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Artificial ageing of aluminum alloys. Statistical studies of results

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Abstract

The materials used in aircraft industry beside the light specific weight, must respond to some specific requirements for creation of new materials and also the improvement of the material properties used in the present.In modern aircraft construction there are many casting pieces, such as props, fittings, flanges, handles, crossing tight bodies, etc. Casting alloys used are based on aluminum alloys, magnesium-lithium alloys, vanadium-aluminum alloys, titanium alloys, etc.Aluminum alloy, the ones which are light and have good physical and mechanical properties, are part of common materials used in producing some components found in aircraft technology. In terms of experimentally point of view, the application of different artificial ageing heat treatments leads to an improvement of the mechanical properties compared with the results registered by natural aging.Experimental researches made on samples of ATSi6Cu4Mn aluminum alloy artificially aged by unconventional heat treatments highlights the obtaining of improved mechanical properties, the results representing a very useful database under the terms of the data being properly recorded.The verification by a statistical test of the experimental data registration in a normal distribution represents in this case the necessary condition for the validation of the results.

Key words: aluminum alloy; heat treatment; mechanical properties; mathematical statistic

1. Introduction

Mathematical statistics applied to heat treatments gives a relatively small number of observations (data collected), which can explain why the experimental data recorded by studying of artificial ageing phenomenon is used to improve the mechanical properties of the aluminum alloys. Measurements are subjected to measurement and observation of errors which are inevitable.

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Analyzing their causes it is shown that measurement errors occur due to the precision class of instruments, but also to the involuntary errors in matching and reading the instruments.The samples were natural and artificially aged by heat treatment, the results being recorded at the room temperature and presented in the following tables.

The prints were measured at the room temperature for determining the Brinell hardness, the properly corrections and the calculated values of the precision indicators for the measurements on initial state specimens are found in Table 1.

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Table 1. Prints, corrections and precision indicators for samples at ambient temperature which were not heat treated, [5]

$ATSi_6Cu_4Mn$ alloy (sample no.)	Print D_{ij} [mm]	Apparent correction v_j [mm]	Precision indicators [mm]
46	1,74	(0,02); 0,01	
47	1,74	(0,02); 0,01	
48	1,74	(0,02); 0,01	
49	1,73	0,03	$s_{D_{11}} = 0{,}04$
50	1,74	(0,02); 0,01	
51	1,74	0,02	$E_1 = 0{,}10$
52	1,74	0,02	
53	1,76	0,00	$CV = 2{,}27\%$
54	1,85	-0,10	
55	1,75	0,01	$T = 3s_{D_{11}} = 0{,}12$
56	1,76	0,00	
57	1,73	0,03	$\Delta_{max} = 0{,}12$
58	1,73	0,03	
59	1,84	-0,08	$\Delta_{max} \le T$
60	1,76	0,00	
	$\overline{D}_{11}$=1,757	($[v]$=0,04); $[v]$=0,00	

The measure of the measurements precision or the rank of dispersion of individual results of print diameters $D_{ij}, i = \overline{1,8}$, (i - number of heat treatments, j - number of samples) than the average $\overline{D}^i$, is represented by the standard deviation of a measurement $s_{D_{ij}}$,calculated by equation 1 [1;5]: $s_{D_{ij}} = \sqrt{\frac{[vv]}{n-1}}$; (1)

where $[v] \overset{not.}{=} \sum_{j=1}^{n} v_j$ and $[vv] \overset{not.}{=} \sum_{j=1}^{n} v_j^2$ is the Gauss sum, and $v_j = \overline{D}^i - D_{ij}$ represents the apparent corrections for the total number of samples (n). The accuracy of the corrections is given by condition:

$[v] = 0{,}00$. There are some situations when $[v] \neq 0{,}00$ (to second decimal being nonzero). In these conditions, we compensate the hundredth (more or less) with the number of corrections equal to the second nonzero decimal [1; 5].

The results recorded in tables 2 and 3 represent the experimental data measured after the natural aging treatment (7 days) and the artificially one (2 h) and their corresponding statistical interpretation.

The good results achieved by artificial aging applicated for two hours were also obtained after artificial aging maintained for four hours.

Table 2. Prints, corections and precision indicators for natural aged samples at the ambient temperature, [5]

$ATSi_6Cu_4Mn$ Alloy naturally aged (sample no.)	Print D_{ij} [mm]	Apparent correction v_j [mm]	Precison indicator [mm]
4	1,68	0,03	$s_{D_{12}} = 0{,}03$
8	1,68	0,03	
9	1,70	0,01	$E_2 = 0{,}01$

34	1,70	0,01	$CV = 1{,}75\%$
35	1,75	(-0,04); -0,03	$T = 3s_{D_{12}} = 0{,}09$
36	1,67	0,04	$\Delta_{max} = 0{,}08$
37	1,70	0,01	$\Delta_{max} \leq T$
38	1,67	0,04	
39	1,74	-0,03	
40	1,74	-0,03	
41	1,75	(-0,04); -0,03	
42	1,73	-0,02	
43	1,74	-0,03	
44	1,73	-0,02	
45	1,70	(0,01); 0,02	
	$\overline{D}_{12}$=1,712	($[v]$ = 0,03); $[v]$ =0,00	

The aplication of the artificial aging heat treatment for four hours has determined registering some prints whose values belong to sufficiently small length, calculated precision indicators (Table 4) certifying that the experimental measurements represent a database which can be used to improve physical and mechanical properties of the aluminum alloys.

Table 3. Prints, corrections and precision indicators for artificially 2h aged stamples at ambient temperature, [5]

$ATSi_6Cu_4Mn$ Alloy artificially 2h aged (stample no.)	Print D_{ij} [mm]	Apparent correction v_j [mm]	Precision indicators [mm]
1	1,73	(-0,04); -0,03	
2	1,68	(0,01); 0,02	
3	1,67	0,02	
5	1,66	0,03	
6	1,70	-0,01	$s_{D_{13}} = 0{,}03$
7	1,75	(-0,06); -0,05	
22	1,68	0,01	$E_3 = 0{,}01$
23	1,67	0,02	
25	1,66	0,03	$CV = 1{,}77\%$
26	1,74	(-0,05); -0,04	
29	1,66	0,03	$T = 3s_{D_{13}} = 0{,}09$
30	1,70	-0,01	
31	1,68	0,01	$\Delta_{max} = 0{,}09$
32	1,67	0,02	
33	1,75	(-0,06); -0,05	$\Delta_{max} \leq T$
	$\overline{D}_{13}$ =1,693	($[v]$=-0,05); $[v]$=0,00	

Table 4. Prints, corrections and precision indicators for artificial 4 h aged stamples at ambient temperature, [5]

$ATSi_6Cu_4Mn$ alloy artificially 4h aged (stample no.)	Print D_{ij} [mm]	Apparent correction v_j [mm]	Precision indicators [mm]
10	1,66	0,02	$s_{D_{14}} = 0{,}03$
11	1,64	(0,04); 0,03	
12	1,72	-0,04	$E_4 = 0{,}01$
13	1,67	0,01	

14	1,67	0,01
15	1,66	0,02
16	1,73	-0,05
17	1,72	-0,04
18	1,68	0,00
19	1,64	0,04
20	1,73	-0,05
21	1,67	0,01
24	1,66	0,02
27	1,68	0,00
28	1,66	0,02
	$\overline{D}_{14}$=1,679	($[v]$=0,01); $[v]$=0,00

$CV = 1{,}78\%$

$T = 3s_{D_{14}} = 0{,}09$

$\Delta_{max} = 0{,}09$

$\Delta_{max} \leq T$

2. Statistical interpretation of the results

According to experimental data, the measurements on specimens at ambient temperature have deviations, but the calculated precision indicators highlight that all of the measurements belong to the allowed specific tolerance.

The processing of the experimental highlights that the measurement process can be accompanied by errors whose influence can be reduced by a large number of determinations. Irrespective of the chosen amount of data, random errors (aleatory) can not be avoided, being necessary to check the hypothesis that the aleatory variables have a normal distribution.

Thus for a relatively small measurement amount ($3 < n < 50$)can be used *Shapiro-Wilk* test [1;5] or W test W to verify the normal distribution, test which can be applied only to the measurements for which keep the condition $\Delta_{max} \leq T$.

Choosing the critical value $W(n, \alpha)$ is done according to two parameters n and α, where n is the number of random variables and α. The significance limit or the error probability. The value of α depends on the application field for industry and technology $\alpha = 0{,}05$, which means that a results set is accepted with a probability of 95% [1;5].

Using statistical tables of the test [1;5], the critical value is chosen $W(n, \alpha)$, value which is compared with the calculated one; if $W > W(n; \alpha)$, is accepted the hypothesis of normal distribution of considered random variables (prints).

3. Conclusions

The calculations performance to verify the normality for the recorded values determines the obtaining of the following parameter values in tables(average values, standard deviations, standardized diameters):

Table 5. *Shapiro -Wilk* test applied to the average values of the prints *[5]*

Parameters \ *j*	**1**	**2**	**3**	**4**
$\overline{D}_{1j}$	1,757	1,712	1,693	1,679
$s_{D_{1j}}$	0,04	0,03	0,03	0,03
$\overline{D}_{1j}^{*}$	43,92	57,06	56,43	55,97
x_i	43,92	55,97	56,43	57,06

The result $W = 0,858$ shows that the calculated value is bigger than $W(4;0,05) = 0,748$ so that we can say with 95% statistical certainty that all prints values measured at room temperature on samples of ATSi6Cu4Mn aluminum alloy studied belong to a normal distribution.

The experimental results highlight the improvement of the average Brinell hardness value determined after artificial aging (compared with natural aging), and the statistical interpretation confirms these data.

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