurement by using sensitive balance with an accuracy of ± 0.0001gm (Mettles type HK 160). The equation used to convert the weight loss into wear rate is [٧]:

$$\textbf{Wear rate} = \Delta W / X \qquad \text{-------------} \ (2)$$

The total sliding distance (X) calculated as: -

$$X = S \times t \qquad \text{-------------} \ (3)$$

Where:

X: Sliding distance (cm).
S: Linear sliding speed (m/s).
t: Running time of wear test (min.).

2.5 Sliding speed:

The disc rotating speed was 450 rpm with a linear sliding speed was calculated as:

$$S = \pi D N / 60 \qquad \text{-------------} \ (4)$$

Where:

D: Sliding circle diameter (mm).
N: Disc speed (rpm).

2.6 Applied load:

Loading was carried out by putting suitable weight on the specimen holder weighting 10, 15, 20, 25 N.

2.7 Coefficient of friction:

The friction force between the pin and disc surface was measured using strain gauges bounded on the vertical faces of the lever arm of wear machine, in order to measure the elastic bending strain resulting from tangential force at the sliding interface. Figure (2) shows the calibration curve of the system to estimate the value of tangential force using the micro strain reading.

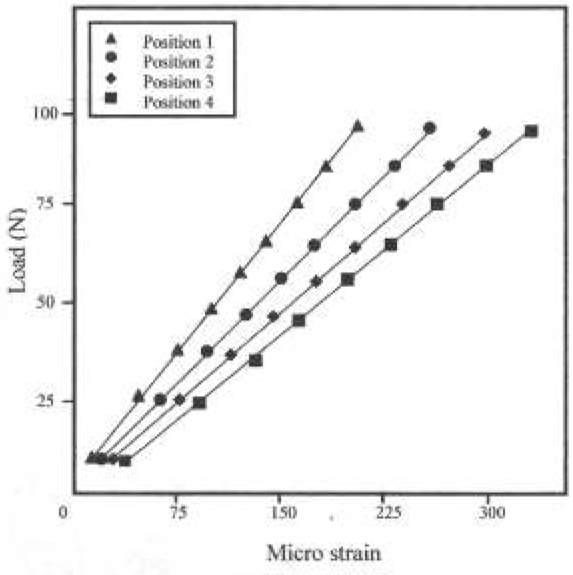

Figure (2) Calibration curve for the lever arm.

3. Results and Discussion:

3.1 Time and temperatures effect on dezincification process:

The relationship between the weight loss and dezincification time is shown in Figures (3) to (5). To examine the relationship between the weight loss and dezincification time at different temperatures a mathematical relationship is used as follows:

$$\Delta W/A = B\, t^{d} \qquad \text{-------------} \ (5)$$

Where:

A: Area (cm^2).

B: Constant [gm/ ($cm^2 . \sqrt{hr}$)].

d: Dezincification rate.

The relationship between ($\Delta W/A$) and dezincification time at different temperatures is shown in Table (3).

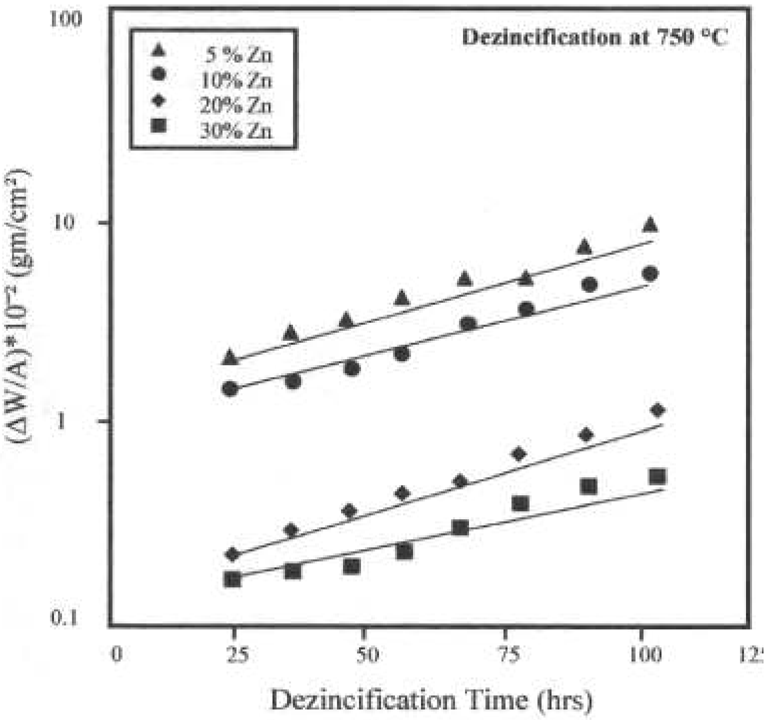

Figure (3) Relationship between the weight loss and dezincification time.

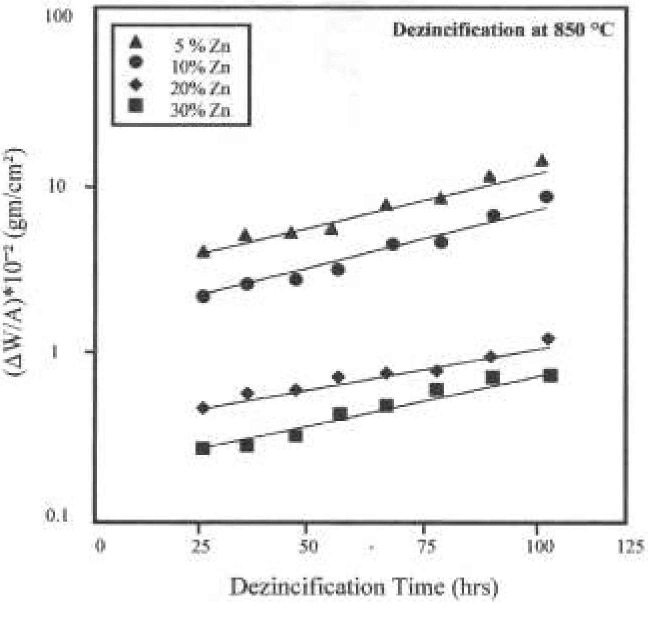

Figure (4) Relationship between the weight loss and dezincification time.

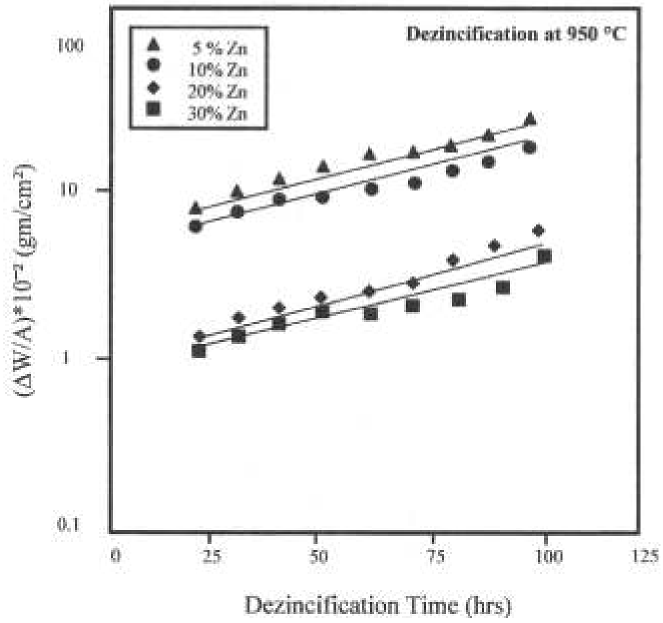

Figure (5) Relationship between the weight loss and dezincification time.

Table (٣) Relationship between [ΔW/A] and dezincification time at different temperatures and zinc concentrations.

Zinc Concentration %	Dezincification Temp. °C	$(\Delta W/A) = B\,t^{d}$
٥	750	$0.0008\,t^{0.48}$
10		$0.0019\,t^{0.57}$
٢٠		$0.0063\,t^{0.49}$
٣٠		$0.009\,t^{0.57}$
٥	850	$0.0018\,t^{0.60}$
10		$0.007\,t^{0.49}$
٢٠		$0.023\,t^{0.49}$
٣٠		$0.031\,t^{0.49}$
٥	950	$0.008\,t^{0.45}$
10		$0.009\,t^{0.49}$
٢٠		$0.08\,t^{0.44}$
٣٠		$0.07\,t^{0.40}$

3.2 Dezincification process at isothermal conditions:

The dezincification process at isothermal condition and at different zinc concentration, the dezincification constant is taken as (D):

$$D = B^2 \qquad \text{-------------} \; (6)$$

The relationship between (D) and zinc concentration can be expressed as:

$$\mathbf{D = YZ^n} \qquad \text{------------- (7)}$$

Where:

D: Dezincification constant [gm/ (cm^2.$\sqrt{hr}$)].
Y: Constant [gm^2 / (cm^4.hr)].
Z: Zinc concentration.

The values of (Y) and (n) are shown in Table (4).

Table (4) Values of (Y) and (n) for dezincification at isothermal conditions.

Temperature °C	**$D = YZ^n$**
750	$0.0012\ Z^{2.5}$
850	$0.08\ Z^{3.3}$
950	$0.083\ Z^{3.1}$

3.3 Dezincification process at isoconcentration conditions:

The dezincification rate with temperature can be expressed as:

$$\mathbf{D = P}\ e^{(-Q/RT)} \qquad \text{------------- (8)}$$

Where:

P: Constant [gm/ (cm^2.$\sqrt{hr}$)].
Q: Activation energy for diffusion (J/ mole).
R: Gas constant [8.314 J / (mole °K)].
T: Absolute temperature (°K).

Figure (6) shows the relationship between (D) and the inverse of dezincification temperature using equation (8) where the slope represents the activation energy (Q). The values of activation energy are shown in Table (5).

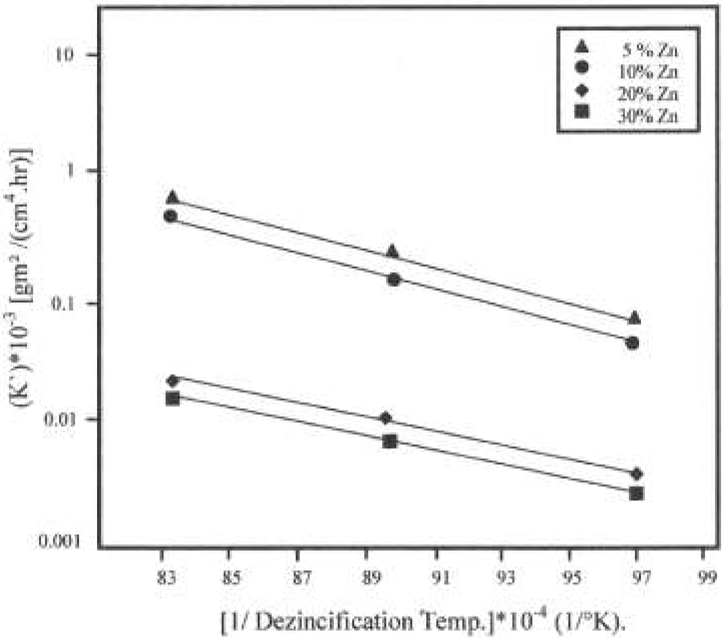

Figure (6) Relationship between the dezincification constant and the inverse of dezincification temperatures.

Table (5) Values of activation energy for dezincification at isothermal conditions.

Zinc Concentration %	D = P exp (-Q/RT)
5	218000/RT)-exp (^{4} 10× ٥,٦
١٠	221000/RT)- exp (^{5}10 × ١,٧
20	242000/RT)- exp (^{8} ×10٢,٣
٣٠	249000/RT)- exp (^{8}10× ٦,٨

The values of activation energies found in this work varying with zinc concentration, these values are 218, 221, 242& 249 KJ/mole, for zinc concentration 5, 10, 20 & 30 % respectively. This indicates that the activation energy increases with increasing zinc concentration.

3.4 Time and temperatures effect on wear rate for dry and wet sliding conditions under different loads and sliding speeds:

The wear rate for dezincified brass with 30% Zn at 950 °C is lower because the pore diameter and volume fraction of pores at 950 °C is higher. Also during sliding the oxide and metallic debrief generated acts as a cover for the disc surface. That is as if a brass pin is sliding on a brass disc. Which equals that soft metal is sliding against soft metal surface. This decreases the wear rate. In wet sliding conditions an oil lubricant is used by immersing the dezincified specimens in oil for 24 hrs. It is clear that the wear rate for dezincified specimens wear rate at 950 °C is lower because the pore diameter and volume fraction produced at 950 °C is higher. Therefore the amount of oil absorbed by specimen at 950 °C is higher.

The wear rate for dezincified specimen is less than that of as received specimen, because the pores act as a capillary, keeping a lubricant film at any time and thus reducing the frictional force and heat generation, therefore the wear rate decreases. During dry sliding conditions the temperature increases for all specimens and it will reach to steady state, because at the beginning the roughness is high and then it decreases. Thus the contact area increases between the specimen and disc, then the oxide and metallic debris are generated and fill the pores and cover the surface of the disc. Thus it decreases the sliding temperature.

3.5 Time and temperatures effect on coefficient of friction for different loads and sliding speeds:

The coefficient of friction for as received specimen is lower than the coefficient of friction for dezincified specimen, because of the roughness of dezincified specimen increasing with increasing dezincification temperature and time as shown in Table (6). The grain size is also increased with increasing dezincification temperature and time.

Table (6) Relationship between zinc concentration and dezincification temperatures.

Zinc Concentration%	**Dezincification Temperature °C**		
	٧٥٠	850	950
5	0.048 t + 2	0.048t + 2.7	0.08 t + 2.6
10	0.026t +1.4	0.047 t + 2.5	0.047 t + 2.3
20	0.008 t	0.008 t	0.008 t
30	0.0013 t	0.005 t	0.008 t

Increasing dezincification temperature causes decreasing in coefficient of friction, because the flash temperature increases with increasing sliding speed causing a softening of the surface asperities between the specimen and disc. Thus, the required force to separate the interface contact leading to lower coefficient of friction [8].

4. Conclusions:

The following are the most notable conclusions can be summarized as follows:

1- Dezincification process is controlled by diffusion process.
2- The dezincification constant and the activation energy for diffusion increase with increased zinc concentration.
3- The wear rate for dezincified specimens with 30% Zn at 950 oC is lower because the pore diameter and volume fraction of pores at 950 °C is higher.
4- The wear rate for dezincified specimens is less decreases because the pores act as a capillary, keeping a lubricant film at any time and thus reducing the frictional force and heat generation.
5- The coefficient of friction increases with increasing dezincification temperature under different load, but decreases with increasing sliding speed under dry sliding conditions, as shown in table (6).

5. References:

[1] Balluffi R.W., & Alexander B. H., *Journal of Metals*, “Metal and Materials”, Vol.191, No.11, 1952.

[2] James P.S., Ashok S., Stephen D.A., Thomas H.S & Steven W., “*The Science and Design of Engineering Materials*”, Von Hoffmann Press, USA , 1995.

[3] Das D.K., Vakil S., & Joshi S.V., *Journal of Metals* “Oxidation of Metals”, Vol. 57, No.3, 2002.

[4] Miller N. S. & Simkovich W., *Journal of Materials Sciences*, “Metal and Materials”, Vol. 19, No.18, 2000.

[5] Callister W.D., “*Materials Science and Engineering*”, 5th Edition, John Wiley and Sons, New York, 2000.

[6] Metal Handbook, “*Metallographic and Microstructure for Metals*”, 9th Edition, American Society for Metals, Metals Park, Ohio, 1985.

[7] C830, Annual Book of ASTM Standard, American Society for Testing & Material, USA, 1988.

[8] Dale T.P., *Journal of Materials Sciences*, “Advanced Materials and Processes”, Vol.150, No.4, 2000.