MEASURE AND DESIGN OF STRESSES IN ADHESIVE BONDED TRUSSES: EXTENSOMETRICAL AND LASER-ELASTICIMETRICAL METHODS

L. BEN AICHA*, Y. GILIBERT**, A. RIGOLOT***

E.N.S.T.A. - L.M.E.
Groupe Composites et Collage
Centre de l’Yvette, Chemin de la Hunière
91120 PALAISEAU

1. INTRODUCTION

Used since the remotest antiquity, the bonded assemblage has been developed in the technological field since the beginning of the 20th century. However, the fundamental researches about this way of bonding dates back to, at the very most, forty years. Coupled with important progresses in joint design and improved knowledge of bonding processes, the result is an ever growing variety of adhesive bonded assemblages, depicted for instance in references [1].

One of the aims of this paper is to show with the help of examples, that the extensometrical method with electrical gauges is suitable for the study of the mechanical behaviour of bonded structures.

This method, elaborated by GILIBERT [2] in the years 1971-73, allowed to validate a finite elements method [5].

In 1977-78, GILIBERT and RIGOLOT have developed an analytical theory of double lap bonded joints by using the method of matched asymptotic expansions [3] [4]; since then, the comparison between measurements and computations allowed conclusive progress with regard to this complex domain of solid mechanics.

In 1985, with the collaboration of FERRE [6], BEN AICHA and GILIBERT used a laser-photoelasticimetry method to measure the stresses in double lap bonded joints with the aim of confirming theoretical results.

2. PREPARATION OF THE SURFACE AND MEASUREMENT OF THE GEOMETRY

2.1. Properties of the Adherends

A low carbon steel (0.18 % carbon; XC 18 French standard equivalent to SAE-AISI 1017) was used for the adherends of the specimens studied. The properties of the steel were controlled using mechanical measurements and microscopic observations. The Young's modulus ($E_y = 207,700$ MPa) and the Poisson's ratio were determined using tension tests with strain gauges at a very low strain rate ($\varepsilon$ about $10^{-6}$ s$^{-1}$) on steel specimens with 100 mm$^2$ square cross section and 250 mm length. The Brinnell hardness (HB = 210) test showed the uniform quality of the material, whereas microscopic observations indicated a ferritic microstructure.

*Thésard ENSTA/LME/GCC
**Chef du Groupe Composites et Collage, Maître de Conférences, Docteur ès Sciences
***Conseiller Scientifique du G.C.C., Professeur des Universités à Reims

2.2. Preparation of the Rough Adherends, Finishing and Blasting

A shaping machine with a traversing tool was used in the preparation of the rough adherends.

This was followed by milling and after which a grinding was effected with a horizontal surface grinding machine under different conditions: coarse or fine grain grinding wheels. For all these operations, machining conditions (speed, feed, depth of cut, lubrication, sharpening of the tools) were strictly controlled and are described in Reference 2, Chapter 4.

The finishing procedure for some of the specimens was completed with sand blasting under four conditions using different particle diameters (115, 169, 282 and 423 μm) or with shot blasting. The particles with a 115 μm diameter were made of high purity white alumina (Al₂O₃>99.5 %), whereas the particles with diameters of 423, 282 and 169 μm were of brown corundum, i.e. less pure alumina (composition: Al₂O₃>94 %; TiO₂<2.5 %; SiO₂<.5 %). The blasting pressure used was 0.4 to 0.5 MPa. The sand jet was inclined at 60° from the specimen surface and displaced at a speed of 24 mm s⁻¹. The shot blasting was conducted with iron shots 1 mm in diameter.

In this paper, the various surface states are designated as follows:
- RF - fine ground state; RFS - fine ground sans blasted state;
- RG - coarse ground state; RGS - coarse ground sans blasted state;
- RGG - coarse ground shot blasted state.

The numbers following RFS and RGS designate the particle mesh size.

2.3. Measurement of the Surface Roughness Parameters

The surface profiles were determined using probes with an air bearing of 25 μm and 750 μm travel distances. The specimens used had the same section as the adherends and were machined and treated at the same time under the same conditions. The surface profiles were measured, before and after blasting, along reference paths, the ends of which are marked with two notches remaining after blasting.

Data were recorded and processed by a computer to determine the various parameters of the surface defects describing the total profile, roughness and waviness. The calculations were done using a method developed by B. Scheffer of RENAULT (FRANCE).

We observed that the surface roughness parameters alter very quickly during the first few seconds of blasting and do not change after a while. We selected a time lapse of 30 seconds which ensured a stable state of these parameters.

Measurements showed that the surface roughness parameters are not dependent on the direction of measurement for blasted states, whereas condition as ground showed some anisotropy.

Reference 2, chapter IV, table IV.1 presents values of the surface roughness parameters for the various surface states studied. These are the total depth of roughness, Rₜ; the average depth of roughness, R; the maximum depth of roughness, Rₘₐₚ; the roughness levelling depth, Rₚ; the arithmetical mean deviation from mean line of roughness, Rₐ; and average spacing of roughness, Aᵢₚ.

From these data, it can be seen that the surface roughness parameters for sand blasted states depend on both the initial grinding and the mean diameter of the particles used for blasting. For all surface preparations, the maximum depth of roughness Rₘₚ is very close to the total depth Rₜ, which indicates that surfaces have no aberrant defects of roughness and are consequently fairly homogeneous; for the fine ground state, the roughness parameters increase steadily with the particle diameter whereas for