INTERPRETATION OF THE EXPERIMENTAL RESULTS ON THE MECHANICAL PROPERTIES OF THE ALUMINUM ALLOY $ATSi_6Cu_4Mn$

Mihaela SMEADĂ *, Maria STOICĂNESCU **

*"Henri Coanda" Air Force Academy, Brasov, Romania
** "Transilvania" University of Brasov, Romania

Abstract: *A highly and actual matter in aircraft construction is the use of lightweight materials so that the obtained aircraft to provide a high degree of maneuverability. The use of aluminum alloys follows this path so that the experimental researches carried out to improve the properties of these materials are a requirement of the Aerotechnic Industry, the validation of experimental results being an extremely important factor.*

Keywords: *aluminum alloy, heat treatment, precision indicators, statistical tests*

1. INTRODUCTION

Aerospace industry requires that the materials used and the manufacturing technologies to be constantly improved as the aircraft functionality to be realized in safe and high efficiency conditions. Studies and researches in this domain are focused on finding new materials or technologies to better respond to the requirements of this industry without neglecting the economic factor [4].

Safety on aircraft flight is closely related to the safe operation of all systems and subsystems components which led to the diversification of equipment and installations on the aircraft. On the other hand, the resistance of the aircraft is continuously re-evaluated so that the carriage of passengers and goods by air is now more secure than transport by land or water.

According to I.C.A.O. statistics, the ratio between the number of transported passengers and number of passengers injured or dead in air disasters, over a year, shows the aircraft as the safest mean of transport [3, 4].

Because the light materials have lower mechanical strength than the heavy metals, special alloys (light) based on aluminum are used [3, 4] (with alloying elements Cu, Mg, Zn, Mn, Ni, Cr, Li, Cd, Ti, V, Zr, Si), based on magnesium (with alloying elements Zn, Zr, Rh, Th, Mn, Al, Li), based on titanium (with alloying elements Mn, Fe, Cr, Mo, Al, Cu, Zr) and based on beryllium (with alloying elements Al, C, Fe, Si) [3, 4].

Aluminum is a light metal with high plasticity, low mechanical strength, high electrical and thermal conductivity and resistance to corrosion in air, water and organic acids. The main disadvantage of aluminum is connected to the very low tensile strength, so that its alloys have a wider use. Properties of aluminum alloys can be improved by heat treatment, which includes hardening, recovery and annealing, known as recovery hardening or aging. Natural aging lasts a long time and the mechanical characteristics are not changing very much, so it is replaced by artificial aging. Through artificial aging is reduced the total aging time at few hours, and the mechanical characteristics are significantly improved [3,4].

2. INTERPRETATION OF EXPERIMENTAL RESULTS

During the experimental researches we have used standard aluminum alloy test tubes $ATSi_6Cu_4Mn$, whose chemical composition is shown in Table 1.1. The heat treatments applied have been carried out according to the following steps: the samples were heated in an oven at 520 ° C for 40 minutes, quenched and then naturally and artificially aged at a constant temperature of 170 ° C over various time intervals (two and four hours) [2, 4, 5, 6].

Table 1.1. The chemical composition of the test tubes used, [%],[4]

Alloy $ATSi_6Cu_4Mn$ (Test tube number)	Si	Cu	Mn	Al	Others
[1; 60]	5,439	3,944	0,417	88,626	1,574

Measuring of the prints and then determining Brinell hardness using table's values are subject to errors of measurement and observation, errors which are inevitable, so we have considered necessarily the results to be processed and interpreted using mathematical statistics. Measurement errors appear both because of the precision class of instruments and also because of unintended errors of reading and matching the instrument, and errors of observing are related both to an observer as to a series of random influences [1, 2, 4].

Precision indicators calculated are[1;2;4]:

- standard deviation of a measurement $s_{D_{ij}}$,
- standard error (standard deviation of the average values obtained), E_i,
- the variation coefficient $CV\%$,
- tolerance, T,
- Maximum spread Δ_{max}

The variation coefficient may take the following values: a) between 1…10%;
b) between 10…30%;
c) >30% .

When the variation coefficient takes values in the first range, the measurement results fall within a small scatter around the mean value; values that are included in the second range are defining the medium dispersion, and if the variation coefficient takes values greater than 30%, the obtained results are indicating a high dispersion.

Classifying the variation coefficient in one of the first two categories expresses the existence of acceptable measurements from statistically point of view, measurements that are certifying that the experimental data are correct, the registered deviations being extremely small.

For values exceeding 30% is considered that the measurements are affected by errors too large, so the experimental data are not taken into account [1, 2, 4], and the set of measurements is resumed.

For calculated precision indicators, indexes have the following meaning:

- first index is the temperature of test tubes when are measured; in the situation 1, is the temperature of the environment;
- second index represents the state in which the test tube are (a number of samples were left as initially, others were heat treated): 1, non heat-treated test tubes, 2 test tubes naturally aged, 3 test tubes artificially aged by heat treatment applied for two hours, 4 test tubes artificially aged by heat treatment applied for four hours [2, 4, 5, 6].

Precision indicator values calculated for prints measured on studied aluminum alloy samples at ambient temperature are:

- for test tubes non heat treated:

$$\overline{D}_{11} = 1,763mm; s_{D1} = 0,04mm; E_1 = 0,10mm$$

$$CV = 2,27\%; T = 3s_{D11} = 0,12mm$$

$$\Delta_{max} = 0,12mm; \quad \Delta_{max} = T$$

- for test tubes naturally aged:

$$\overline{D}_{12} = 1,724mm; s_{D12} = 0,031mm; E_2 = 0,01mm$$

$$CV = 1,79\%; T = 3s_{D12} = 0,09mm$$

$$\Delta_{max} = 0,08mm; \quad \Delta_{max} \le T$$

- for test tubes artificially aged for two hours:

$$\overline{D}_{13} = 1,698mm; s_{D13} = 0,037mm; E_3 = 0,01$$

$$CV = 2,18\%; T = 3s_{D13} = 0,11mm$$

$$\Delta_{max} = 0,09mm; \quad \Delta_{max} \le T$$

- for test tubes artificially aged for four hours:

$\overline{D}_{14} = 1{,}681mm; s_{D14} = 0{,}031mm; E_4 = 0{,}01mm$

$CV = 1{,}84\%; T = 3s_{D14} = 0{,}09mm$

$\Delta_{\max} = 0{,}09mm; \quad \Delta_{\max} \le T$

The low values of variation coefficient calculated for all the studied samples indicate that the measurements are correct, measurement errors being very small (CV between 1…10%).

Condition $\Delta_{\max} \le T$ performed for all studied samples allows a statistical study to be applied in order to verify the normal distribution of the experimental data obtained.

For a relatively small volume of measurements ($3 < n < 50$) we have used the *Shapiro-Wilk test* [1, 2, 4] or *W test* for the verification of normal distribution. Stages to be completed in this regard are:

- standardization or normalization of corrections on sizes $\overline{D}_{ij}$ (medium value of print)
- normal distribution testing of standardized sizes $\overline{D}^{*}_{ij}$;
- choosing critical values $W(n, \alpha)$ from table 1.2. [1];
- verifying the normal distribution of considered selection;
- for $W > W(n; \alpha)$ is accepted the hypothesis of normal distribution of random variables considered (average values of measured prints on studied aluminum alloy samples) [1;4].

Table 1.2. Critical values of W test[1]

	3	4	5
0,01	0,653	0,687	0,686
0,05	0,767	0,748	0,762

Using statistical tables of W test is chosen the critical value W (n, α) value that compares with the one calculated. [1,4].

Value considered critical, for measurements in technical domain, if we choose four random variables and an error of 0.05%, is $W(4;0{,}05) = 0{,}748$.

If $W > W(n; \alpha)$, is accepted the normal distribution hypothesis of considered random variables (print) [1].

Normality test calculations for precision indicators determines parameter values (average values, standard deviations, standardized diameters) as those listed in Table 1.3 where the values x_i represents in ascending order the placement of standardized values ($\overline{D}^{*}_{1j}$) corresponding to average values of the print.

Shapiro-Wilk test applied to the average values of measured prints on all samples at ambient temperature leads to the value of $W = 0{,}9579$.

Table 1.3. Average values of precision indicators

i	1	2	3	4
$\overline{D}_{1j}$	1,763	1,724	1,698	1,681
$s_{D_{1j}}$	0,039	0,033	0,041	0,033
$\overline{D}^{*}_{1j}$	45,21	30,30	41,42	50,93
x_i	30,30	41,42	45,21	50,93

The obtained result, $W = 0{,}9579$, indicates the fact that the calculated value meets the required condition $W > W(n; \alpha)$ [$W(4;0{,}05) = 0{,}748$] (as for the tables 1.2. and 1.3), so that it can be said with 95% statistical certainty that the measured prints are fitting into a normal distribution.

CONCLUSIONS

After processing the experimental results the following conclusions can be set:

- factors that positively influence Brinell hardness (mechanical properties) are the time required during the application of heat treatment and the temperature at which the samples are maintained;
- precision indicators calculations demonstrates that from statistically point of view the measurements are well designed, the collected data is entered in the margin of admitted error, measurement errors being very small;
- measurement errors (calculated with precision indicators) of the prints, highlights the fitting of experimental data into a normal distribution.

The experimental researches carried out on the aluminum alloy *$ATSi_6Cu_4Mn$* subject to heat treatments, correlated with the statistical study, represents is in this way a very useful database on aluminum alloys and their behavior from the point of view of mechanical properties.

BIBLIOGRAPHY

1. GHIȚĂU, D., (2009) „*Prelucrarea măsurătorilor geodezice*”, Topoexim Publishing House, Bucharest.
2. MUNTEANU, B., SMEADĂ, M., PIRNUTA, O., A., (May 28-31, 2009) „*Statistical Processing of Experimental Data in the Case of Impression Diameters of Aluminum Alloys Samples Used in AirCraft Engineering”,* The Seventh International Congress in Materials Science and Engineering, Iaşi, pag. 73-78
3. PREOTU, O., (2001) “*Construcția şi calculul aeronavelor”,* Technical Publishing House, Bucharest.
4. SMEADĂ, M., (2011) ”*Studii şi cercetări privind îmbunătățirea proprietăților fizico-mecanice ale materialelor utilizate în tehnica aerospațială”,* Doctorate Thesis, Transilvania University of Braşov.
5. SMEADĂ, M., STOICĂNESCU, M., MUNTEANU, B., (May 25-27, 2011) *Mechanical Properties of the Aluminum Alloys at Low Temperatures*. *Statistical Processing*, ModTech International Conference - New face of TCMR, Chişinău, pag.1017-1020
6. STOICĂNESCU, M., SMEADĂ, M., GEAMĂN, V., (September 24-26, 2009) „*Unconventional heat treatments applied to aluminum alloys used in air force technique”* Proceedings of the 1st International Conference on Advances in Manufacturing Engineering Quality Production System*s* (MEQAPS 09), volume II, Braşov, pag. 440-444.