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USING SANDBLASTING AND SOL GEL TECHNIQUES FOR THE PREPARATION OF A METAL SURFACE AND THEIR EFFECTS ON THE DURABILITY OF EPOXY-BONDED JOINTS

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Abstract

The epoxy-bonded joints are widely employed in aerospace in the Composite Patch Bonded Repair (CPBR) method used for repair metallic and composite structures. The properties of epoxy usually meet the mechanical and environmental requirements, but the durability of bonded joints depends also on the surface preparation.

The most common techniques used for the surface preparation are Forest Product Laboratory's (FPL) technique and Phosphoric Acid Anodizing (PAA). Both methods ensure very good adhesion but they have some disadvantages. They require the application of toxic and aggressive acids, dangerous for the operator. Also, the use of acids for cleaning the surfaces can cause corrosion.

The sandblasting treatment of metal surfaces ensures quite good adhesion. This technique requires neither specialist equipment nor the use of toxic substances. Recommended by the Royal Australian Air Force (RAAF) the technique is also used by the Air Force Institute of Technology.

Sol Gel is a new product developed for the treatment of metal surfaces before bonding. It is not hazardous for the operator and it does not cause corrosion due to its specific chemical composition.

The article describes the behavior of bonded joints between two metal surfaces prepared using sandblasting and Sol Gel. The investigations were carried out in various environment conditions according to the ASTM Standards.

1. INTRODUCTION

Existing research shows that the type of bonded materials has a marginal influence on the strength of a joint bonded with an adhesive epoxy film, provided the bonded surfaces have been prepared properly (Fig. 1).

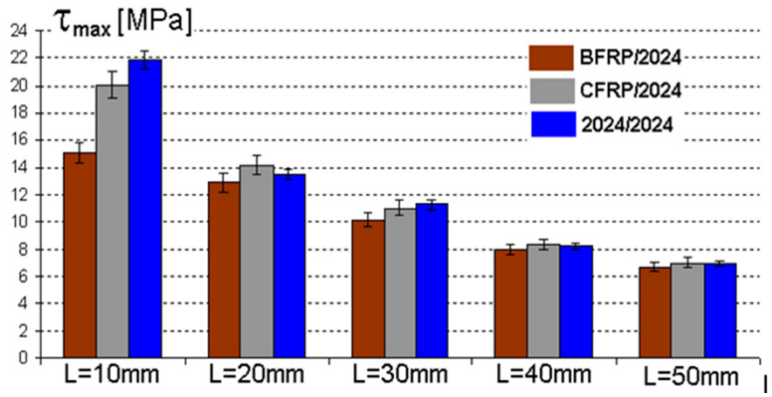

Fig. 1. The influence of the length of the adhesive-bonded joint on its strength **[1]**

The preparation of the composite specimen's surface for bonding consists of its thorough cleansing and, optionally, increasing the contact surface by roughening. After a layer of the adhesive film has been applied and subjected to a heating cycle (cure cycle), there occurs diffusion of the adhesive into the composite along with the polymerization of the adhesive film molecules as well as the bonded composite and the adhesive.

Bonding of metals with the use of epoxy adhesives is based on the diffusion effect. So, the surface preparation affects only the contact surface between the glue and the metal, wetting ability and capillary forces (Fig. 2).

$$\gamma_{sv} = \gamma_{sl} + \gamma_{lv} \cdot \cos\Theta$$

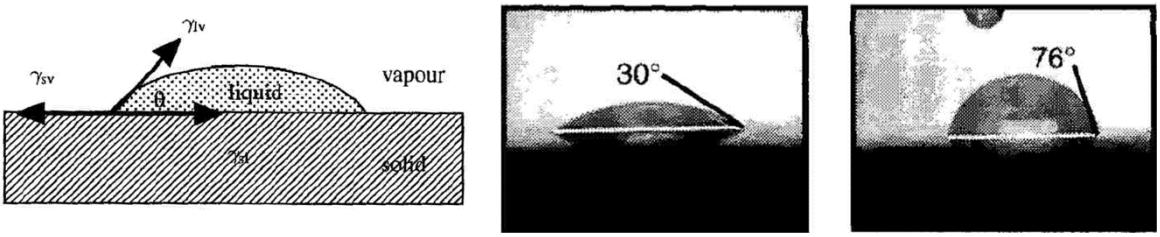

Fig. 2. Balance between the liquid drop and the solid substrate: γ_{sy} – tension solid-vapor, γ_{sl} – tension solid-liquid, γ_{ly} – tension liquid-vapor, Θ – equilibrium contact angle **[2]**

The Sol Gel technique of metal surface preparation is a revolutionary method. The Sol-Gel layer bonds chemically to the inorganic metal part of the surface, leaving unsaturated amine molecular bonds, which in turn take part in the hardening process of organic epoxy resin (Fig. 3).

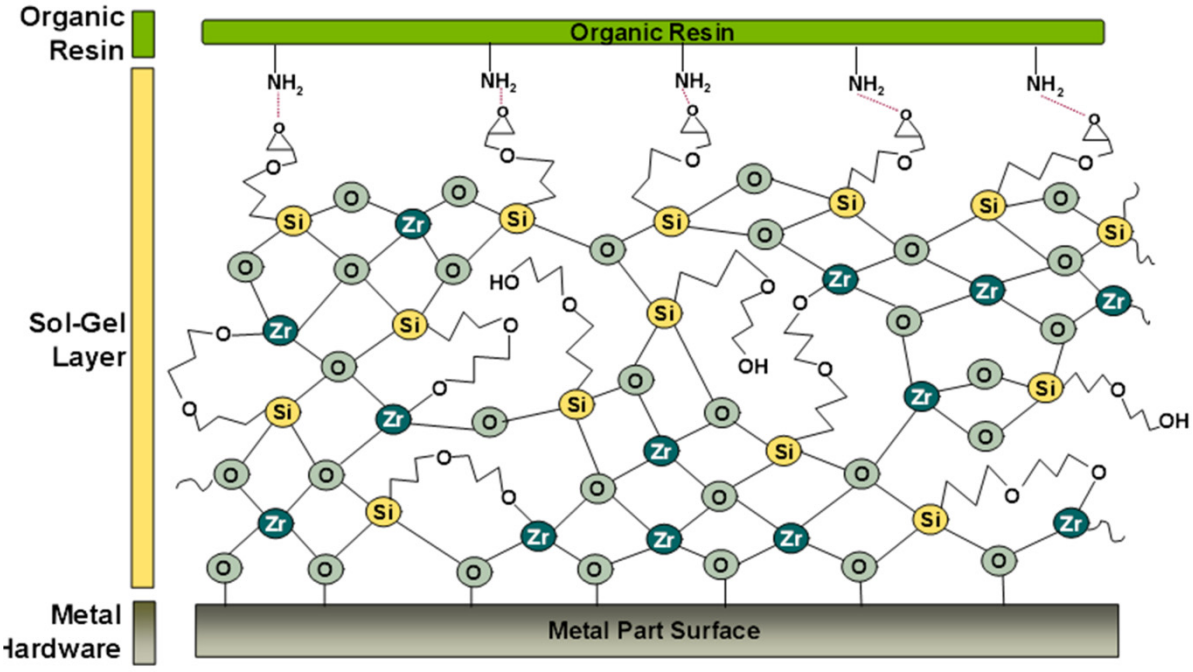

Fig. 3. The scheme of metal-epoxy joint made using the Sol Gel technique for surface preparation **[3]**

The paper presents the results of the comparative environmental investigations into the influence of low temperature and high humidity on the durability of bonded joints made using the

standard surface preparation method including sandblasting, and the Sol Gel preparation method. The tests were performed according to the "ASTM D3762 - 03(2010) Standard Test Method for Adhesive-Bonded Surface Durability of Aluminum (Wedge Test)".

2. EXPERIMENTAL METHOD

The Wedge test is an experimental method for research of damage propagation in a glue joint between two metal sheets. Damage is caused by inserting a wedge between the metal sheets.
For making the test coupons, 2024-T3 3 mm trick metal sheets were used. Two series of coupons were made. First group of coupons was sandblasted before joining. The second group was cleansed with acetone and covered with Sol Gel. In both cases the surfaces were protected from oxidation with a BR127 primer. Adhesive film AF 163-2 was used for all glue joints (fig. 4).

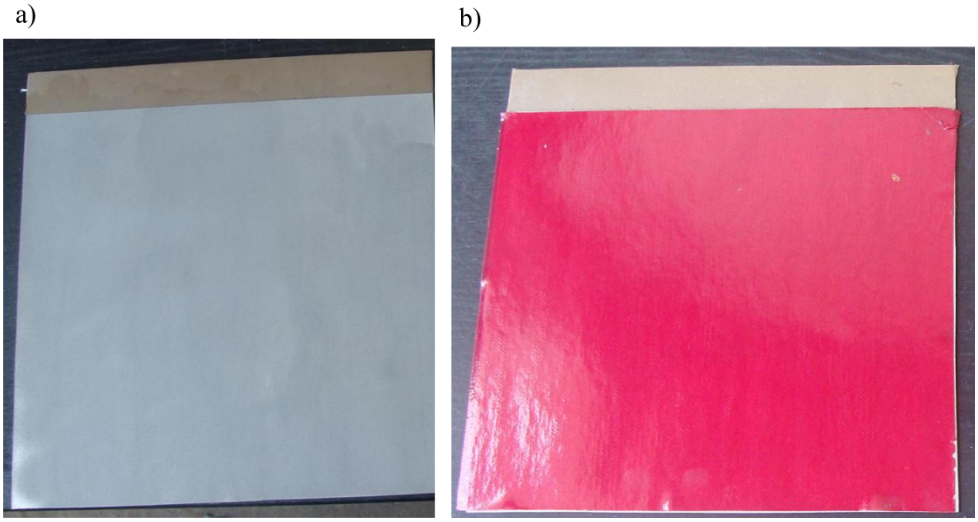

Fig. 4. The test coupon before gluing, a) the sheet after sandblasting protected from oxidation with the BR127 primer, b) sheet with the adhesive film AF 163-2

Cure cycle has been performed using the Heatcon 9200FL system and a heating blanket in a vacuum bag providing the required pressure.

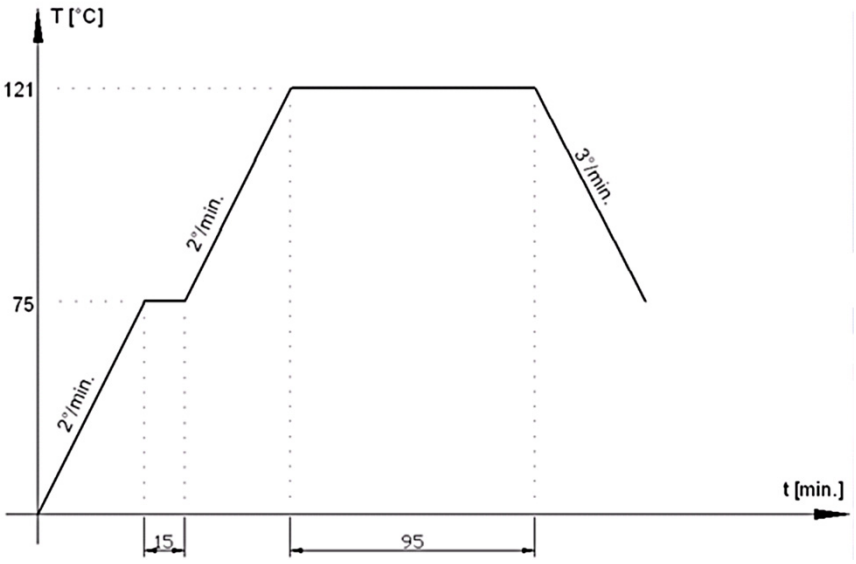

Fig. 5. Thermal cycle during gluing

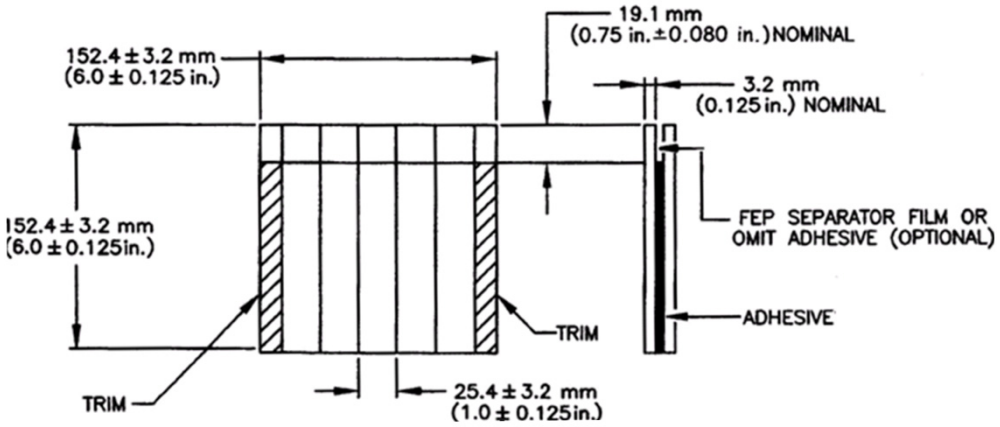

Fig. 6. The method for cutting out the sheets from prepared panels

Residual stresses were introduced into the coupons in accordance with the standards, and the coupons were subsequently placed in various environmental conditions:
(humidity ~ 40%):

- -23°C – freezer,
- 4°C – refrigerator,
- 24°C – ambient conditions,
- 53°C – radiator (central heating),
- Variables -15°C ÷ 0°C – freezer,

Water 24°C.

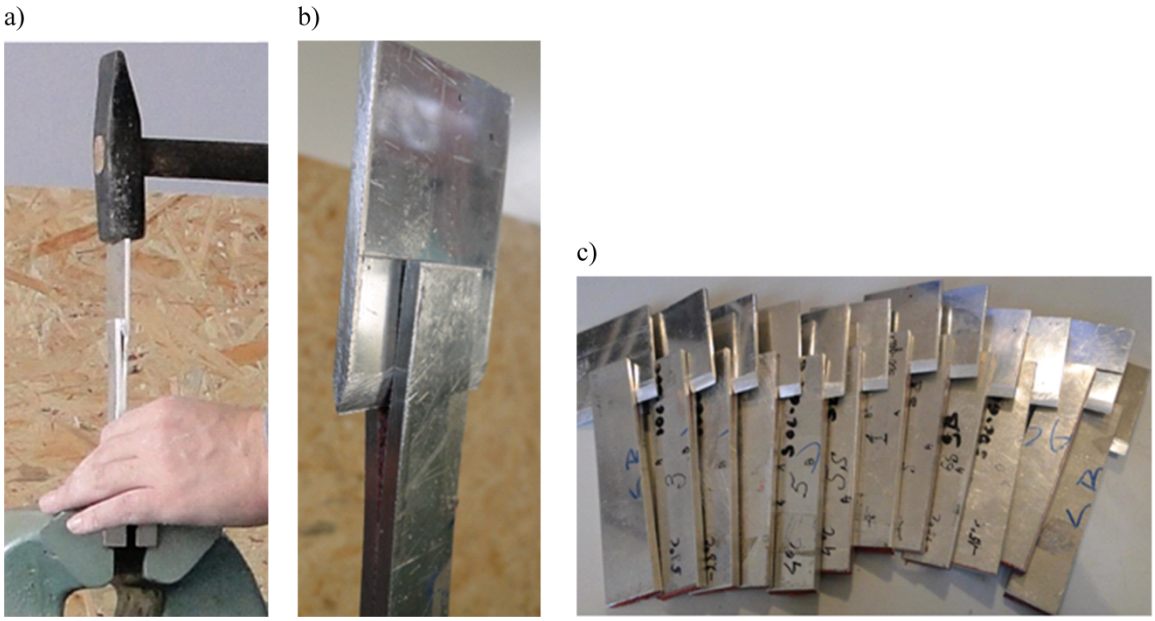

Fig. 7. Preparation of test samples, a) inserting the wedge between the metal sheets, b) initial damage, c) the set of test samples

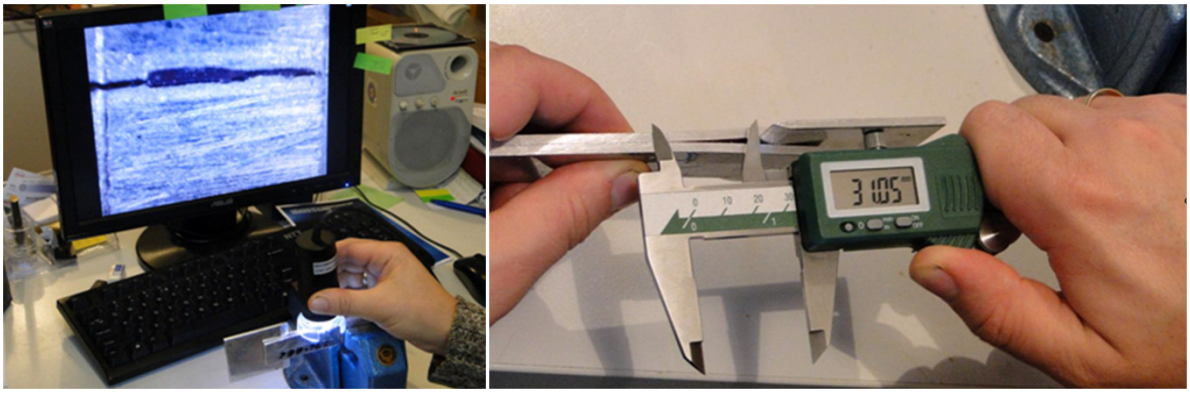

Fig. 8. Measurement of damage propagation

3. TEST RESULTS

The tests were conducted in the span of 15 days. Delamination growth was measured daily using the electronic microscope and electronic slide calipers (Fig. 8).

The measuring error was estimated based on the initial cracks measurements.
$\sigma=\sigma$(Initial cracks)=1,32mm < 5%

The damage of all the tested samples had a de-adhesive character.

4. CONCLUSIONS

Comparison of the methods for flat coupons 160x160 mm / One CPBR:

- In terms of tooling, in both cases no special environmental conditions are required. For sandblasting, a compressor and aero-gun are needed.
- Hazards: for both repair types, gloves, safety glasses and masks are necessary.
- Inspection capability is better in the case of sandblasting than for Sol Gel.
- The materials for both methods are not expensive, although the order lead times for the sol-gel may be considerable.
- In terms of material condition after treatment, sandblasting causes deformation of thin metal sheets and loss of material. For Sol-Gel treatment the material state remains unchanged.
- The bonded joint condition when exposed to various environmental conditions differs for both methods. For sandblasting, de-adhesion occurs in all environments while for Sol-Gel de-adhesion occurs only in water environments.
- The bonded joint manufactured after surface preparation with Sol-Gel exhibits better durability in the Wedge Test. The average gain in durability is ~7%. Use of better adhesive films for the Sol Gel technique is likely to further improve the durability of the bonded joint.

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