Influence of the Roughness in the Mechanical Adhesion of Single Lap Joints for Composite Materials

R. Hunter, N. Ibacache, B. Pavez, P. Flores
Universidad De La Frontera

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Introduction

This research describes the recent results in the study of the roughness influence in the mechanical adhesion of single lap joints in composite test specimens made of Fiberglass Reinforced Plastics. Analysis techniques were based on both, finite element and experimental approaches.

For the above explained purpose, two cases were simulated:

1. The first one with a superficial roughness of the adherent on the joint overlap, and
2. The second one without it.

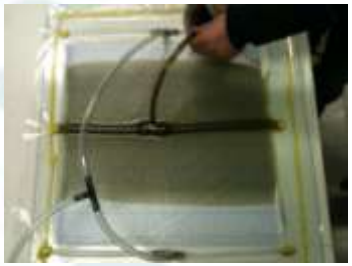
It was considered that the adhesive behaves like an isotropic material and that the adherents do not vary their mechanical properties.

As for the specimens used in the experimental tests, the superficial roughness of the adherents was controlled by using an anti-adhering fabric.

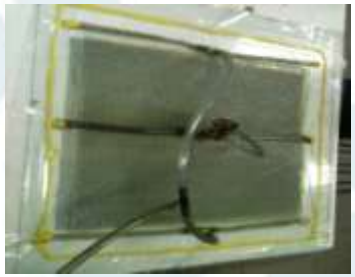
Methodology

For the mechanical characterization of the single lap joint, both the adherent and adhesive layer was considered as lineal elastic isotropic.

Two types of specimens were selected from the same matrix (with and without roughness) for the adherent layer.



The adherent layer is manufactured by vacuum infusion process, in order to ensure the homogenization of the adherent layer.



The roughness values are 0.106 microns for specimens without roughness and 0.2 mm for specimens with roughness.

The roughness used in the case of specimens with roughness is a kind of mesh form adopted by the fabrics used in the vacuum infusion process.

Methodology

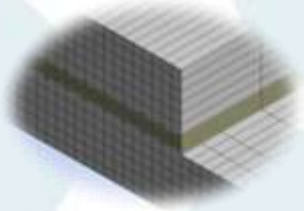
The adhesion process of the single lap joint was carried out at the same time for all test probes (with or without roughness).

The thickness of the adhesive layer was controlled for all test probe, and set up the thickness in 1 mm.

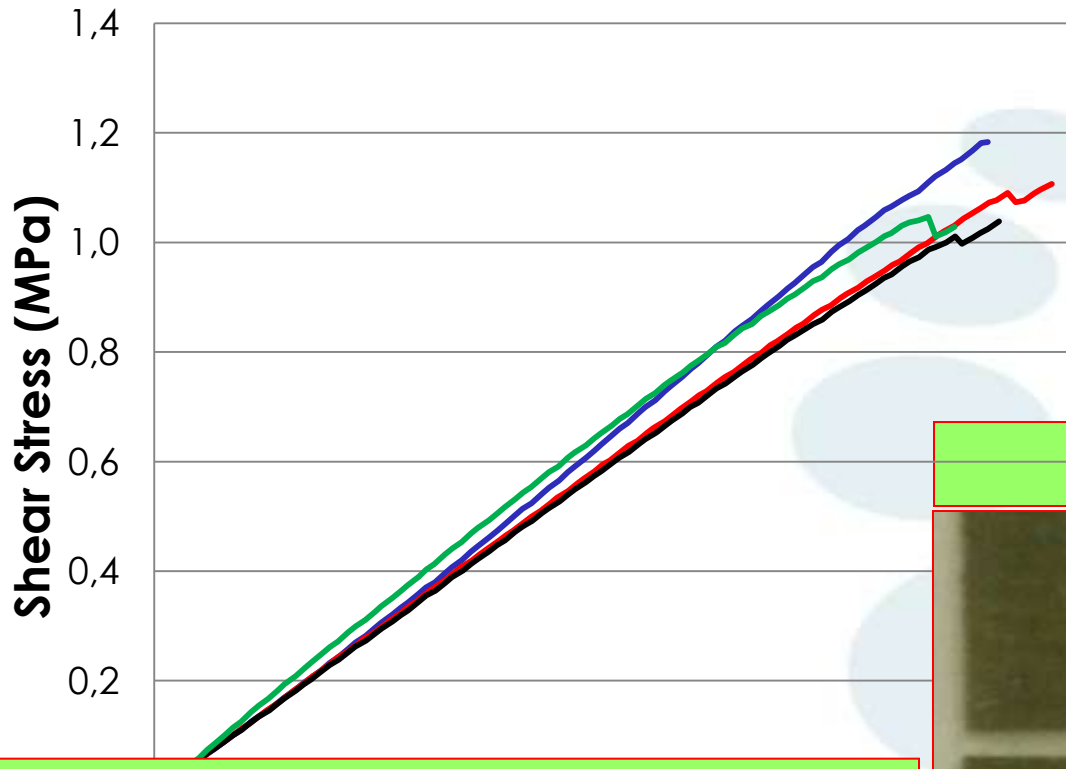
The curing time of the test probes has been set at 48 hrs., for all test probe.

The tension test has been developed under the same conditions of speed, temperature and Humidity of the room.

For the specimen with and without roughness, it was considered hexahedral and tetrahedral elements. The boundary conditions are the same that the tensile test.



Results Experimental test

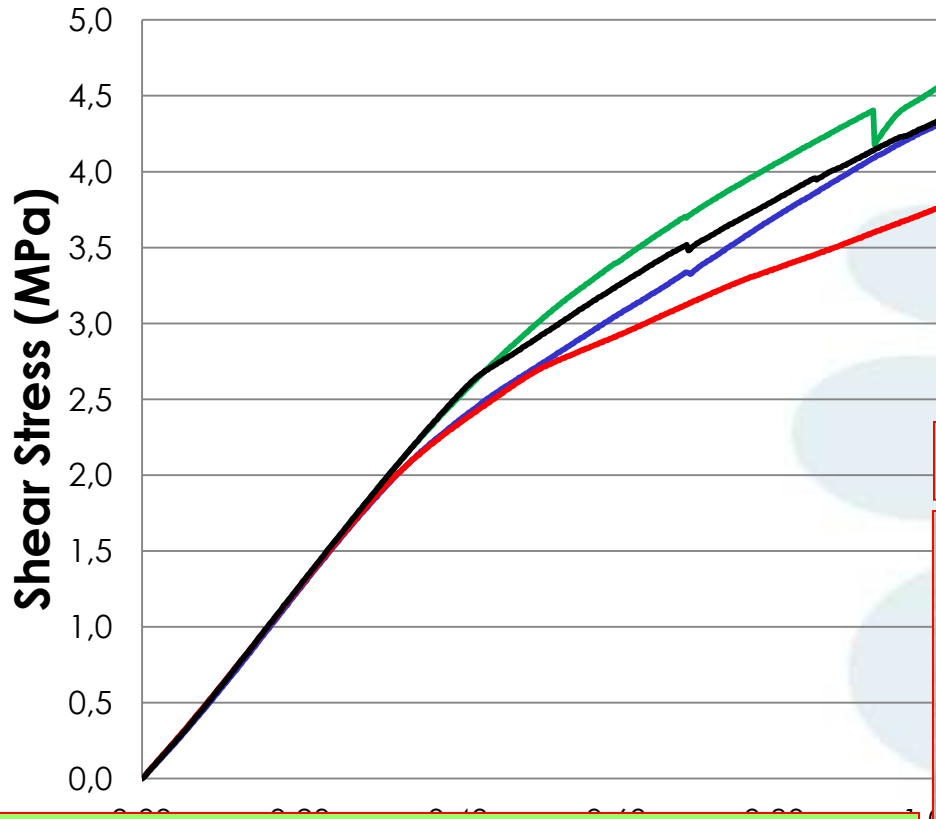


Test	Maximum Force (N)	Maximun Stress (Mpa)
Test 1	768,42	1,19
Test 2	769,33	1,18
Test 3	852,16	1,28
Test 4	794,79	1,19
Average	***796,18***	***1,2***
Standard Desviation	***39,27***	***0,04***
%	***4,93%***	***3,7%***

SLJ Failure

In all cases, the failure is produced in the adhesive layer. The adherent layer does not suffer any damages in the overlap zone.

Results Experimental Test

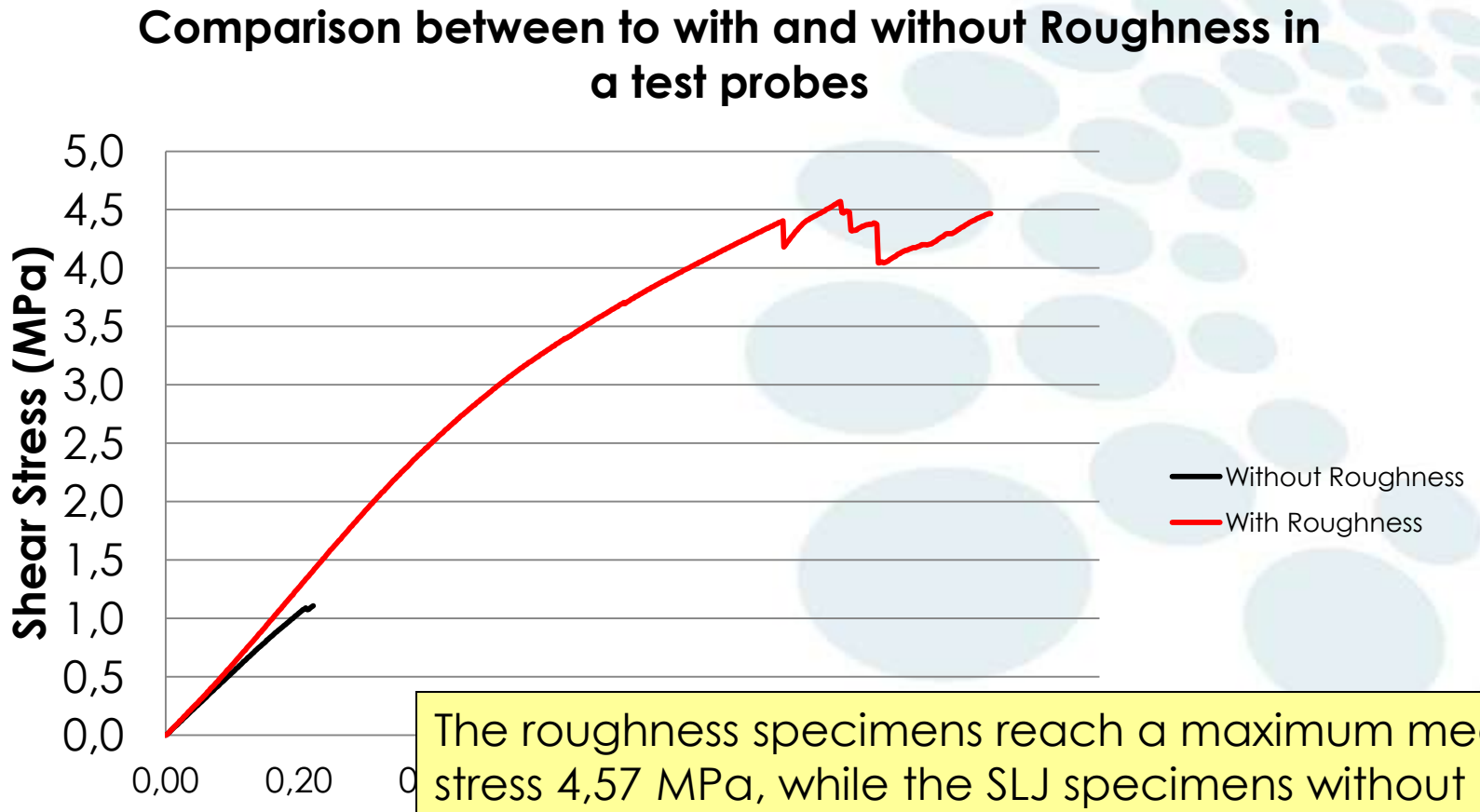


Test	Maximum Force (N)	Maximun Stress (Mpa)
Probe 1	2968,53	4,43
Probe 2	2924,75	4,57
Probe 3	2819,17	4,37
Probe 4	2701,15	3,98
Average	***2853,40***	***4,3***
Standard Desviation	***119,30***	***0,3***
%	***4,18%***	***5,8%***

SLJ Failure

In all cases, the failure of the SLJ is produced in a cohesive way. The adherent layer suffers serious injury in a overlap zone.

Comparison of two test probes



The roughness specimens reach a maximum mean stress 4,57 MPa, while the SLJ specimens without roughness only reach a maximum stress of 1,28 MPa average.

Results

Single Lap Joint Without Roughness

Test	Maximum Force (N)	Maximun Stress (Mpa)
Test 1	768,42	1,19
Test 2	769,33	1,18
Test 3	852,16	1,28
Test 4	794,79	1,19
Average	***796,18***	***1,2***
Standard Desviation	***39,27***	***0,04***
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Single Lap Joint With Roughness

Test	Maximum Force (N)	Maximun Stress (Mpa)
Probe 1	2968,53	4,43
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Average	***2853,40***	***4,3***
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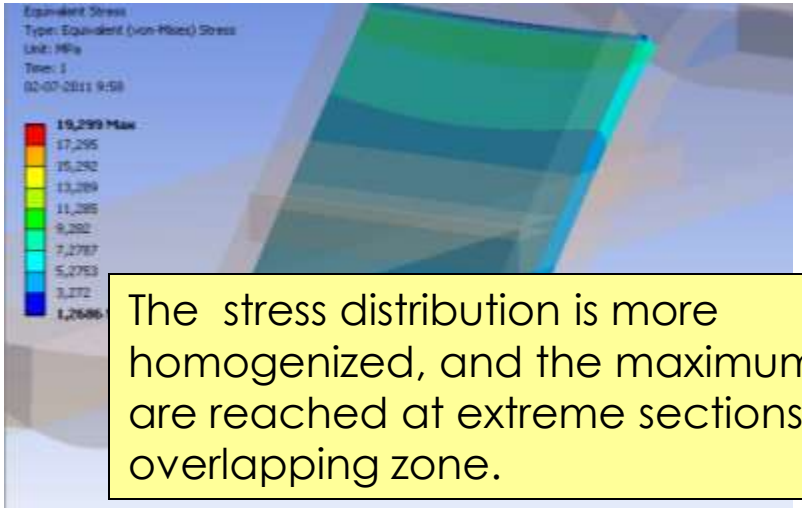
%	***4,18%***	***5,8%***

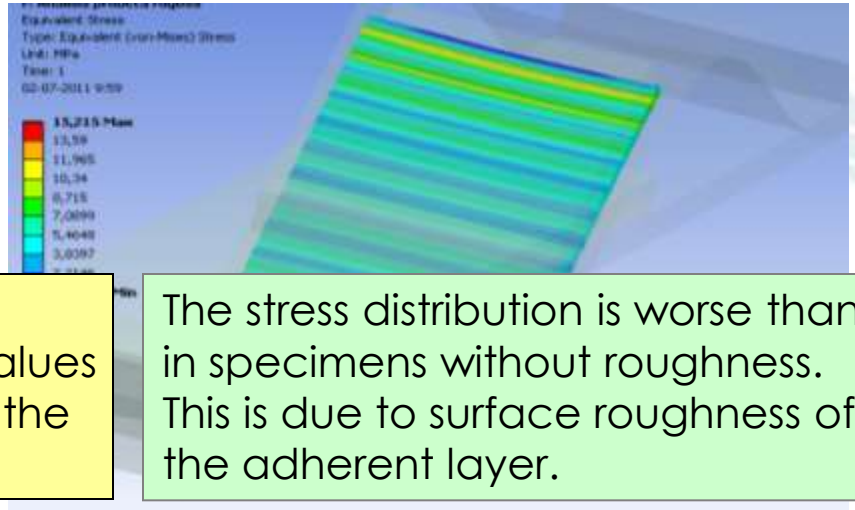
The difference between the stress the single lap joint without and with roughness is 4 times.

The difference between the force on the single lap joint without and with roughness is 3.58 times.

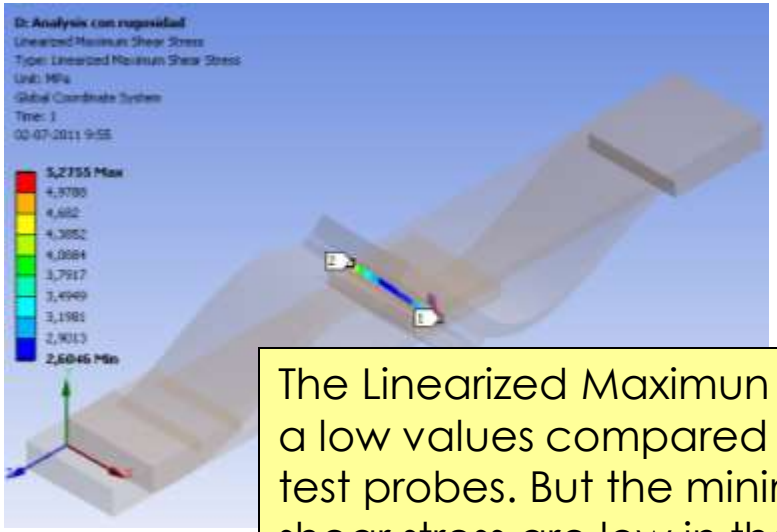
Simulations of the SLJ

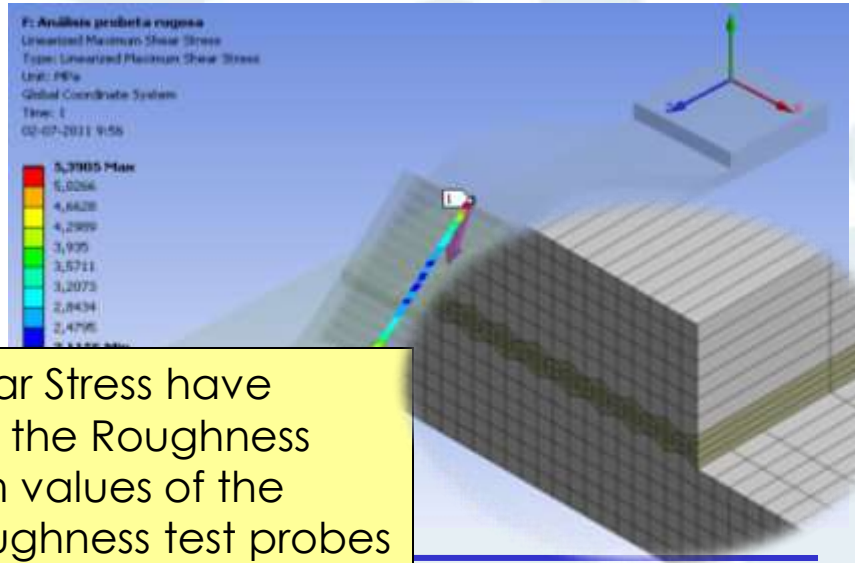


The stress distribution is more homogenized, and the maximum values are reached at extreme sections of the overlapping zone.



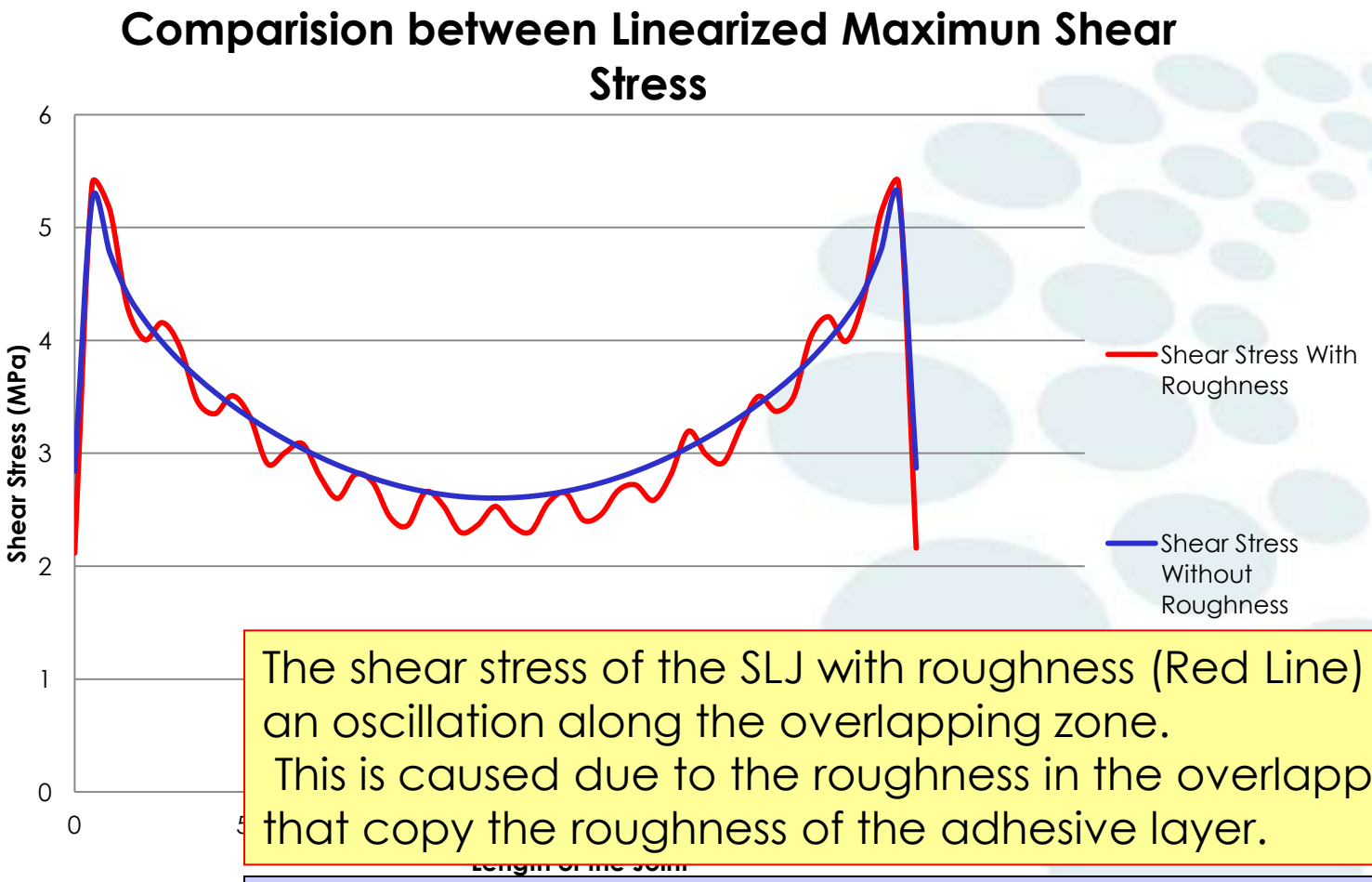
The stress distribution is worse than in specimens without roughness. This is due to surface roughness of the adherent layer.





The Linearized Maximun Shear Stress have a low values compared with the Roughness test probes. But the minimum values of the shear stress are low in the roughness test probes

Simulations of the SLJ



The shear stress of the SLJ with roughness (Red Line) presents an oscillation along the overlapping zone.
This is caused due to the roughness in the overlapping zone, that copy the roughness of the adhesive layer.

The shear stress of the SLJ without roughness shows a behavior homogenous along overlapping zone of the SLJ.

Conclusions

- All single lap joint are used the same adhesive with the same thickness.
- The test probe with roughness resists 4 times more Stress than a test probe without roughness.
- The Strain in the test probe with roughness have a average to 0,040 (mm/mm) while the test probe without roughness have a strain average of 0,008 (mm/mm).
- The failures of the SLJ without roughness was cohesive in the adhesive layer and in the samples with roughness it was cohesive in the adherend layer.

- Study the influence of different types of roughness (forms and dimensions) in the adherend layer on the behavior of the SLJ.
- Study the interfaces in the FEM model.
- Determine the influence of the nano-particles of glass and carbon (on the adhesive layer) to improve the Stress and Strain of the single lap joint.

Thanks for your attention