

Report: HI 2401

An introduction to the

Adhesion Institute

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Abstract:

This report presents a condensed overview of the Adhesion Institute of the Delft University of Technology, its mission and projects of interest as well as the research facilities available.

Prepared:	Dr. I Cringus
Checked:	Dr. J.A. Poulis
Approved:	Ir. A. Kwakernaak

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1. Introduction

The Adhesion Institute was founded 18 years ago at the Delft University of Technology by three faculties: Chemical Engineering, Aerospace Engineering and Civil Engineering. Today, the Adhesion Institute is known in Europe as an independent knowledge centre specialized in surface treatment, adhesive bonding, material development and testing. Tests performed within the Adhesion Institute aim to determine the strength and durability of the bonded joints, the adhesive quality and material properties as well as the structural performance of the adhesive bond joints. A team of specialists with backgrounds in Aerospace, Mechanical Engineering, Polymer Chemistry, Coatings, Industrial Design and Physics perform both application oriented research for industry as well as fundamental scientific research. For example the Faculty of Aerospace Engineering is well known as the birthplace of Glare (the successful hybrid material that is now used in the Airbus A380).

2. Goals

The Adhesion Institute aims to promote and extend the knowledge on adhesive bonding technology and structural adhesive bonds with practical industrial applications on the latest developments in this field. In order to achieve our aims we proceed as follows:

- The implementation of bonding technology and related manufacturing methods in industrial sectors in the Netherlands and Europe;
- Translate customer needs into solutions;
- Disseminate knowledge by education in the area of adhesion and adhesive bonded joints by means of lectures, courses, symposia;
- Constantly looking for innovative and effective solutions to existing problems in the field of adhesion and adhesive bonding;

3. Subjects of interest

In our institute we perform the following types of main research:

Material Characterization/Properties

- Characterization of the adhesives used to describe the damage growth;
- Fracture toughness energy determination by Double Cantilever Beam (DCB) in Mode I, Mode II and Mixed mode (I/II) in order to obtain GI, GII and GI/GII respectively;
- Interlaminar shear strength determination by 3 point bending tests;
- Impact tests on GLARE, metals and composites;

- The use of standard test methods for strength determination of adhesive bonded joints, such as overlap shear and peel tests conducted at high and low temperatures for joints in initial condition as well as after ageing (moisture, salt spray, etc);
- Testing and qualification of the adhesive bonds and adhesives at different temperatures ranging from -55 °C to +80 °C as well as after their exposure to moisture/high temperature or salt spray;
- Surface treatment of metals and polymers to increase the adhesion between the coatings and the substrates and to improve the product durability;
- Surface characterization by means of SEM, AFM, Infrared and contact angle measurements;
- Adhesive characterization by means of DSC, DMA and TGA.

New developments

- Development of new composite and hybrid materials, thermoset as well as thermoplastic, with superior properties suitable for space/aerospace applications;
- Innovative coatings that are environmental friendly and resistant to high temperatures (up to 1000 °C);
- Optimization of the adhesion bond quality and adhesive selection for better performance in specific applications such as pipelines, shipbuilding and aerospace;
- Development of calculation models both analytical and FEM for the strength and durability prediction of bonded structures, using state-of-the-art methods such as LEFM, NLFEM and DCZM, including the development of material models and experimental determination of material parameters;
- Development of hybrid joining techniques (combined adhesive bonding with mechanical joining) to improve joint durability and reduce assembly time and costs. The focus is directed towards adhesive selection, determination of adhesive mechanical properties and calculation models;
- Research and development of industrial products in terms of design, material and process selection and production techniques.

Design of joints

- The damage tolerance approach for bonded structures in general, aiming to describe the damage growth mechanics in bondlines and at interfaces in layered structures under either static or repetitive loading. That includes description of the disbond growth using strain energy release rates;
- Fracture mechanics describing damage growth with (preferably analytical) calculation models. This covers linking the damage growth to applied stresses.

Based on this, initial damages and flaws in bondlines can be assessed in terms of what initial flaw and damage growth is allowed in structures.

- The information on damage growth is translated into characteristics required for the adhesive polymer to obtain improved damage growth resistance. Initial work has been done on the above presented topics and further research will be done in layered composites.
- Design, material and process selection and experimental verification of bonded patch repairs to improve damage tolerance capabilities of aircraft structures

These research projects have been either part of EU funded research projects, or resulted from the collaboration with industrial partners such as Shell, Philips, Akzo Nobel, Stork Fokker, Airbus etc. Additionally, fundamental research has been carried out at the Adhesion Institute and the Department of Mechanics, Aerospace Materials and Structures as part of STW, NIMR projects or in collaboration with ESA.

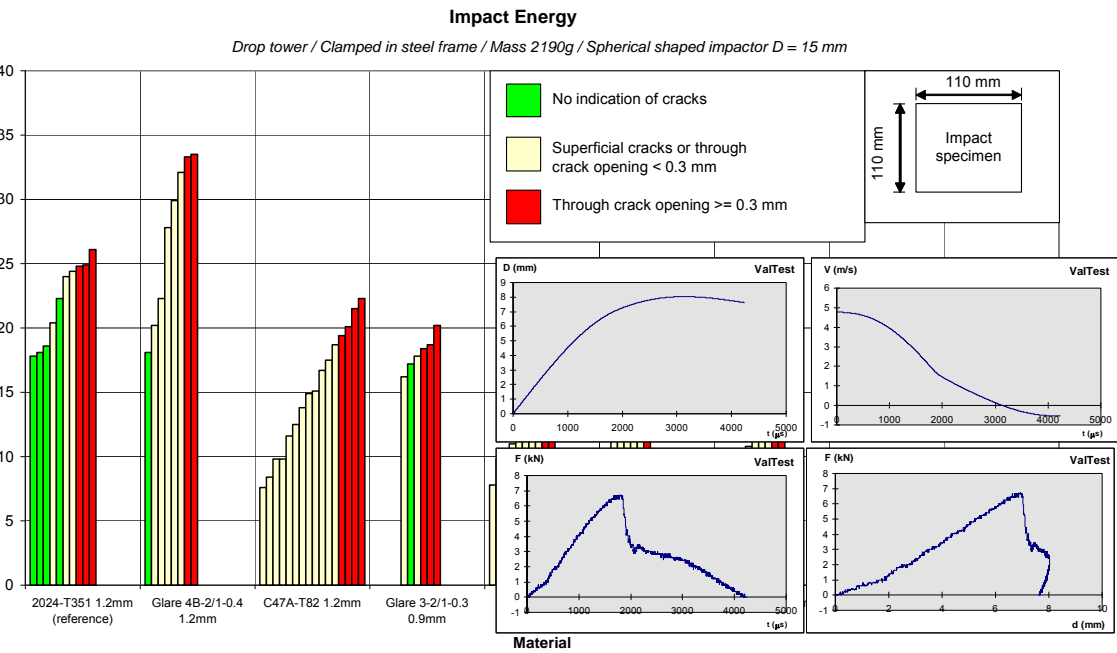
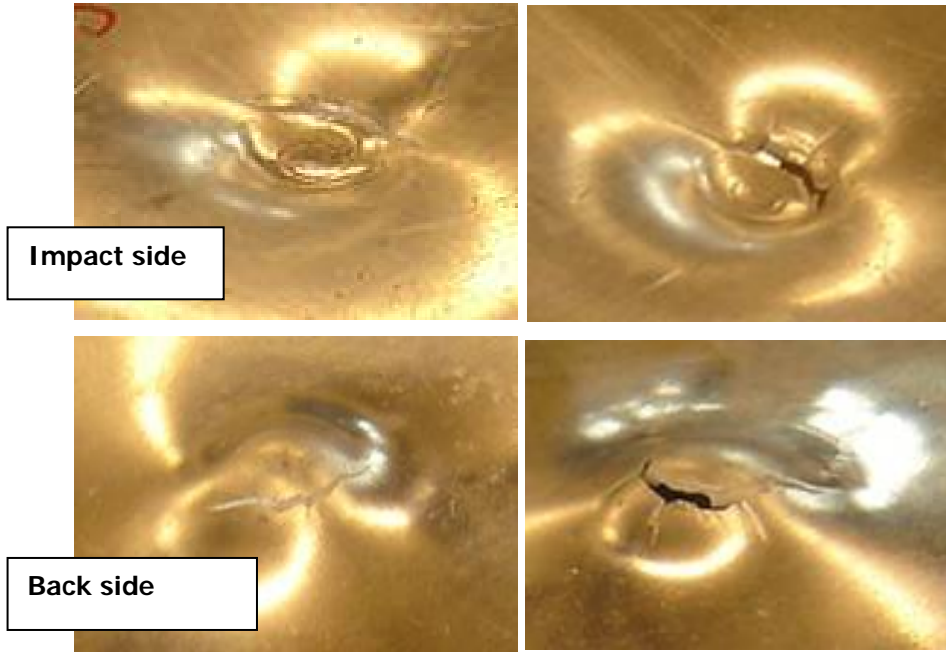
4. Research facilities

Our research facilities cover the areas of material and surface characterization for metals and polymers as well as mechanical testing, including manufacturing and quality control. Examples thereof are given below. A total overview can be found at <http://www.labs.tudelft.nl>

Impact tests

Recently impact tests have been performed on a new type of Fibre Metal Laminate (FML). The impact tower of the Structures and Material Laboratory (SML) was used. The impactor head is equipped with strain gauges in order to measure the force during the impact as function of time.

This allows a precise determination of material behavior during impact. In addition to the standard properties such as impact energy and dent depth, other more advanced properties can be determined based on the force-time graph. Examples are the absorbed energy, failure mode, impact-energy vs time, etc. This allows a better comparison with the reference material. Impact tests are performed according to Airbus or Boeing standards.

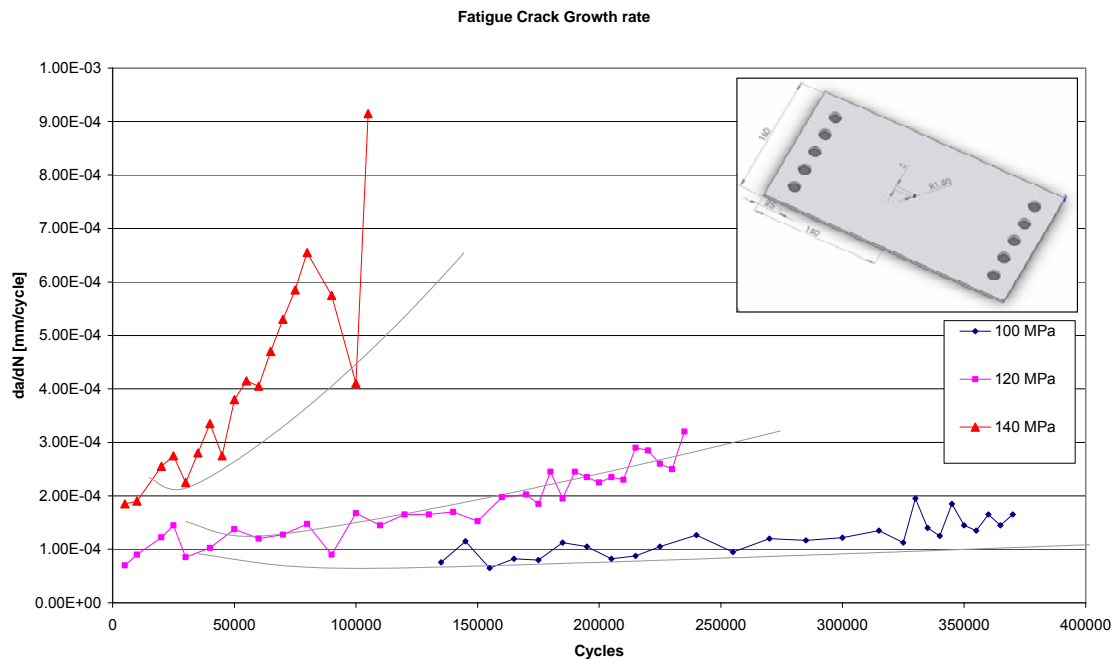
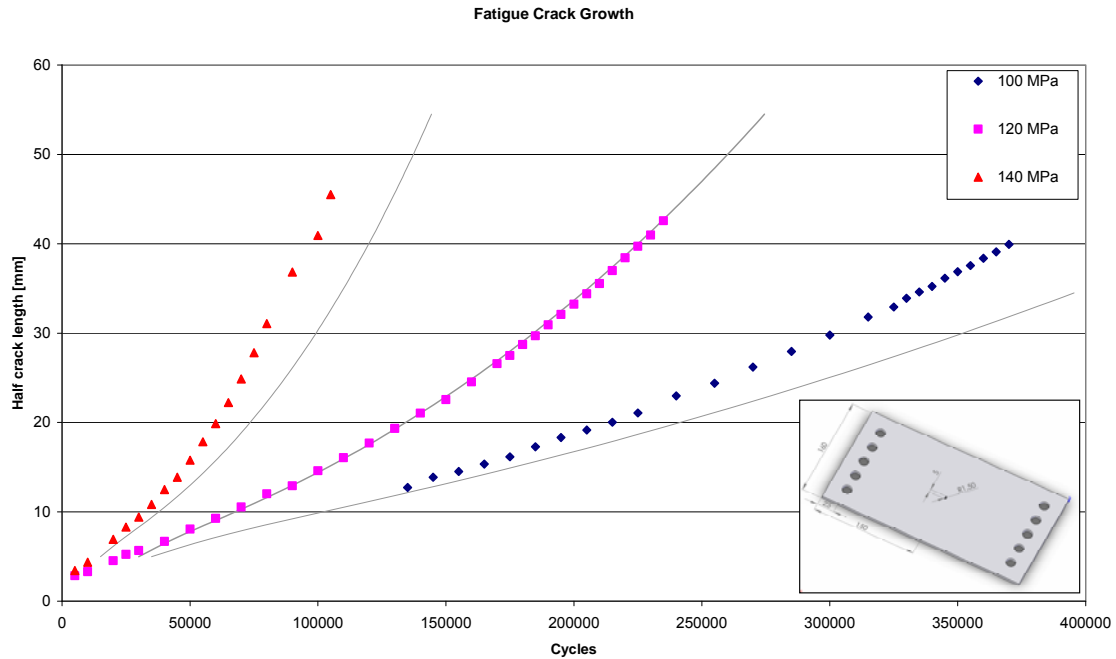


Fatigue tests

Fatigue tests are performed either as coupon tests based on standards, or performed on structural elements.

The Structures and Materials Laboratory of the TU Delft has seven dynamic hydraulic tests machines, ranging from 1kN to 3500kN.

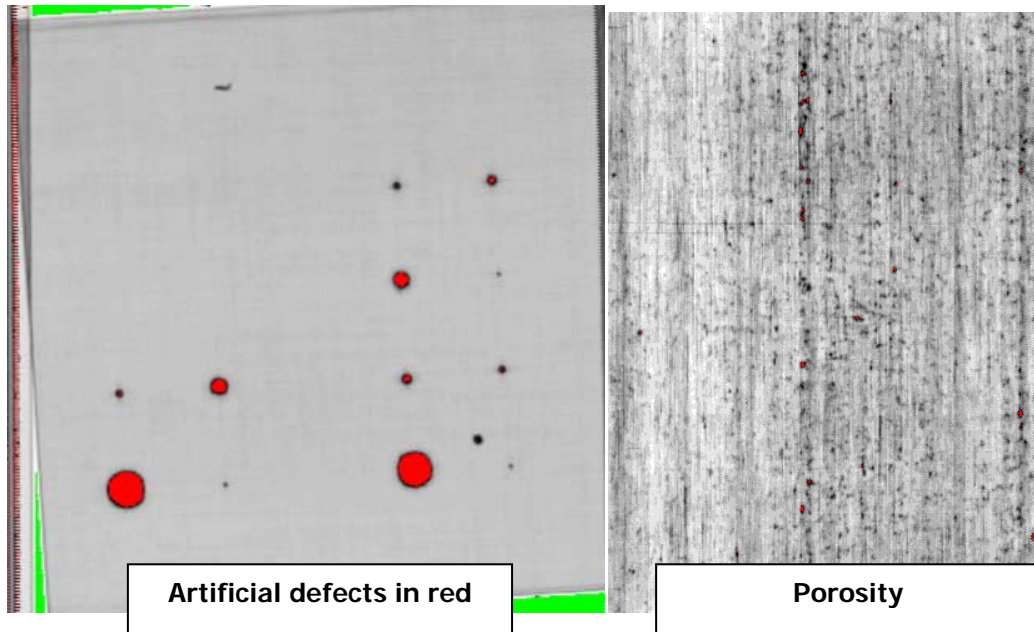
The fatigue properties of the new materials (dotted lines) can be compared with the reference material or to a calculated model (continuous line).



C-scan

The Adhesion Institute offers several non-destructive test methods, of which the C-scan ultrasonic test method is the most often used. The system uses a high frequency signal which passes through the test material. The attenuation of the signal is related to the quality of the bond in the scanned area.

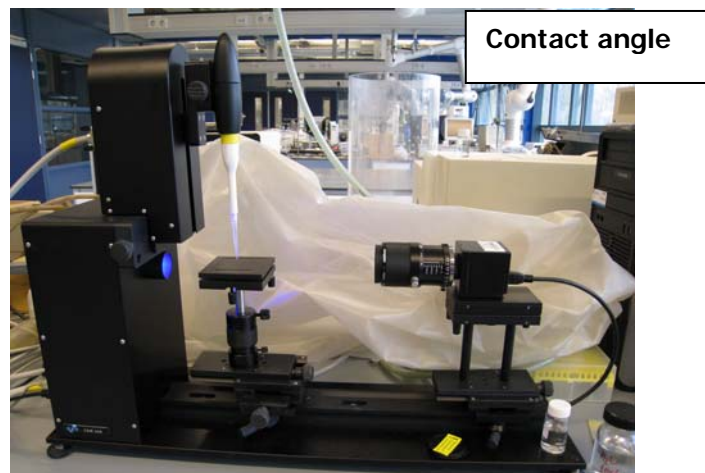
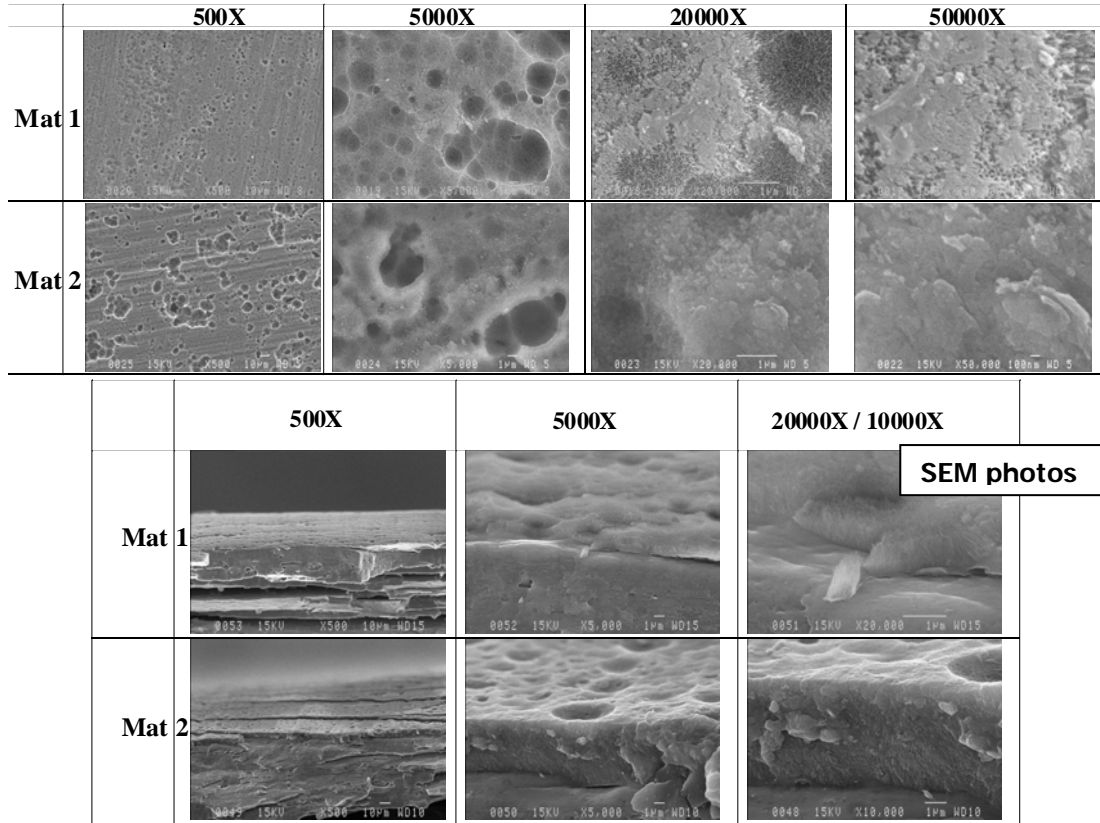
The system is used to detect porosity, defects, inclusions, etc. It can also be used to determine the size of a (growing) delamination.



Surface analysis and bond strength

A **Scanning Electron Microscope (SEM)** is available at the Adhesion Institute in order to determine for example the surface quality and layer thickness as a function of the selected pretreatment. The SEM device has incorporated an EDX equipment which can be used for determination of the surface composition.

In addition, a number of optical **microscopes** and a **contact angle** instrument are available.



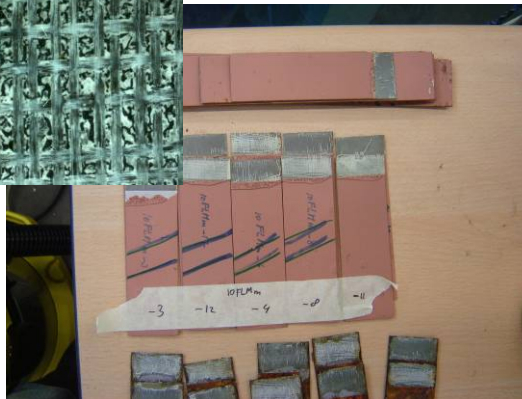
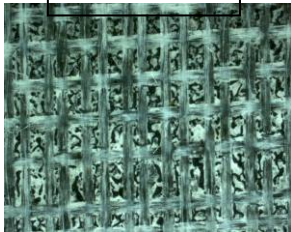
Static tests

Standard peel and lap shear tests are performed on a 2-tons static test machine in order to determine the strength of an adhesive in combination with a selected pre-treatment or substrate. Another static machine of 25-tons is also available for larger test coupons.

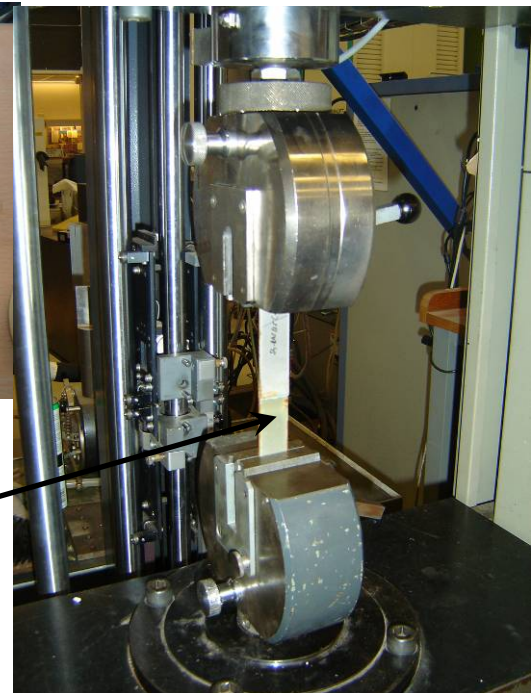


Peel test specimens

Adhesive structure



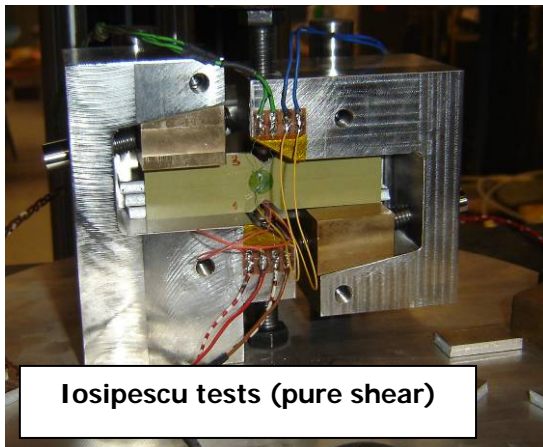
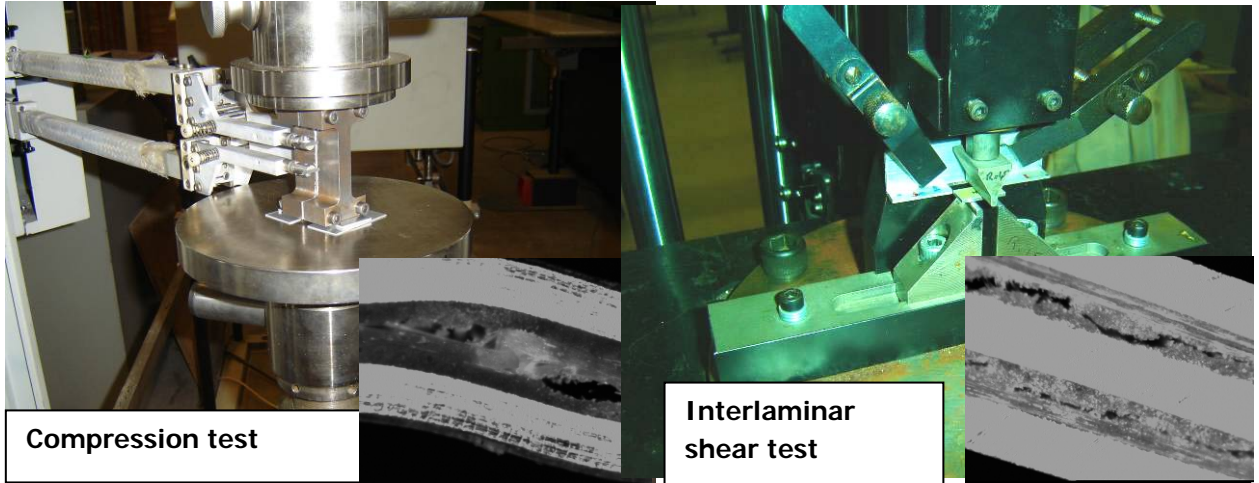
Lap shear test specimens



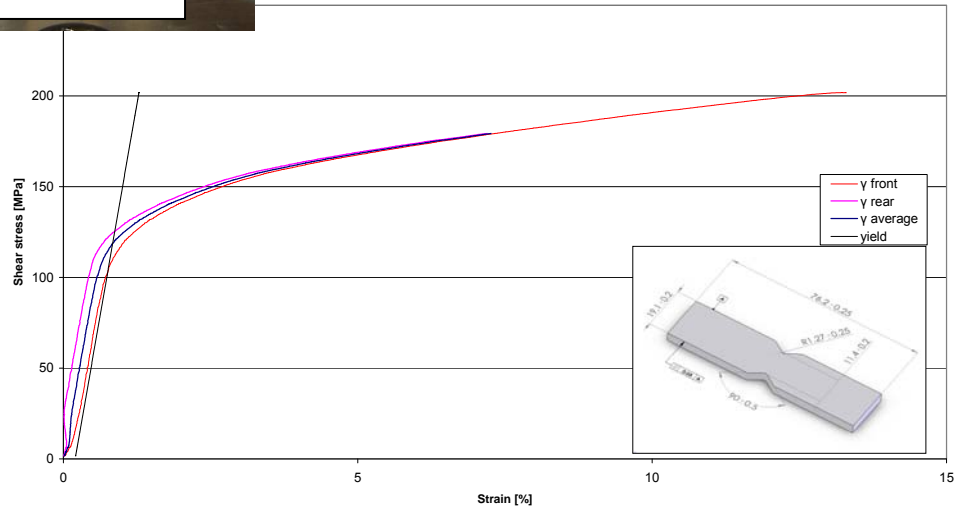
Specimen

Static coupon tests

Several types of static coupon tests have been performed on new types of FML, composites and adhesives. These tests range from simple tensile tests to complex thick-adherend tests at either elevated or very low temperatures. An automated analysis of the thick-adherend test results has been developed by the Adhesion Institute. Some examples:

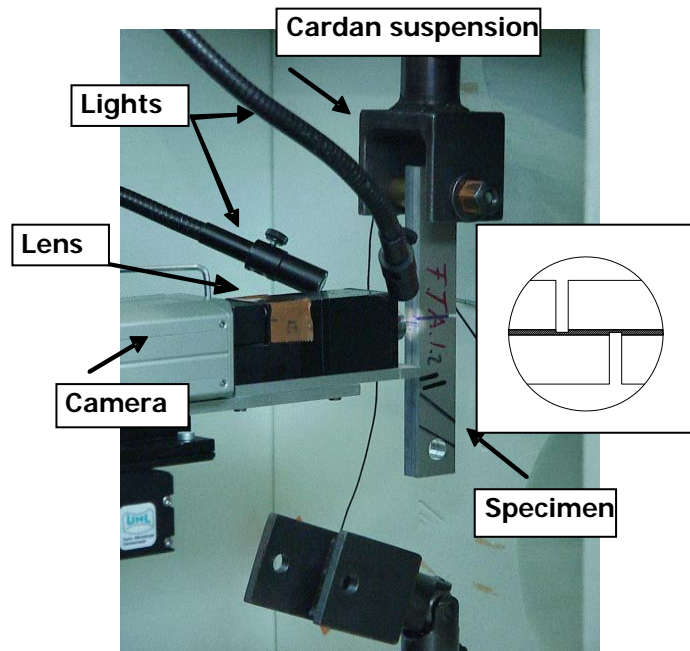


Shear stress strain curves
Iosipescu tests / ID1388-56 / Zylon Glare 3-3/2-0.4 / WP1.7 Round Robin

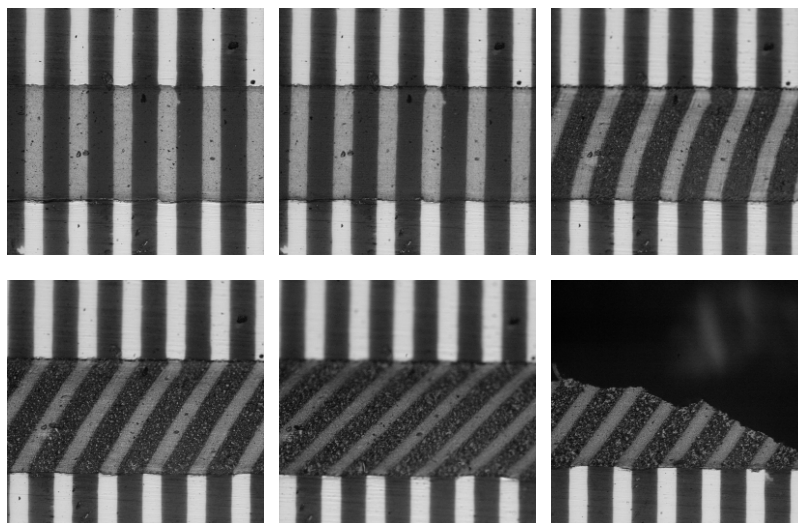


Thick adherend test

Thick Adherend tests are used to determine the shear stress strain behavior of structural adhesives. During the test the bondline deformation together with the applied load is recorded in real time by digital optical microscopy using a high resolution CCD camera (1380 x 1024 pixels). Using in-house developed software for a grid of points the location is determined on each image by means of digital image correlation. From these data the local strains are calculated. The optical method is more accurate than mechanical extensometers and lacks problems like slippage. Based on this test, only the average shear strain is calculated, but the method potentially can determine strain variations in any complex shape, for instance for validation of FEM models.

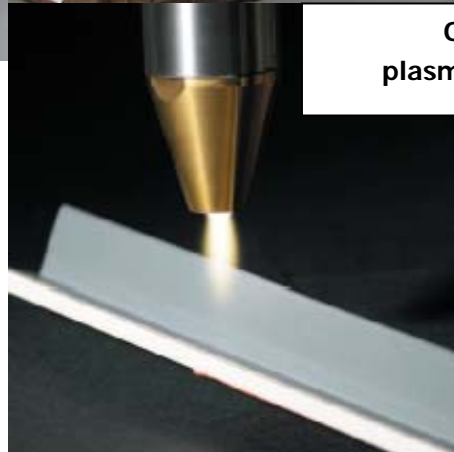


Bondline deformation of a thick adherend specimen



Surface pre-treatment

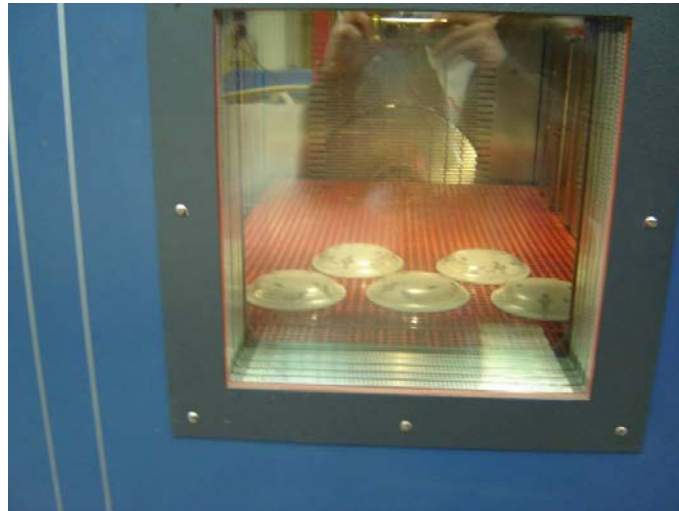
The improvement of the adhesion between the adhesives/coatings with the metals or polymer surfaces can be obtained either by increasing their surface energy or by removing the native oxide layer. On one hand, the increase of the surface energy of the polymers can be done by using one of the **plasma**, **corona** or **UV/ozone** treatments. On the other hand, abrasive particles (aluminium oxide) accelerated and directed against the materials surface remove contaminants from the surface and the native oxide layer formed during metal exposure to air by a so called **grit blasting** process.



Next to this, a line of surface treatment tanks is available to perform standard chemical, electrochemical processes or to develop new processes.

Durability

Coupon test specimens or complete products can be placed in climate controlled cabinets in order to determine long term effects on material performance. The cabinets can have moisture or salt-spray conditions at low, room or elevated temperature. Temperature cycle test cabinets are also available.



Autoclave

An autoclave is available for the adhesive or composite curing at high temperatures under pressure and is used for specimen preparation. Out-of autoclave curing techniques such as hot-plate press, hot-air ovens, vacuum bagging, ultrasonic and infrared are also available.



Specimen manufacturing

Next to in-house surface treatment and adhesive bonding capabilities, a dedicated metal workshop for cutting and milling of specimens and manufacturing of test equipment is available. The workshop contains CNC milling machines.

Calculation tools

State-of-the-art FE programs such as NASTRAN, PATRAN, ABAQUS, Stress-Check and others are available.