TAMPERE UNIVERSITY OF TECHNOLOGY

ADHESIVE JOINTS

General Aspects and Long-term durability

CONTENT

- General Aspects of Adhesive Joints
- Future trend of adhesive joints
- Durability of Adhesive Joints
- Pre-treatments of adherends
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GENERAL

- Adhesive bonding offers many advantages over traditional joining techniques and adhesive joints are nowadays widely used in several technical areas. Today most cars, buses, aircraft and trains use structural or semi-structural adhesives.
- Adhesive joints are nowadays common eg. in aircraft/aerospace industry, electronics, packaging industry, automotive industry, construction industry and consumer products.
- According to Ceresana the size of the global market for adhesives and sealants was defined at 12,8 million tonnes and a value of €33 bn in the year 2012.

GENERAL

- In the future the meaning of the adhesive joining will increase in the joining technology area, when there is increasing tendency to make efficient structures and components by joining dissisimilar structures. The development of materials, both adhesive and adherend make it possible to use it in different technical areas and replacing the “traditional” joinings like welding and mechanical fastening.

DURABILITY OF ADHESIVE JOINTS

- Long-term durability is one of the most important properties of most adhesive joints.
- The long-term durability of adhesive joints depends on several variables which can be divided into: **environmental, material and joining process-dependent categories.**
- The importance of adhesive bond durability is dependent on the particular application and environment.

DURABILITY OF ADHESIVE JOINTS: ENVIRONMENT

- From the environmental factors moisture and temperature are the dominating ones. Together with static or dynamic loading these environmental factors tend to weaken the joint.
- It is well known that the strength of the joint will decrease when bonded structure is exposed to high humidity, liquid water and/or to high temperatures.
- Adhesives are polymeric materials and the temperature may influence to the curing process, it may cause eg.oxidation of adhesive or adherends, introduce brittleness.

DURABILITY OF ADHESIVE JOINTS: ENVIRONMENT

- All polymers are degraded to some extent when high temperatures are influencing. Physical properties are lowered after exposure at high temperatures and there is also possibility to degrade during thermal aging.

- Cryogenic temperatures may also cause problems.

DURABILITY OF ADHESIVE JOINTS: ENVIRONMENT

- The influence of the moisture is the most deleterious when comparing to the influence of temperature and load.
- During service all the adhesives will be exposed to moisture which is problem for both the adhesive itself and for the adhesive joint.
- There are several ways for water to absorption into adhesives and adhesive joints. These are e.g. the diffusion through the adhesive, the transport of water along the interface between the adhesive and adherend and the diffusion through the adherend.

DURABILITY OF ADHESIVE JOINTS: ENVIRONMENT

- The absorption of water may cause many undesirable effects in the adhesive. Moisture can swell the adhesive, it can lower the glass transition temperature, it may form cracks and crazes and cause the hydrolysis of adhesives. Swelling will cause stresses that can weaken the joint.
- There might be water absorbtion into the interface region when adhesive joints are exposed to wet environments. This might cause hydrating and corroding the adherend surfaces.
- Reduction in the glass transition temperature (Tg) may reduce the upper use/service temperature.

DURABILITY OF ADHESIVE JOINTS: STRESSES

- The stresses are also influencing to the durability of adhesive joints.
- The environmet and the type of stress are influencing to the durability of adhesively joint structures. The cyclic stresses tends to lower the bond durability more than constant stresses
- High stresses (stressing level) together with moisture content environment is dangerous. Stresses enhanced and modify the water diffusion rate in adhesives and may cause cracking and crazing.

DURABILITY OF ADHESIVE JOINTS: MATERIALS

- The adherend, adhesive and interphase are influencing to bond durability.
- Surface pre-treatment of adherend is one of the most important parameters influencing the strength and durability of the adhesive joints. Correct and carefully made pre-treatment is the basis for the joint durability.
- The importance of pre-treatment is more pronounced in the precence of moisture.

PRETREATMENTS

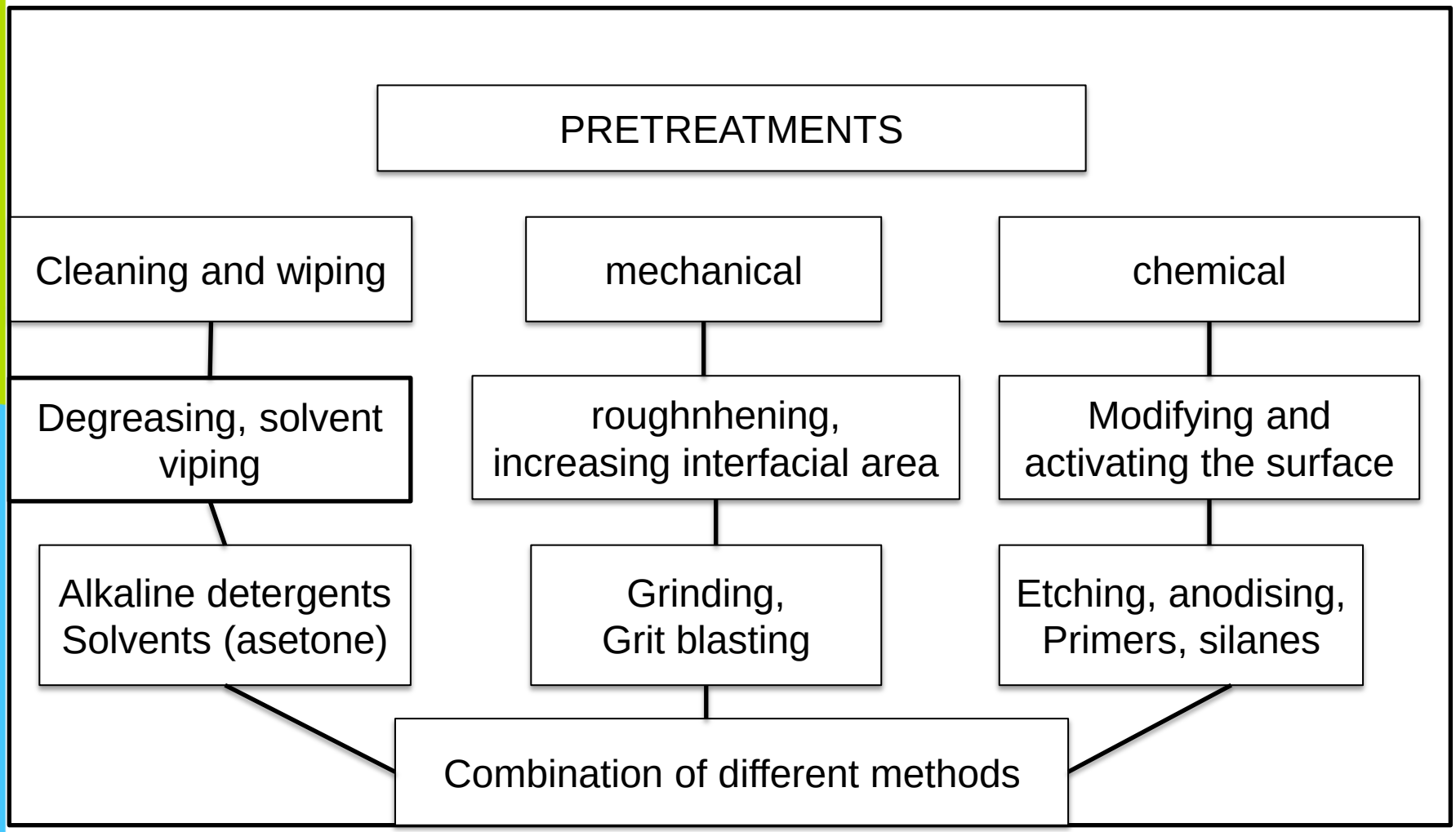
- The morphology of adherends surface determines the degree of physical bonding with the polymer and adherends chemistry determines the degree and type of chemical bonding. With different pre-treatments the surface roughness and the structure of the oxide layer are possible to influence. The surface pre-treatment stabilizing the oxide against hydration can improve the joint durability significantly.

PRETREATMENTS

- To obtain the optimum performance from an adhesive joint a pre-treatment is required.

- The purposes of the pretreatment are:
  - Enhance mechanical properties of joint
  - Improve joint durability in aggressive environments (moisture, temperature, chemicals…)
  - Increase service-life of component
  - Make it possibly to join difficult materials (e.g. polyolefins and polytetrafluoroethylene)

SURFACE PREPARATION



ADSORPTION / SURFACE ENERGIES FOR DIFFERENT MATERIALS

Material	E [1x10E-6 N/cm]
ABS -plastic	35
Epoxi	47
Polycarbonate (LEXAN)	46
Polyethylene	31
Polytetrafluorieteeni (TEFLON)	18
PVC	39
Silicone	24
Aluminium	500
water	73
Polyurethane	43
Lubricant oil	29

PRETREATMENTS OF ALUMINIUM

- Aluminium is nowadays widely used material for adhesive bonding.
- Aluminium has high strength-to-weight ratio, it has good formability and the corrosion resistance is good in most environments. Aluminium has a high surface energy and organic adhesives easily wet it.
- The initial strength of the aluminium`s surface oxide is high but moisture causes hydratation of the surface (boehmite). The volume changes creates stresses and together with the low mechanical strength of the boehmite it will cause crack propagation near the hydroxide-metal interface.

PRETREATMENTS OF ALUMINIUM

- There is a requirement for surface pretreatment to stabilize and control the oxide structure against hydration.
- Most surface pretreatments used in the bonding of aluminium joints rely on etching and anodising techniques utilizing aggressive and toxic chemicals. For aluminium joints haxavalent chromium conmpounds and strong acids are commonly used in surface pretreatments.
- Today the legistlation restricts the use of, e.g. hexavalent chromate containing pre-treatments.
- Organosilanes are considered as one of the environmental friendly alternatives for replacing the toxic pre-treatments.

PRETREATMENTS OF ALUMINIUM

- Several studies have shown that the silanes enhance the adhesion especially in wet environments.
- Organosilanes that are used to promote the adhesion have dual reactivity. Silane molecules contain polar silanol groups that can chemically react with adherend surface and they contain organofunktional groups capable of reaction with polymers.
- Silanes creates strong chemical bonding between the adhesive and adherend surfaces.The initial bond strength of the joint may increase and the use of silanes may also stabilize the interface and increase the durability of the joint, especially in humid conditions.

PRETREATMENTS OF STEEL

- The grit blasting is the most common method for preparing steel surfaces.

- Different kinds of cleaning treatments and chemical etchings have been used for different kinds of steels but none of these pre-treatments have been superior to grit blasting.

- The composition of steel is influencing a lot for the microstructure which is formed in etching proces.

THE STRENGTH OF THE EPOXY-BASED ADHESIVE ALUMINIUM JOINTS

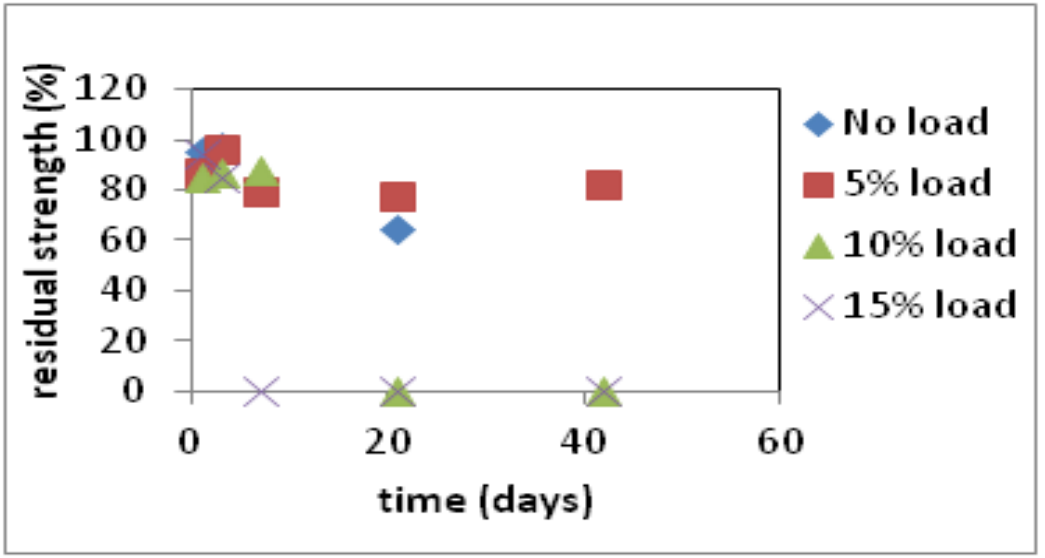
- In our tests the strength and the durability of the epoxy-based adhesive aluminium joints was studied under the combined static loading and environmental aging conditions.
- The influence of the the surface pre-treatment on the durability and strength was also studied.
- The residual strength of the joints after exposure to constant humidity of 75% RH and constant temperatures of 60°C and 70°C at different static loading levels was measured as a function of time.

THE STRENGTH OF THE EPOXY-BASED ADHESIVE ALUMINIUM JOINTS

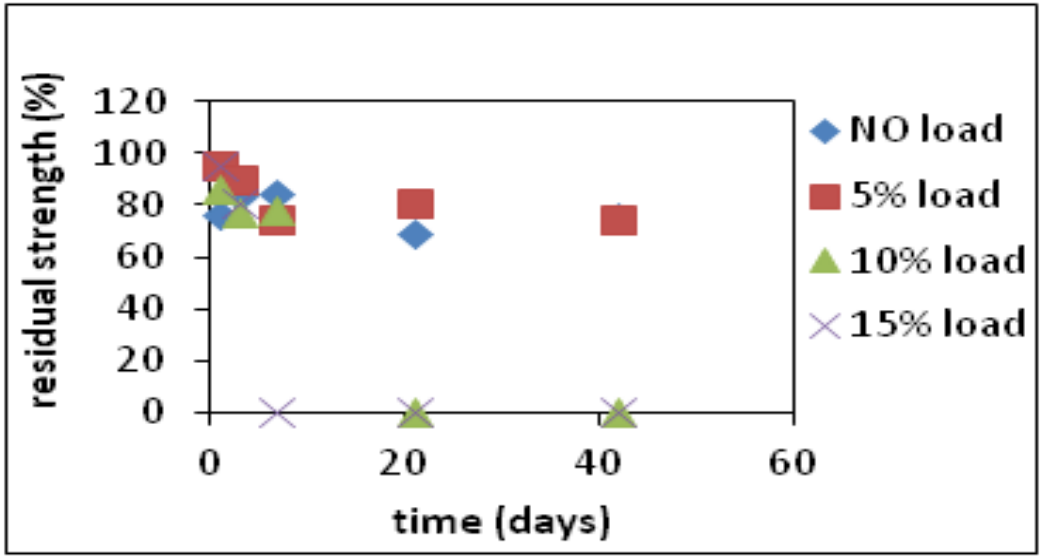
- Test results were compared to the aging results under ambient laboratory conditions.
- The fracture surfaces of the tested specimens were studied for evaluating the type of the joint failure and for revealing the weakest link in the joint.
- The adherend surfaces were either mechanically pre-treated by sand blasting or pre-treated by the combination of sand blasting and silane pre-treatment.
- The chemical pretreatment with silane was also studied.
- Part of the mechanically pre-treated joints were protected with silicone to prevent the moisture attacking the joint.

Test Results:

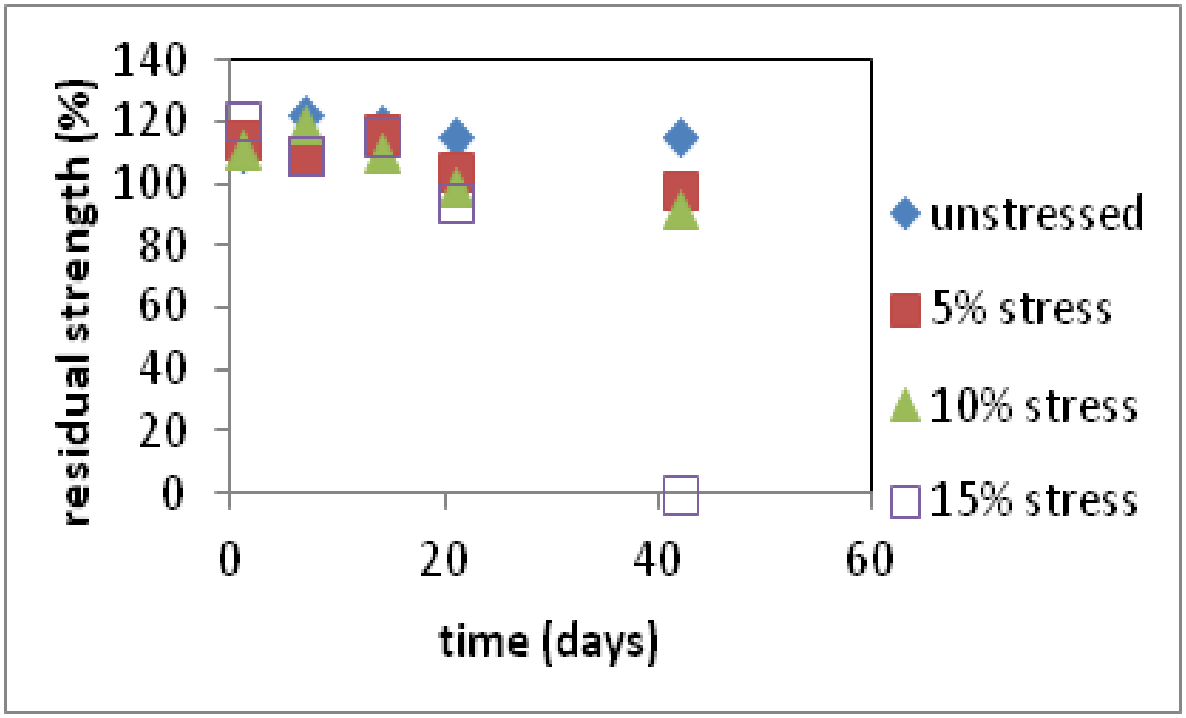
The residual strength of the specimens as a function of time after aging under 60°C and 75%RH. The results for the sand blasted and acetone decreased.



The residual strength of the specimens as a function of time after aging under 60°C and 75%RH. The results for the sand blasted, acetone degreased and silicone protected.



According to our tests:The residual strength of the sand blasted, acetone degreased and silane pretreated specimens as a function of time aging under 60°C and 75%RH at different stress levels



THE FRACTURE SURFACES

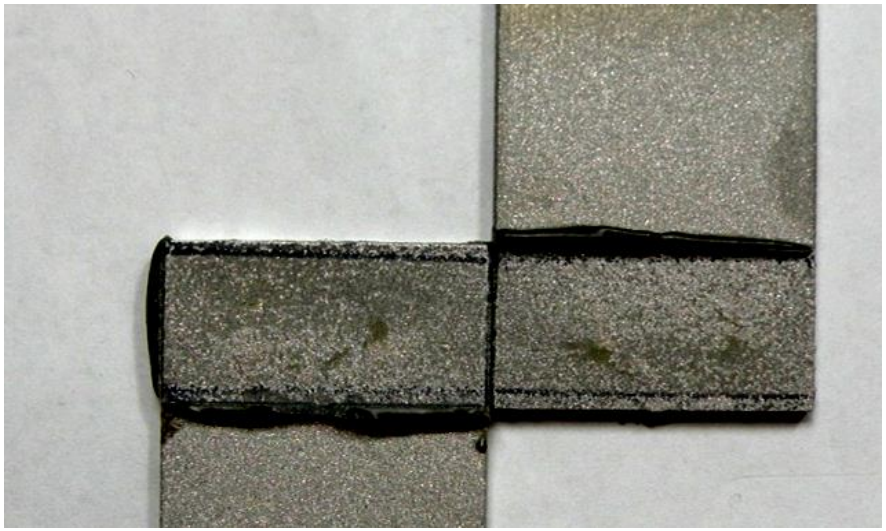
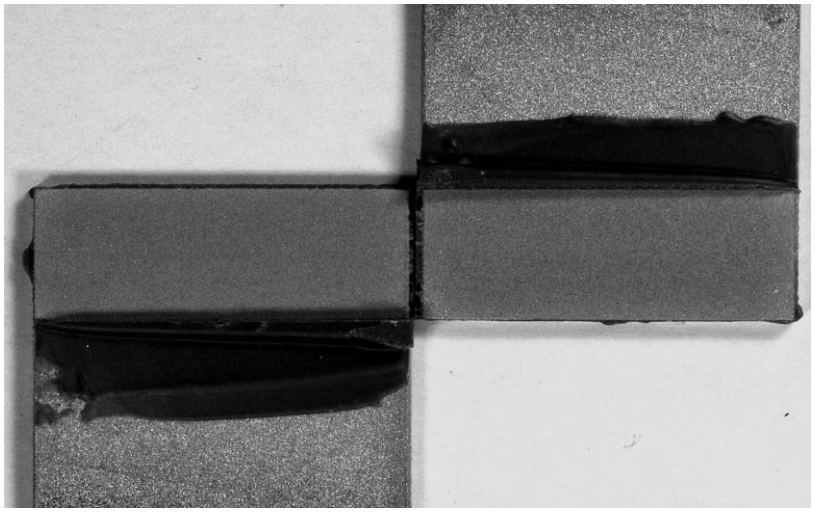


Fig 3. Typical fracture surfaces of the sand blasted single –lap joint aged under 70ºC and 75%RH at 15% load of initial strength.

THE FRACTURE SURFACES



- Fig 4. Typical fracture surfaces of the sand blasted and silane pre-treated single lap joint aged under 60°C and 75%RH at 15% load of initial strength

THE FRACTURE SURFACES

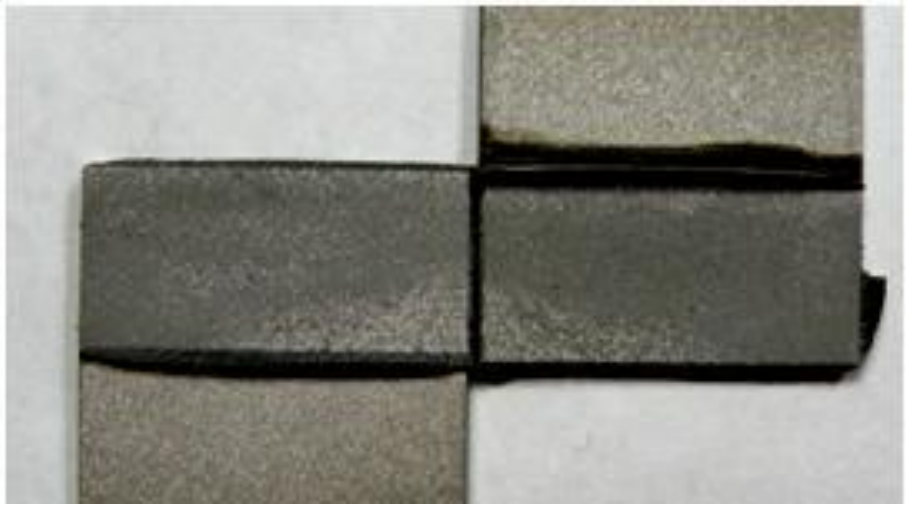


Fig 4. The fracture surfaces of the single -lap joint aged under 70ºC and 75%RH at 5% load of the initial strength

THE FRACTURE SURFACES

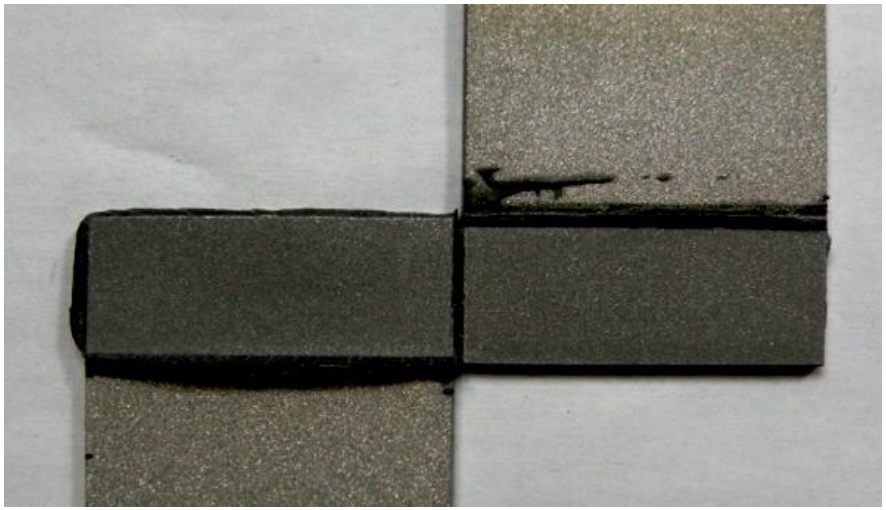


Fig 5. Typical fracture surfaces of the sand blasted single-lap joint aged for 3 weeks at room Temperature and at 10% load of the initial joint strength.

CONCLUSIONS:

- **According to our tests the silane pre-treatment has no influence on the initial strength of the joint.**
- **In our tests under aging conditions of 60ºC and 75% RH the silane pretreatment together with sand blasting increases the joint durability of the loaded epoxy adhesive joints when comparing to sand blasted or "only" silane pre-treated joints. Especially at higher load stress levels of 10% and 15% the silane pretreatment remarkable increases the strength of the joint.**
- **In our tests decreasing the temperature from 70ºC to 60ºC has no Influence on the durability of sand blasted and stressed joints at 75%RH.**

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