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[1.] DINU DRĂGAN, [2.] MIRCEA CRISTIAN ARNĂUTU,
[3.] ION SIMION, [4.] NICUŞOR LAURENŢIU ZAHARIA

FATIGUE TESTS AT HYBRYD ALUMINUM ALLOY JOINTS

Abstract:
This paper presents a study on fatigue performance of adhesive/rivets joints in an aluminum structures. Hybrid joints were shown to have greater strength, stiffness and fatigue life in comparison to adhesive joints. The results from fatigue tests confirm the static tests made on the same type of test samples.

Keywords:
Aluminum, Adenit, Si-Plane, joints

INTRODUCTION

Aluminum alloy joints are used in aircraft construction, some cars, railway vehicles etc.
The joints can be assembling by welding, gluing, rivets etc.
In this paper it will be presented joints assembled hybrid (gluing and rivets).
The tests were performed in the CEEX program named "Adhesives, Rivets and Hybrid Aluminum Alloy and Composite Materials Joints".

MEASUREMENT DEVICES AND JOINT TYPES

The tensile fatigue tests were performed at Romanian Railway Authority – AFER on universal testing machine SI-PLANE 942-1 type (fig. 1). The testing machine was designed and manufactured by British Company Si-Plan Electronics Research Limited in the year 2005.
The machine is hydraulically manipulated from a computer and can perform tests with tensile or compressive forces (static and dynamic) and it has the next characteristics:

- Maximum force for static tests: $\pm$350kN;
- Maximum force for dynamic tests: $\pm$250kN;
- Maximum high for the vertical tests: 400mm;
- Frequency for dynamic tests: $\leq$ 40Hz.

All the preparing operations and the test are performed by the hydraulic installation of the machine. He steps for performing the tests were:

a. Each type of joint was named **N"tip"n** , where „**tip**" means the joint type of the aluminum alloy (nit – rivet joint, hib – hybrid joint or adz – adhesive joint), **N** is given by the thickness of the material or the joint geometry and **n** is the identification number for the same type of joint.
b. For each of joint a reference tensile force was calculated based on static tests which were performed on other stage of the project.
c. Based on reference tensile force, the maximum and minimum dynamic tensile forces were calculated for five value domains as following: 80%, 70%, 60%, 50% and 40% from the reference tensile force and the minimum values were 10% from the maximum values (the 1/10 value was used for each fatigue cycle).

d. A 5Hz frequency was used for all fatigue tests. During the test it was cases when the joints break it after hundreds of cycles before to reach the stability of the dynamic regime at 5Hz frequency (the test was repeated if it was possible on another same type joint) or the joint doesn't break it not even after 500.000 cycles.

e. For each joint it was recorded the number of cycles when the joint was break it and the type of joint break (adhesive, cohesive or adhesive-cohesive).

f. Photos were made on each joint before, during and after the tests. Also a print screen on Si-Plane machine computer for each joint was made. In this print screen it is shown the minim and maximum of force cycle, frequency and number of cycles.

g. Based on values recorded at step number 6, the normalized curve $S-N$ (Wöhler curve) was draw by quasi-linearity interpolation which crosses the horizontal axis in the point which has the coordinates (0; 1).

$$\frac{F_M}{F_R} = 1 - k \cdot \lg(N) \qquad (1)$$

which mean that the ratio between maximum force of the cycle and the reference force depending on decimal logarithm of breaking number of cycles.

h. The tests were performed at 21 degree Celsius temperature and 55% relative humidity.

Figure 1 The Universal Testing Machine SI-PLAN 942-1 type

Many types of joints were tested. The aluminum pieces were jointed in different shapes: end to end, one above other, angle joint etc. as follows:

- Adhesive joints;
- Hybrid joints (adhesive+rivet).

In fig. 2÷3 are shown the types of joints were the value of ratio 1/K had the highest value.

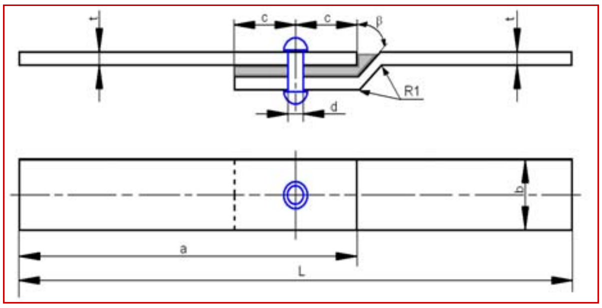

Figure 2 4hib joint type

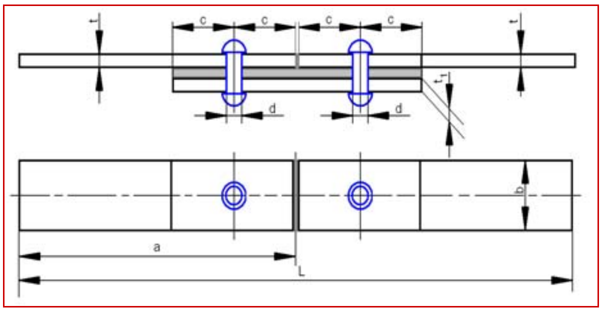

Figure 3 5hib joint type

RESULTS

4hib joint type

In table number 1 are presented the results for 4hib joint type.

Table 1. Results for 4hib joint type.

Proof sample	F_{max}	F_{min}	N	Lg(N)
4hib_3	170	17	59844	4,78
4hib_4	200	20	184432	5,27
4hib_5	200	20	2579	3,40
4hib_6	230	23	68413	4,84
4hib_7	230	23	2583	3,41

Regarding to this table the following explanation are necessary:

- F_{max} and F_{min} measured in daN units are maximum and minimum value for a pulsate cycle at 5Hz frequency;
- The value F_{max}=170daN, is represent 60% from tensile reference force;
- The value F_{max}=200daN, is represent 70% from tensile reference force;
- The value F_{max}=230daN, is represent 80% from tensile reference force;
- N is the number of cycles when the joint break it

In fig. 4 is shown the normalized Wöhler curve draw by quasi-linearity interpolation.

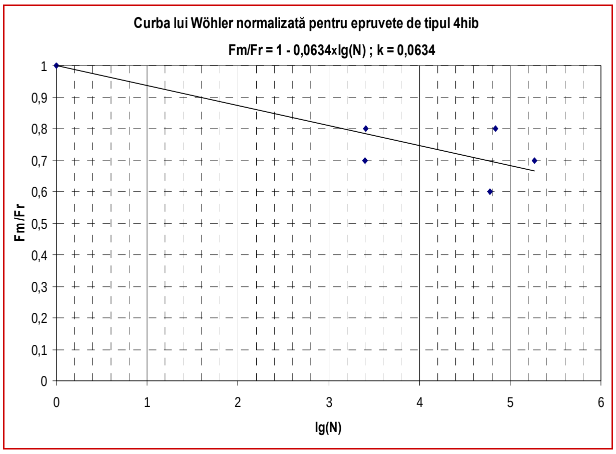

Figure 4. Wöhler curve for 4hib joint type

The proof sample 4hib_3, 4hib_4 and 4hib_6 were break it in the metal and the proof sample 4hib_5 and 4hib_7 were break it in the adhesive.
In fig. 5 it is presented an adhesive break and in fig. 6 it is presented a metal break.

Figure 5. Adhesive break

Figure 6. Metal break

5hib joint type

In table number 2 are presented the results for 5hib joint type.
Regarding to this table the following explanation are necessary:

- *F_{max} and F_{min} measured in daN units are maximum and minimum value for a pulsate cycle at 5Hz frequency;*
- *The value F_{max}=190daN, is represent 60% from tensile reference force;*
- *The value F_{max}=220daN, is represent 70% from tensile reference force;*
- *The value F_{max}=260daN, is represent 80% from tensile reference force;*
- *N is the number of cycles when the joint break it.*

Table 2. Results for 5hib joint type.

Proof sample	F_{max}	F_{min}	N	Lg(N)
5hib_6	190	19	240037	5,38
5hib_4	220	22	103031	5,01
5hib_7	220	22	120806	5,08
5hib_8	220	22	40100	4,60
5hib_5	260	26	605	2,78
5hib_9	260	26	1939	3,29
5hib_10	260	26	5537	3,74

In fig. 7 is shown the normalized Wöhler curve draw by quasi-linearity interpolation.

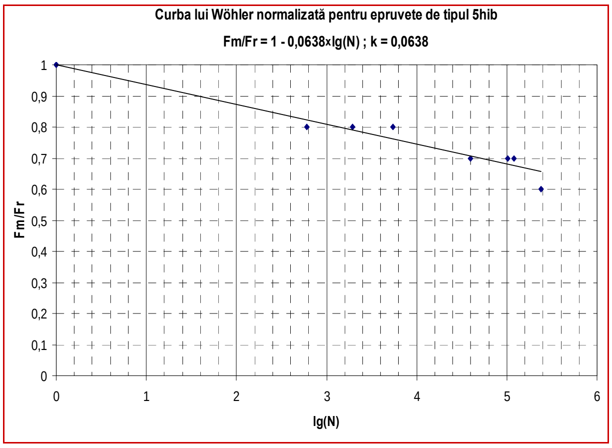

Figure 7. Wöhler curve for 5hib joint type

The proof sample 5hib_6 has an adhesive break but not a rivet break. The proof sample 5hib_4 has an adhesive-cohesive break and the other proof sample had an adhesive break.

Figure 8 5hib_6 proof sample

Figure 9 5hib_9 proof sample

In fig. 8 it is presented an adhesive break and in figure 9 it is presented an metal break.

CONCLUSION

In fig. 10 the different types of joints had been arranged from the point of view of 1/K ratio (the inverted of normalized Wöhler curve) which significance is the fatigue lastingness of the proof sample.

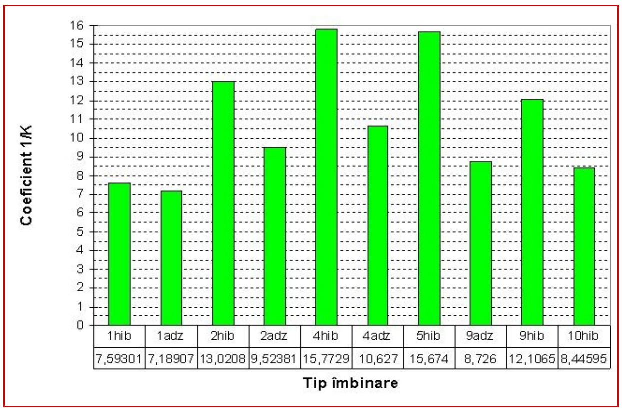

Figure 10. 1/K ratio histogram

From fig. 10, it can be seen that the hybrid proof sample number had a higher lastingness but we must remember that the tensile reference forces are different from one type of joint to other (the tensile reference forces are higher at adhesive joints).

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AUTHORS & AFFILIATION

[1.] DINU DRĂGAN,
[2.] MIRCEA CRISTIAN ARNĂUTU,
[3.] ION SIMION,
[4.] NICUŞOR LAURENŢIU ZAHARIA

[1. 2. 3. 4] Romanian Railway Authority – AFER, Bucureşti, ROMÂNIA