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Effect of temperature on curing time of single-lap adhesive joints in marine applications

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Chaired by: PROF. RAMAN SINGH, PROF. DIGBY MACDONALD AND PROF. RHYS JONES
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ADHESIVE JOINTS IN MARINE APPICATIONS

- In the framework of **marine applications**, during last decades the requirements of *lightweight* and *durability* became fundamental in the design phase.

- Materials such as *aluminum alloy* allow a significant reduction of the weight of the structures mantaining their mechanical performances.

- **Structural adhesives**, when compared with other joining technique, lead to several advantages:

  - ✓ better distribution of the stresses
  - ✓ no galvanic corrosion
  - ✓ water-proofing

ADHESIVE JOINTS IN MARINE APPICATIONS

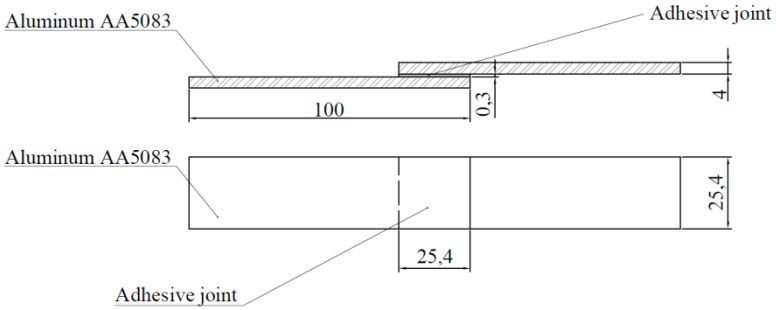
- In industrial field, **manufacturing time** is one of the most important factors affecting the production costs.

- Structural adhesives require long curing times (i.e. 3-4 weeks) before the joined components can be safely employed.

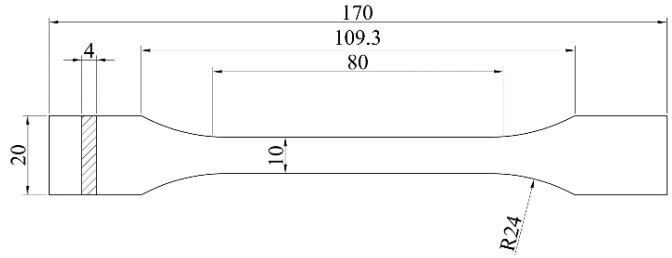
Aim: to test the effect of thermal treatments on a commercial epoxy structural adhesive, on the final resistance of single lap joints, trying to attain the possibility of a curing time reduction.

EXPERIMENTAL CAMPAIGN

Single-lap adhesive joints (ASTM D1002)



Dog-bone (UNI EN ISO 527-2)



Substrate: Alluminum AA5083 H111

Young's modulus [GPa]	71
Ultimate tensile strength [MPa]	250
Elongation at break [%]	22
Density [g/cm^3]	2.7

Adhesive: 3M 7260

Chemical base	Two-part epoxy adhesive
Consistency	Controlled flow
Working time at 22 °C [min]	90-300
Application temperature [°C]	15-25
Service temperature [°C]	-40+120
Shear strength [MPa]	33.50
Young's modulus [GPa]	3
Elongation at break [%]	3
Use	Structural

EXPERIMENTAL CAMPAIGN

Curing temperature:

- **T0**, Laboratory temperature 22°C
- **T50**, Climatic chamber temperature 50°C

Experimental Curing time
(+24h laboratory conditions)

- 2h
- 24h
- 48h
- 96h
- 8 days

Standard Curing time

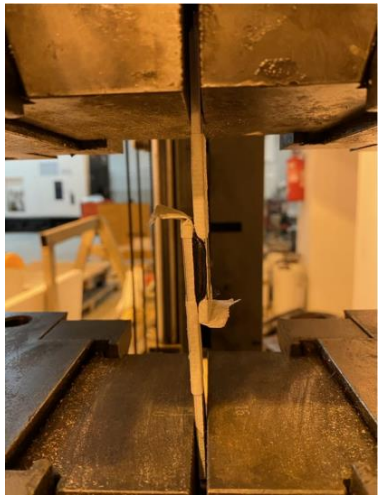
- 28 days

Increased Curing time

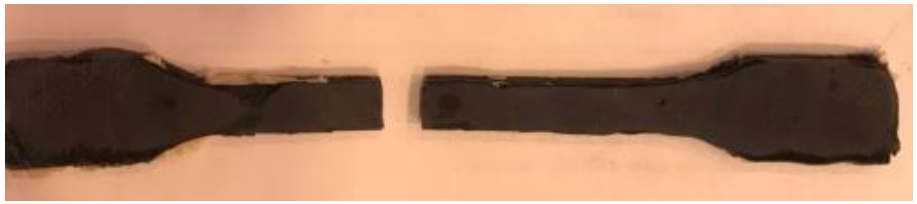
- 3 months

EXPERIMENTAL RESULTS

Tensile tests on a **Zwick/Roell Z600** Universal testing machine 600 kN load cell

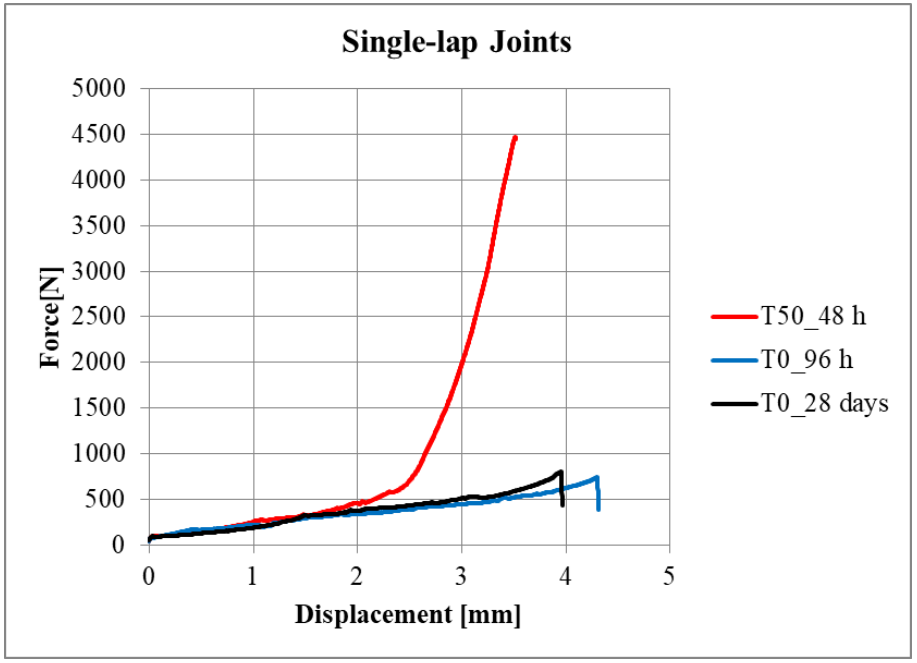


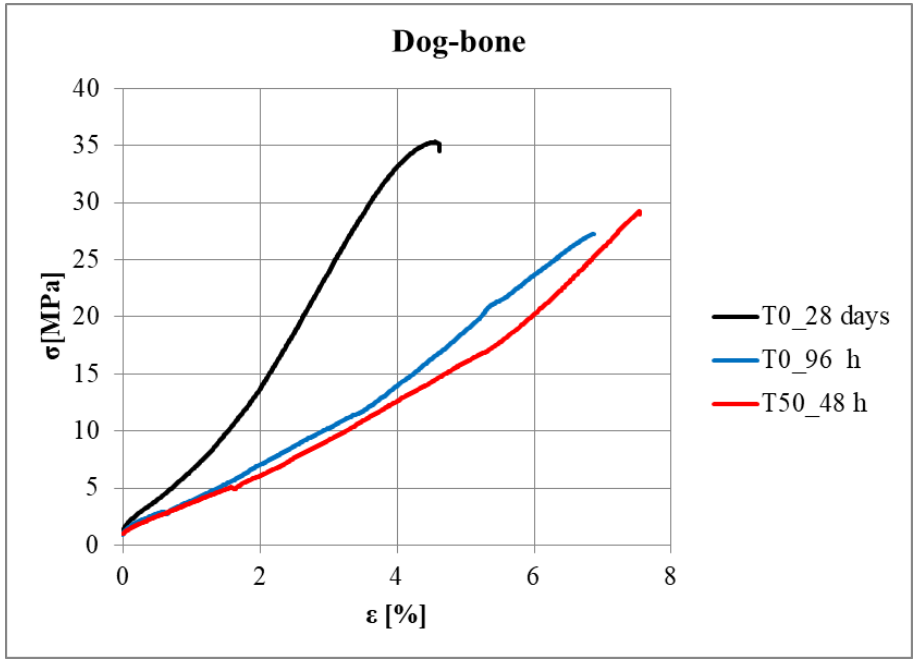
Adhesive failure



EXPERIMENTAL RESULTS

Representative curves





- With regard to the *single-lap* specimens thermal treatment has significant effect on the final resistance of the joint

- For the *dog-bone* specimens temperature and curing time do not affect the mechanical performances

EXPERIMENTAL RESULTS

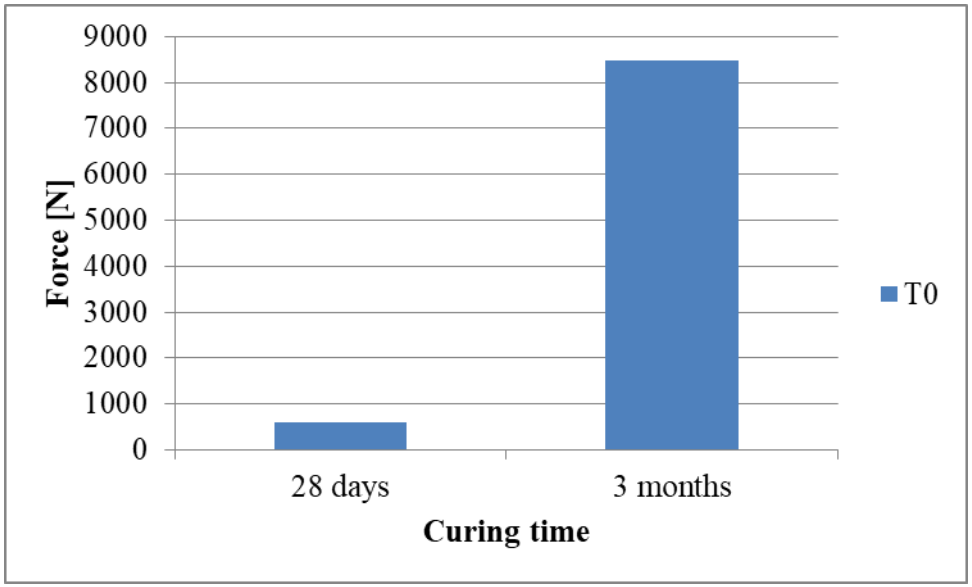
Failure modes

28 days

Adhesive failure

3 months

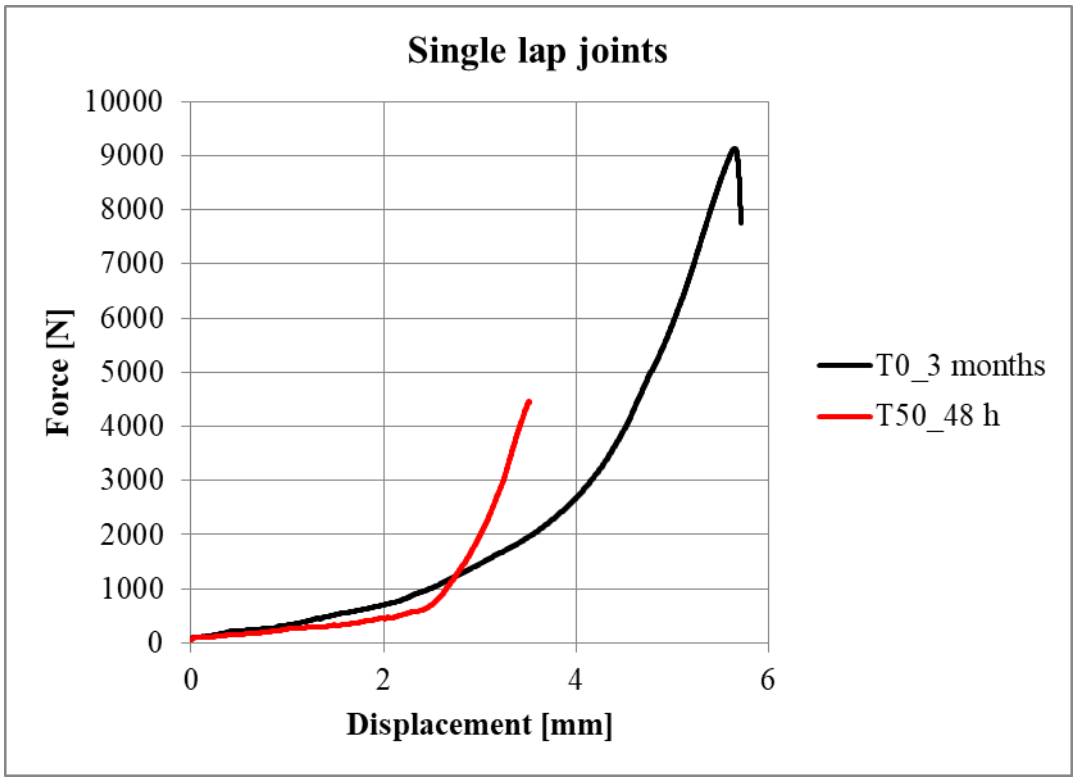
Adhesive/cohesive failure



- The *standard curing time* of 28 days recommended by the manufacturers is *referred to* the *adhesive*.

- The curing time of the joint is influenced by the *interface* between adhesive and substrate.

EXPERIMENTAL RESULTS



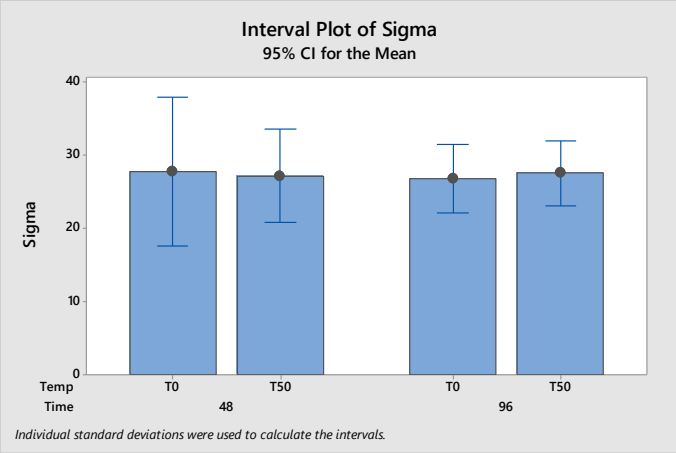
- **Thermal treatment** allow to obtain sufficient mechanical performances with a *drastic reduction of the curing time*

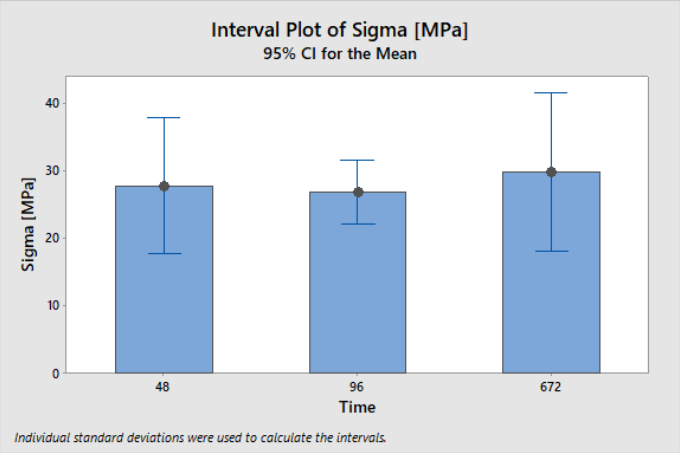
- The adhesive, exposed to heat, undergoes to a *reduction* of its *viscosity*, with consequent *improvement* of the *wettability* of the surface.

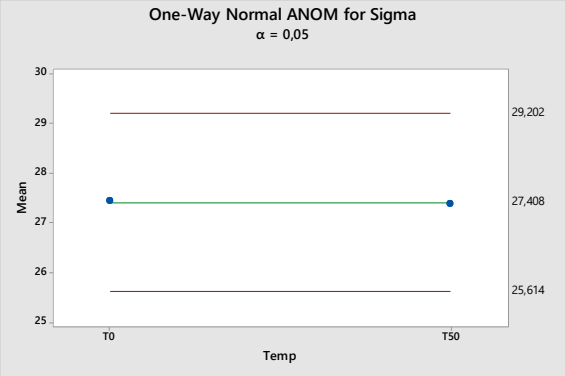
STATISTICAL ANALYSIS_Dog-bone

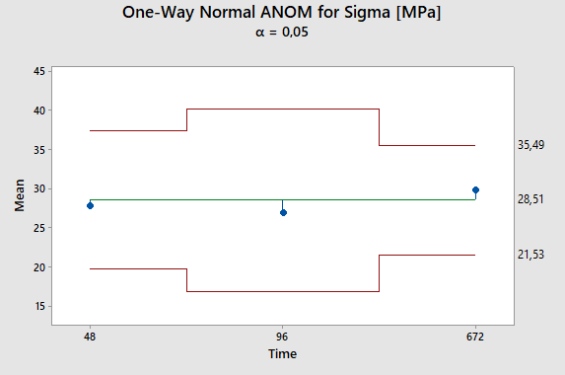
- The analysis of the experimental data has been performed by means of the MINITAB® software, in order to investigate the significance of the two factors:

temperature and *curing time*



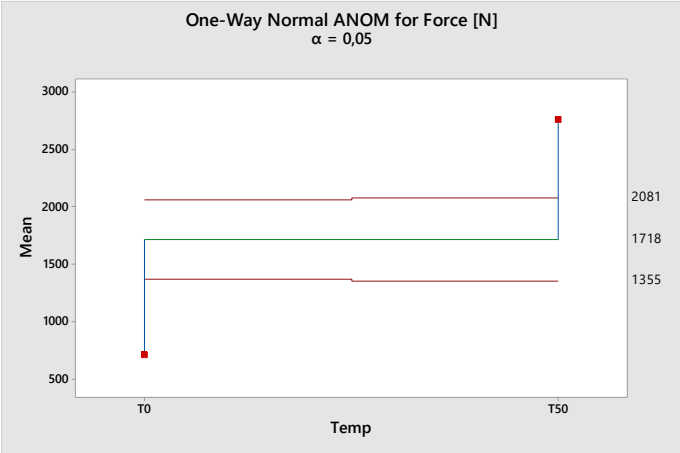




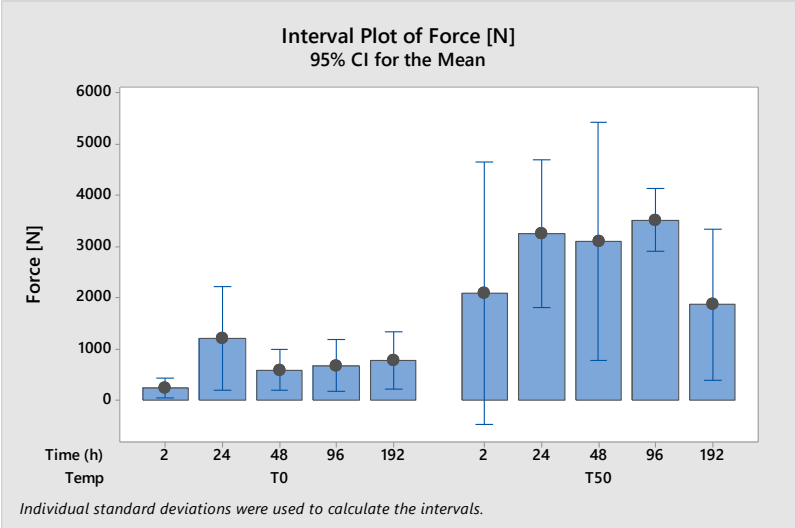


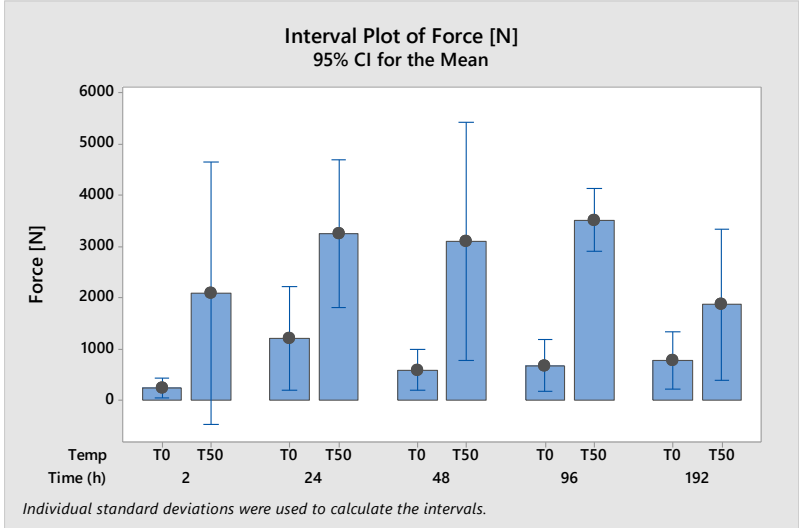
For the dog-bone specimens it can be confirmed that *neither* the *temperature* nor the *curing time* are statistically significant on the mechanical performances of the adhesive.

STATISTICAL ANALYSIS_Single-lap Joint

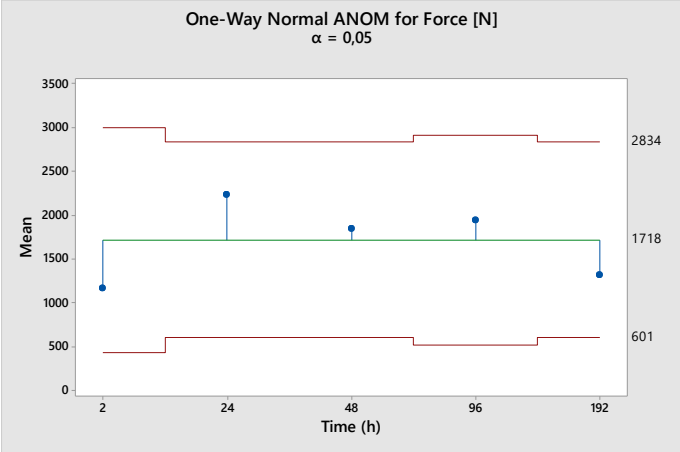


- The temperature has a significant effect on the mechanical performances of the single-lap joint;
- It can be evidenced that exposition to 50°C leads to an important reduction of the curing time, with higher efficiency in term of carrying load capability.

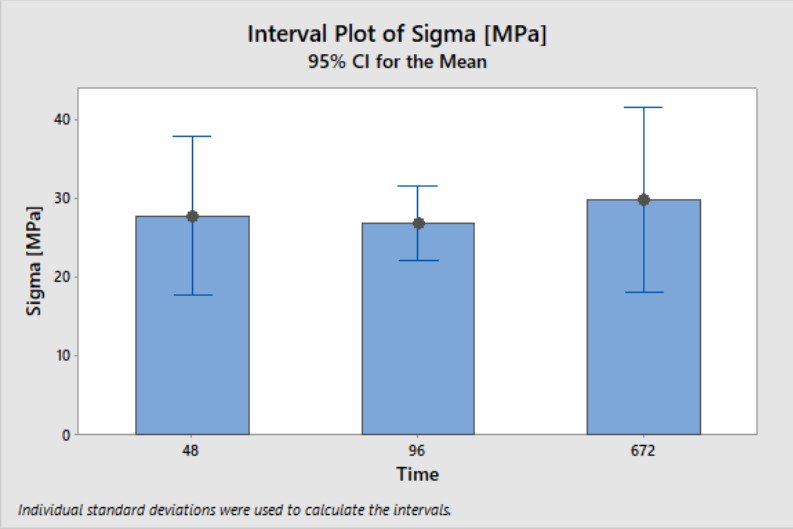




STATISTICAL ANALYSIS_Single-lap Joint



- Curing time has no statistical relevance on the joint resistance



- Exposition to higher temperatures during the curing phase leads to an improvement of the adhesion at the interface with the substrates

CONCLUSIONS

- In the present research work the *effect* of exposition to *high temperature* during the *curing phase* of epoxy adhesive joints has been analised.
- Tensile tests on *single-lap* and *dog-bone* specimens, cured at different *times* and *temperature*, have been conducted.
- A *statistical analysis* on the experimental results has been performed.
- It has been demostrated that the thermal treatment led to a **significant reduction** of the **curing time** and also to an improvement of the adhesion at the interface with the aluminum substrate, with a consequent improvement of the mechanical performances of the joint.

Prospective work: in order to further improve the final resistance of the joint, to test the effect of

- ✓ thermal treatments at different temperatures
- ✓ chemical and mechanical treatments

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Thank you!!

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