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## STUDY OF THE BONDING FORCES OF THE ALUMINUM ALLOY IN THE CASE OF CYANOACRYLATE-BASED ADHESIVES

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**Abstract:** *This paper presents the results of tests conducted to determine the bonding forces achieved with cyanoacrylate-type adhesives on 7075 series aluminum alloy. This study represents an initial step in assessing the applicability of cyanoacrylate adhesives in the production of bonded assemblies. Specifically, it explores their use for joining aluminum parts that serve identification or aesthetic/design functions. Driven by significant pressure to reduce manufacturing times, bonding technologies are increasingly employed as non-detachable assembly methods, alongside traditional assembly techniques. A key advantage of bonding is its ease of automation, which can considerably shorten manufacturing cycles. Based on the tests performed, the tear strengths of the adhesives were determined. Under the test conditions, notable differences were identified in approximately 53% of the adhesives evaluated. The test results suggest potential for use in the applications for which the tests were conducted.*

**Key words:** *aluminum alloy, cyanoacrylate-type adhesives, test, bonding.*

### 1. INTRODUCTION

Bonding techniques, particularly for metals, are essential in the creation of permanent assemblies across various industrial applications. Among the available methods, adhesive bonding has gained widespread use due to its numerous advantages, including reduced weight, simplified design, and the potential for automation in manufacturing processes. A wide range of adhesives is employed for metal bonding, with selection typically based on the specific metals involved and the operational conditions that the bond must endure.

Cyanoacrylate adhesives are of particular interest due to their fast curing times, strong bonding capabilities, transparency, and compatibility with diverse materials.

Despite their widespread use, the detailed mechanisms governing cyanoacrylate bonding, as well as the optimal conditions required to ensure high bond quality, remain incompletely understood.

Furthermore, the performance of these adhesives under varying conditions—such as differing surface properties, environmental factors, and

stress applications—continues to be a subject of interest.

While previous studies have contributed valuable insights, they focus on different materials for the dollies, i.e. different aluminum alloy [1,4,5] (EN AW-5083 and EN AW-6063), the aluminum alloy is not specified [2], steel [3,5] or on different adhesives.

Given the significant influence of adhesive composition and properties on bond performance, this study aims to compare the bonding efficacy of two commercially available cyanoacrylate adhesives.

The comparison is based on tensile strength tests conducted on metal substrates made of Aluminum alloy EN AW-7075 bonded with each adhesive, evaluating the forces required to separate the joined components. Through this approach, the study seeks to contribute to a better understanding of adhesive performance in metal bonding applications and to identify key factors that influence bond strength.

### 2. EXPERIMENT DESIGN

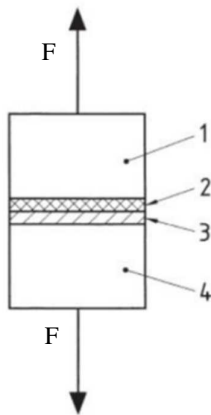
In the experiments included in this paper, a comparison between 2 similar adhesives is

made. The adhesives are manufactured by different companies, but they have resembling characteristics from the chemical point of view. By undertaking these experiments, the resistance of the adhesive film formed on the surface of aluminum alloy made parts is being tested. For the mentioned tests, the aluminum EN AW-7075 alloy has been chosen. The adhesives used in the tests are cyanoacrylate based and were manufactured by Bizon and Loctite respectively.

### 3. EXPERIMENTAL SETUP

The experiments have been designed and conducted based on the methodology described in the ISO 4624: Paints and varnishes — Pull-off test for adhesion (SR EN ISO 4624:2023) – standard.

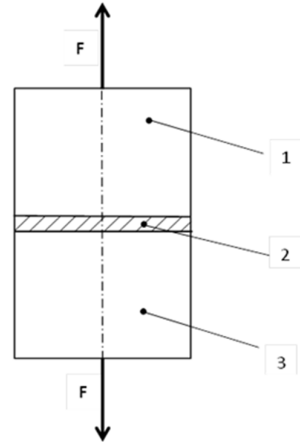
The pull-off test for adhesion requires a test assembly, as depicted in figure 1, which is to be pulled in the directions indicated by the arrows. Figure 1 lists as 1 – the painted dolly, 2 – the layer of paint, 3 – the adhesive, 4 – the dolly covered with adhesive, F – the pull-off force.



**Fig. 1.** Method for tensile testing of adhesives, according to EN ISO 4624/ SR EN ISO 4624:2023 Paints and varnishes — Pull-off test for adhesion

For the actual tests, the assembly recommended by ISO 4624 was adapted to the testing conditions. According to Figure 2, they are marked with:

- 1 and 3 dollies
- 2 layer of adhesive.



**Fig. 2.** The test assembly

Testing stages are:

- Dolly preparation
- Application of adhesive
- Measurement of the pull-off force.

#### 3.1. Dolly preparation

This stage consisted in the preparation of the dollies. The cylindrical shape of the dolly measures 20 mm in diameter and 30 mm in height. (Fig. 3) One of the faces of the dolly contains a threaded M10 hole for the testing equipment and the opposite face comes into contact with the adhesive to be tested.



**Fig. 3.** Test dollies

Before the application of the adhesive, each surface which holds the adhesive has been polished with abrasive paper of P500 silicon carbide grains (Klingspor PS11 A-P500), dusted and washed with acetone, followed by drying. A total of 24 dollies, 6 pairs for each adhesive, have been used. According to the ISO 4624 standard “Paints and varnishes — Pull-off test for adhesion” 6 test specimens must be prepared for force determination. Based on these, force determinations can be carried out and the results can be concluded. For the surfaces on which the

adhesive had to be applied, the surface roughness was measured by randomly selecting 6 dollies. The selection of the 6 dollies was made after a visual inspection that did not reveal significant differences in surface quality. The roughness measurements were performed to obtain numerical values to be used as a basis for comparison for future experiments. The calculated mean roughness value was  $R_a=0,899 \mu\text{m}$ .

The roughness measurements have been done by using a Mitutoyo SJ210 roughness meter. On each of the tested surfaces a number of 3 measurements have been made and their mean value has been considered to be the roughness value for that surface. The roughness measurement values can be found in Table 1.

Table 1

Dolly no.	Dollies roughness values			Mean value
	Roughness $R_a$ [ $\mu\text{m}$ ]			
	Measured value			
	1	2	3	
E1	0,943	0,839	1,024	0.935
E2	0,925	0,955	0,905	0.928
E3	1,034	0,910	1,003	0.982
E4	0,911	0,917	0,899	0.909
E5	0,732	0,655	0,658	0.682
E6	0,972	0,949	0,963	0.961
	Mean value			<b>0,899</b>

### 3.2. Application of adhesive

When applying the adhesive one important condition is to assure the coaxial position of the dollies in contact. This will ensure the correct contact area (if the dollies are not coaxial, the contact area between them will be less than the area of the dolly's face where the adhesive was applied). To assure the coaxial position of the dollies, a specially made centering device has been used (Fig. 4).

Following some preliminary tests, it has come to the conclusion that the material to be used for the centering device is recommended to be PEHD500 because cyanoacrylate adhesives do not adhere to it. The holes in the device, holes that are used for centering the dollies have been drilled in the preassembled position of the 2 holding plates.

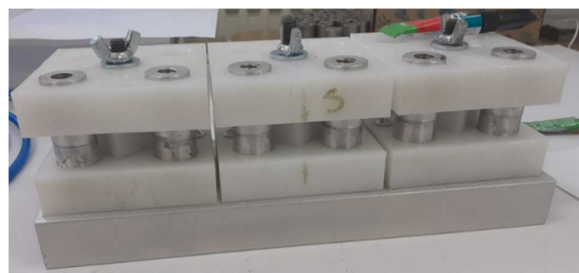


Fig. 4. Dolly centering device used in the experiments

The fit between the dolly and the hole is a clearance fit with a play value of 0.1 mm. The dowel pins used in the centering device have been positioned in such a manner as to avoid the mixing of the elements that make up the assembly.

For the test, 2 sets containing 6 dolly pairs each have been used (Fig.5). Each set has been prepared with a different adhesive (Bison and Loctite).



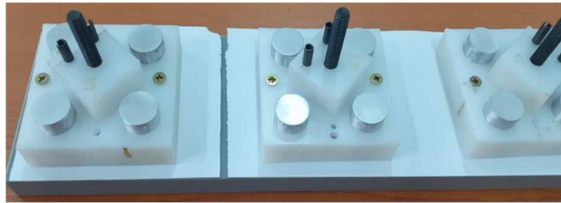
Fig. 5. The dollies used for testing

On the surface of the dollies that were positioned in the lower part of the centering device, the same amount of adhesive has been applied (Fig.6).



Fig. 6. The dosage of the adhesive on the surface of the dollies

After the dollies with adhesive have been placed in the lower part of the centering device (Fig. 7), the upper part of the device has been assembled to complete the centering stage (Fig. 8). The mating dollies have been inserted into the device and a pressing force of 3N applied.



**Fig. 7.** The dollies inserted in the lower part of the centering device



**Fig. 8.** The centering device with the glued dollies awaiting drying

The dollies were left to dry 24 hours before they were subjected to the pulling test.

### 3.3. Measurement of the pull-off force

For the measurement of the pull-off force required to separate the dollies, an assembly consisting of a universal testing machine, dynamometer and clamping system was used (Figure 9).

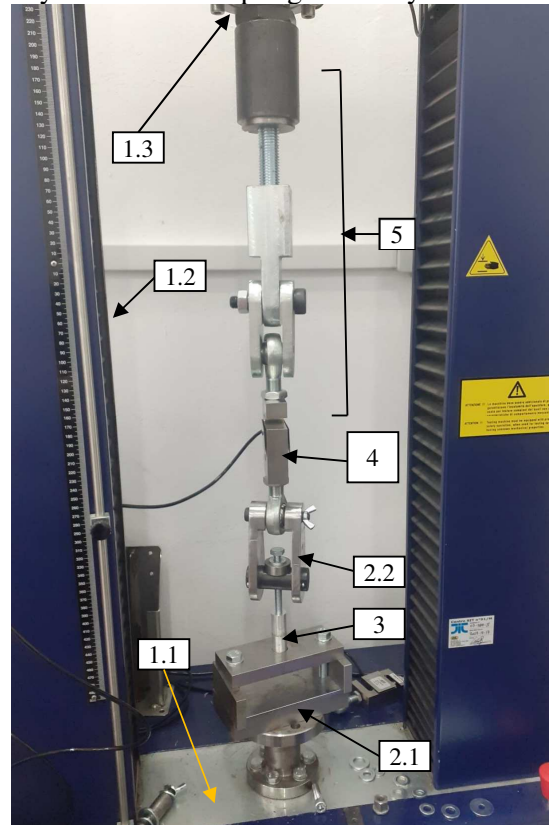
The universal testing machine, model TC100, manufactured by LBC SRL Italy, has a reading accuracy of 0.01 kN (10N). To increase the accuracy of force reading, an Axis FB 1k dynamometer with a 0.2N reading accuracy has been added to the testing assembly.

The dynamometer used communicates via the “TCSoft 2004 Plus” software with the computer and the data transfer is real-time with a frequency of 0.01 seconds for the measuring interval.

In Figure 9 the entire testing assembly is presented, highlighting the following:

- 1.1 – Universal testing machine
- 1.2 – Columns of the testing machine
- 1.3 – Tensiometric dose mounted on the machine’s crossbar
- 2.1 – Lower part of the testing device
- 2.1 – Upper part of the testing device
- 3 – Glued dollies
- 4 – FB1k dynamometer

### 5 – Universal testing machine crossbar dynamometer coupling assembly.



**Fig. 9.** Testing assembly to determine the pull-off force

In the afore mentioned testing assembly, the machine provides the testing force and kinematics and the dynamometer records the variation of the pull-off force for the following analysis.

The testing device used has been designed to provide self-alignment of the glued dollies when subjected to the axial pulling force.

A speed of 10mm/min of the machine’s crossbar has been used during the tests.

*Table 2*

Measured pull-off forces		
Adhesive	Loctite	Bison
Force values [kN]	9,82	4,834
	4,094	4,346
	9,348	5,932
	8,284	5,214
	6,09	5,284
	9,292	4,972

After the pull-off tests, the measured force values have been filtered using statistical tools.

This provided a validation of the obtained values and eliminated the influence of measuring and testing system errors.

The statistical analysis included:

- verification of the random nature of the experimental data. This was performed using the Young test;
- verification of the normality of the distribution of experimental data. The Shapiro-Wilk normality test was used;
- identifying outlier values and eliminating them. The identification of outlier values was done through the Romanowski test.

Following the statistical data analysis, the values of the pull-off forces have been listed in Table 3. These values have been further used for evaluation purposes and for the formulation of conclusions.

For a better visualization of the acquired data, the force values listed in Table 3 have also been plotted in the chart shown in Figure 10.

Table 3

**Pull-off forces validated through statistical processing**

Adhesive	Loctite	Bison
Force values [kN]	9,82	4,834
	disregarded	4,346
	9,348	disregarded
	8,284	5,214
	disregarded	5,284
	9,292	4,972
Mean [kN]	9,186	4,9304
Standard deviation	0,559696	0,334119
Dispersion	0,31326	0,111636

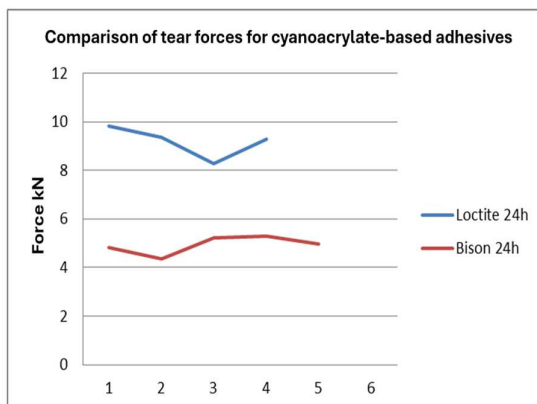


Fig. 10. Pull-off forces

Based on the pull-off force and the area on which the adhesive was applied, the tear strength of the adhesives was also calculated. (Table 4).

The area considered is the area of dolly (the circle with a diameter of 20 mm). This area is identical for each specimen.

Table 4

**Calculated tear strengths**

Adhesive	Pull-off force	Dolly area	Calculated resistance
	[kN]		[N/mm <sup>2</sup> ]
Bison	4,9304	314.159	15.694
Loctite	9,1860		29.239

#### 4. CONCLUSIONS

By analyzing the test results, we concluded that the adhesives have sufficient tensile strength to be used for aluminum assemblies or parts with ornamental or identification purposes. The parts with ornamental or identification purposes that were the basis for initiating the tests have a weight around 10-20 N.

By comparing these values of 10-20 N of the parts to be glued with the experimentally obtained force values of 4,9 kN and 9,1 kN, respectively, which are 100 times higher, we can conclude that gluing is a viable option and can be used.

The assemblies which used the same adhesive had very similar tear resistances. It can be considered that assembling by glueing with the studied adhesives and technology is a stable method.

Comparing cyanoacrylate-based adhesives sold by different manufacturers leads to very different tear strengths. Considering the experimental results, a difference of 53.7% is clearly visible. Even for the same adhesive manufacturer, in a different study [1], the values obtained in similar testing conditions are at a considerable gap.

To deepen the topic, we propose expanding the research to: establish the influence of surface roughness on the tear resistance of the adhesive layer; determine the fatigue resistance of the adhesive layer; determine the durability of the glued assembly; study the environmental influences on the glued assembly.

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### Studiul forțelor de lipire ale aliajului de aluminiu în cazul adezivilor pe bază de cianoacriilați

*Această lucrare prezintă rezultatele testelor efectuate pentru a determina forțele de lipire obținute cu adezivi de tip cianoacrilat pe aliajul de aluminiu din seria 7075. Acest studiu reprezintă un prim pas în evaluarea aplicabilității adezivilor cianoacriilați în producția de ansambluri lipite. Mai exact, explorează utilizarea lor pentru îmbinarea pieselor de aluminiu care îndeplinesc roluri de identificare sau estetice, de design.*

*Sub presiunea semnificativă de a reduce timpii de fabricație, tehnologiile de lipire sunt din ce în ce mai utilizate ca metode de asamblare nedemontabile, alături de tehnicile tradiționale de asamblare. Un avantaj cheie al lipirii este ușurința de automatizare, ceea ce poate scurta considerabil ciclurile de fabricație.*

*Pe baza testelor efectuate, au fost determinate rezistențele la rupere ale adezivilor. În condițiile testelor, au fost identificate diferențe notabile la aproximativ 53% dintre adezivii evaluați. Rezultatele testelor sugerează un potențial de utilizare în aplicațiile pentru care au fost efectuate testele*

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