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Cyclic Heating Effect on Hardness of Aluminum

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ABSTRACT
Presented work discusses research results concerning the effect of the heat treatment process. Thermal fatigue which expresses repeated heating and cooling processes affect the ductility or the brittleness of the material. In this research 70 specimens of aluminum (2 mm thickness, 85 mm length, 32 mm width) are subjected to thermal fatigue at different conditions. Heating temperatures; T_h = 100, 300 and 500 ° C. Number of repeated cycles; N =1 to 100. Results are evaluated then compared to each other and to that of specimens without subjected to thermal fatigue.
Key words: aluminum alloys, thermal analysis, heat treatment, hardness, thermal fatigue

I. INTRODUCTION

Well known advantages of aluminum alloys, like low mass, good mechanical properties, corrosion resistance, machinability, high percentage of recycling, and low costs, are the driving force for their development, i.e. usage in new applications as early as in stage of development of a structures, as well during development of new technological solutions. Thermal fatigue specifies the process of repeated heating and cooling of machine parts. Some investigators show the effect of cyclic heat treatment on phase composition and structure of titanium alloys [1, 2] others show the effect of repeated heating on tempering or hardening of steels [3, 4, 5]. Performed shortened heat treatment results in precipitation hardening of the investigated 320.0 alloy, what according to expectations produces increased hardness of the material [6]. The improvement of mechanical properties of the EN AB-42000 silumin in the aspect of its hardness change due to the performance of the T6 heat treatment is possible only in case of the selection of suitable solutioning and ageing treatment parameters [7]. Different machine tools and elements are.

II. NOMENCLATURE

A Area of spherical surface indentation in Brinell hardness test.[mm^2]
BHN Brinell hardness number. [Kg/mm^2]
d Impression diameter.[mm]
D Ball diameter. [mm]
N Number of thermal fatigue cycles
F Load of hardness test. [Kg]
t_c Cooling time of thermal fatigue cycles. [min]
t_h Heating time of thermal fatigue cycles. [min]
T_C Cooling temperature of thermal fatigue process. [^OC]
T_h Heating temperature of thermal fatigue process. [^OC]

III. METHODS OF ANALYSES

To evaluate the effect of cyclic heating effect on hardness of aluminum, the investigation was carried out thus;

- Preparation of the specimens from aluminum
- Hardness was measured for each specimen before and after cyclic heating operations.
- From the different readings, curves were plotted to know the trends of the property

IV. EQUIPMENT USED

- Laboratory Muffle Furnace
- Hand Polishing Aluminum Stand
- Hardness Testing machine

Preparation of the Hardness Specimens

The material used for this study is aluminum. The sample Fig. 1 preparation was the usual grinding and polishing procedure until a mirrored surface, with no etching, was obtained.

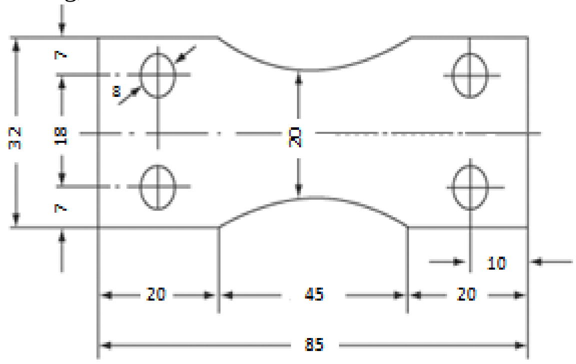

Figure 1 Fatigue sample dimensions in millimeters. Thickness: 2 mm.

Brinell Hardness Test

Brinell hardness is determined by forcing a hard steel or carbide sphere of a specified diameter under a specified load into the surface of a material and measuring the diameter of the indentation left after the test Fig 2.

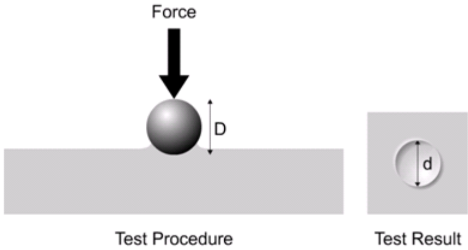

Figure 2 Brinell Hardness Test

The Brinell hardness number, or simply the Brinell number, is obtained by dividing the load used, in kilograms, by the actual surface area of the indentation; A, in square millimeters. The result is a pressure measurement, but the units are rarely stated.

The BHN is calculated according to the following formula:

$$BHN = \frac{F}{\frac{\pi}{2} D\left(D - \sqrt{D^2 - d^2}\right)} \quad (1)$$

The ball diameter and applied load are constant and are selected to suit the composition of the metal, its hardness, and the thickness of the rest specimen, Table 1. The diameter of the indentation is measured with a special magnifying glass containing a scale graduated in terms of a millimeter.

Table 1 Brinell test conditions

Material	BHN	Thickness of test specimen mm	Ratio of load F to ball diam. D	D mm	F Kg	Time load application Sec
Aluminum	8 to 35	Over 5 From 6 to 3 Less than 3	$F = 2.5\ D^2$	10 5 2.5	250 62.5 15.625	60

The chemical composition of the investigated specimen is shown in Table 2.

Table 2 The chemical composition percent.

Chemical composition%			
Al	Fe_2	SI	Cu
99.44	0.34	0.16	0.0041

Laboratory Muffle Furnace

The muffle furnace could be used for heating of test specimen up 1200°C. Fig. 3 shows the characteristic curves of the muffle furnace.

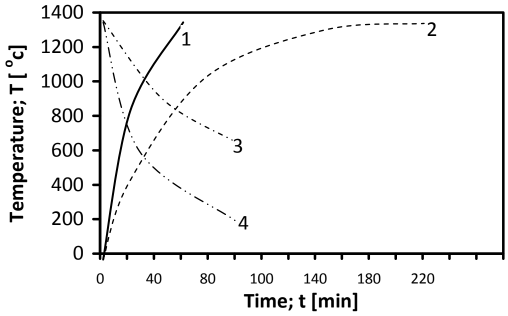

Figure 3 Characteristic curves of the muffle furnace

1 Heating – up curve, full load
2 Heating – up curve, partial load 50%.
3 Cooling Curve, with door closed.
4 Cooling Curve, with door open.

V. METALLOGRAPHIC TEST

The test specimens were firstly polished. A ball of 2.5 mm diameter is chosen according to Table 1 for the test. The load is applied 15.625 Kg for 60 sec.

The hardness values before subjected to thermal fatigue were measured on Brinell hardness tester Table 3 shows the experimental results of hardness test for the specimens of aluminum

Table 3 Experimental results of hardness test of aluminum without thermal fatigue

Thermal fatigue	Hardness Test **F=15.625 Kg D=2.5 mm t=60 sec**							
No Thermal fatigue	First specimen				Second specimen			
	d_1	BHN	d_2	BHN	d_1	BHN	d_2	BHN
	0.64	47.8	0.64	47.8	0.65	46.3	0.67	43.5

Heating temperatures; T_h = 100, 300 and 500 °C. Number of repeated cycles; N =1, 3, 5, 20, 30, 50, 70, 80 and100. The values of hardness are registered in Tables 4 to 6 respectively. The relationship between the hardness values versus number of repeated cycles has been plotted in Figs. 4 to 6.

Table 4 Experimental results of hardness test of aluminum, thermal fatigue heating temperature; T_h=100°C.

Thermal fatigue		Hardness Test **F=15.625 Kg D=2.5 mm t=60 sec**							
T_h	N	First specimen				Second specimen			
°C	**Times**	d_1	BHN	d_1	BHN	d_1	BHN	d_1	BHN
100	**1**	0.64	47.8	0.64	47.8	0.65	46.3	0.65	46.3
	3	0.65	46.3	0.65	46.3	0.65	46.3	0.65	46.3
	7	0.65	46.3	0.65	46.3	0.66	44.8	0.67	43.5
	14	0.60	54.3	0.60	54.3	0.63	49.3	0.64	47.8
	20	0.65	46.3	0.65	46.3	0.65	46.3	0.65	46.3
	30	0.65	46.3	0.65	46.3	0.65	46.3	0.65	46.3
	50	0.63	49.3	0.63	49.3	0.63	46.3	0.63	49.3
	70	0.64	47.8	0.64	47.8	0.64	47.8	0.64	47.8
	80	0.64	47.8	0.64	47.8	0.64	47.8	0.64	47.8
	100	0.64	47.8	0.64	47.8	0.64	47.8	0.64	47.8

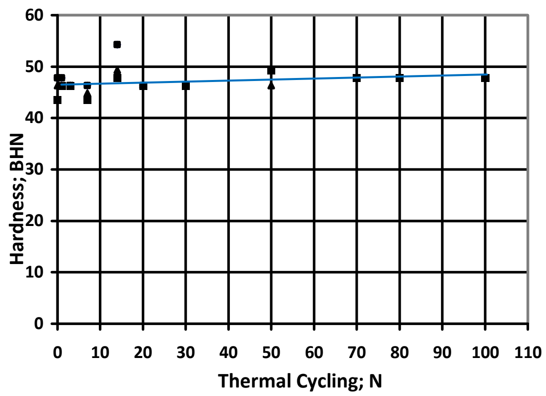

Figure 4 Effect of thermal fatigue on hardness of aluminum at temperature; T_h =100°C

Table 5 Experimental results of hardness test of aluminum, thermal fatigue heating temperature; T_h =300°C.

Thermal fatigue		Hardness Test **F=15.625 Kg D=2.5 mm t=60 sec**							
T_h °C	N **Times**	First specimen d_1	BHN	d_1	BHN	Second specimen d_1	BHN	d_1	BHN
100	**1**	0.63	49.3	0.63	49.3	0.64	47.8	0.64	47.8
	5	0.62 0.65	50.9 46.3	0.62 0.65	50.9 46.3	0.62 0.65	50.9 46.3	0.62 0.65	50.9 46.3
	10	0.63	49.3	0.63	49.3	0.65	46.3	0.65	46.3
	15	0.70	39.8	0.70	39.8	0.70	39.8	0.70	39.8
	20	0.70	39.8	0.70	39.8	0.70	39.8	0.70	39.8
	30	0.71	38.6	0.71	38.6	0.71	38.6	0.71	38.6
	50	0.69	41.0	0.71	38.6	0.72	37.6	0.72	37.6
	70	0.72 70	37.6 39.8	0.72 70	37.6 39.8	0.72 0.72	37.6 37.6	0.72 0.72	37.6 37.6
	80	0.72	37.6	0.72	37.6	0.72	37.6	0.72	37.6
	100	0.72	37.6	0.72	37.6	0.72	37.6	0.72	37.6

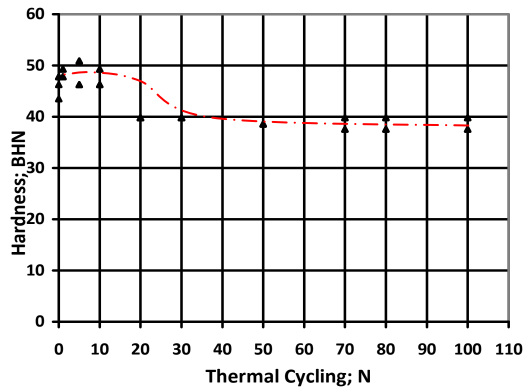

Figure 5 Effect of thermal fatigue on hardness of aluminum at temperature; T_h=300 °C

Table 6 Experimental results of hardness test of aluminum, thermal fatigue heating temperature; T_h =500°C.

Thermal fatigue		Hardness Test **F=15.625 Kg D=2.5 mm t=60 sec**							
T_h °C	N **Times**	First specimen d_1	BHN	d_1	BHN	Second specimen d_1	BHN	d_2	BHN
100	**1**	0.94	21.7	0.94	21.7				
	5	0.94	21.7	0.94	21.7	0.95	21.2	0.96	20.8
	10	0. 96	20.8	0. 96	20.8	0. 96	20.8	0. 96	20.8
	20	0.80	30.2	0.83	28.1	0.95	21.2	0.95	21.2
	30	0.85	26.7	0.90	23.7	0.95	21.2	0.96	20.8
	50	0.82	28.7	0.82	28.7	0.90	23.7	0.94	21.7
	70	0.97	20.3	0.97	20.3	0.97	20.3	0.97	20.3
	80	0.97	20.3	0.97	20.3	0.97	20.3	0.97	20.3
	100	0.97	20.3	0.97	20.3	0.97	20.3	0.97	20.3

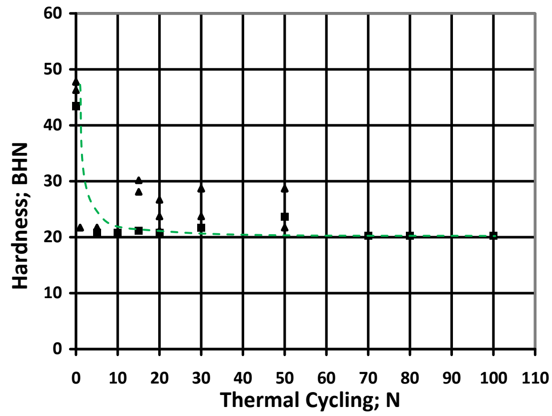

Figure 6 Effect of thermal fatigue on hardness of aluminum at temperature; T_h =500 °C

VI. RESULTS

Hardness aluminum before thermal fatigue amounted to HB 2.5/15.625/60, and was in the range from 47.8 to 43.5. After thermal fatigue, obtained hardness amounted to HB 2.5/15.625/60, at heating temperature; T_h=100 °C, N=1, and was in the range from 47.8 to 46.3, N=3 obtained hardness amounted to 46.3 HB 2.5/15.625/60, N=7 it was in the range from 43.5to 46.3, N=14 it was in the range from 47.8 to 54.3, N=20 obtained hardness amounted to 46.3 HB, N=30 obtained hardness amounted to 46.3 HB, N=50 it was in the range from 46.3 to 49.3 and N=70 to 100 obtained hardness amounted to 47.8 HB Fig. 4 shows the average values of BH hardness.

In cases of heating temperature 300 and 500 °C obtained average hardness amounted to HB 2.5/15.625/60 at different repeated cyclic heating show in Figs. 5 and 6.

Comparison of thermal fatigue effect of hardness of aluminum at different values of heating temperature; T_h = 100, 300 and 500 show in Fig. 7.

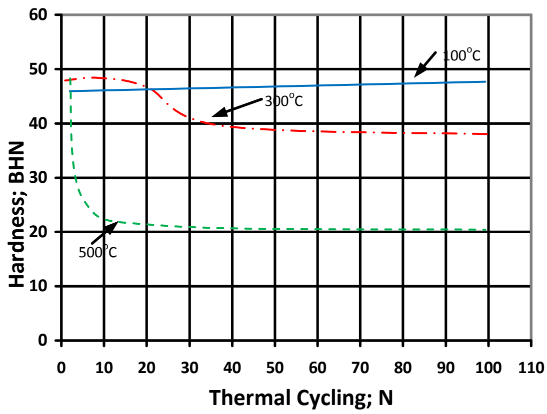

Figure 7 Comparison of thermal fatigue on hardness at different values of heating temperature; T_h=100, 300 and 500 °C

VII. Conclusion

The experimental results show that there is a significant effect of cycling thermal treatment on hardness.

Repeated heating of aluminum specimens at 100 °C show slightly decrease in hardness values, which have no effect by the increase of heating cycles. By cyclic heating at 300 °C the hardness decreases to 37.6 BHN after 20 cycles, then it constant by further heating cycles, while by heating to 500 °C, the hardness decreases to a value of about 20.3 BHN after 10 cycles then remains at this value by further heating cycles.

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