Dynamic characterisation of piezoelectric thick film sensors embedded within dissimilar material joints

A Deligianni[a], J M Hale

[1] *School of Mechanical & Systems Engineering, University of Newcastle upon Tyne, Newcastle upon Tyne, NE1 7RU, UK*

[a]a.deligianni@newcastle.ac.uk

Abstract. Techniques have been developed for making a unique type of piezoelectric thick-film sensor, being termed 'piezoelectric adhesive', using PZT powder as the active ingredient of the piezoelectric composite and epoxy resin as the matrix. The idea of developing this 'piezoelectric adhesive' was to incorporate the sensors into the adhesive layer of a joint without greatly affecting its mechanical properties and use it as strain sensor. Dynamic strain sensors have been produced using this piezoelectric adhesive which were embedded into adhesively bonded joints and gave direct quantitative information of the load distribution along the joint's bond area, aiming at the optimisation of joint design. The evaluation of the piezoelectric adhesive involved assessing the behaviour of the composite material on single metal strips under dynamic loading (4-point bending). In addition bonded specimens were manufactured and been assessed under dynamic loading after the optimum formulation of the composite was identified. The mechanical tests were carried out over a range of displacement amplitudes and frequencies to investigate the sensitivity of the PZT sensors in each case. A computer controlled hydraulic, universal testing machine (Instron DX series) was used for conducting the mechanical tests and the probe signals were conditioned using a custom-made charge amplifier with a sensitivity of 1.0mV/pC.

Key words: Piezoelectric, sensor, joint, strain

Introduction

By mixing a piezoelectric powder with a liquid it is possible to create a piezoelectric sensor that can be applied to almost any surface and monitor the stress distribution of a structure [1, 2]. The first piezoelectric sensors were developed by Newham in the 1980's who also introduced the term 'piezoelectric paint' and then Hale and his co-workers investigated piezoelectric sensors using water-based acrylic resin [3, 4]. Similar composition, using epoxy resin as binder, to be used as strain sensor, as part of the adhesive layer of a structural joint is introduced in this work. For the present study the general requirements of the 'piezoelectric adhesive' as a novel form of thick – film sensor, are summarized as follows:

1. The deposition technique must allow the formation of a thick – film circuit
2. The thick – film sensor must adhere to the adherents of the joint (substrates) to which it is applied and for which the mechanical characteristics are to be monitored
3. It must generate a piezoelectric charge sufficient to be measured using standard instrumentation
4. It must not contain significant residual stresses and affect the mechanical properties of the bond

Materials and Methods

Two different PZT powders were tested in different weight fractions. The powders were nominally the same specification as "soft" PZT, commonly known as Navy type II. These two ceramic powders were PZ 27, produced by Ferroperm Piezoceramics A/S and PZT 5A, produced by Sunnytec Electronics CO. Ltd. Two types of epoxy resin, TechnoWrap 2K and RS-L135, were chosen for mixing with the piezoelectric powders to form the piezoelectric adhesive. Different thicknesses of the piezoelectric sensors were produced using standard K bars to control the film thickness. As part of the assessment of the sensor, the area of the electrode was investigated. In this case the probe signal was recorded as a function of the electrode area. The final step in the piezoelectric composition assessment was the poling process which was necessary to induce the required polarity in the original isotropic crystalline material of the sensor. After the optimum formulation of the piezoelectric adhesive was determined, adhesively bonded joints were manufactured and tested using this piezoelectric adhesive along the adhesive layer of the bond to assess the performance of the sensors [5].

Conclusion

A novel type of piezoelectric thick-film sensor has been developed, using PZT ceramic powder as the active ingredient and epoxy resin as the matrix.70 wt% PZT 5A-RS L135 was proposed as the optimum formulation of the piezoelectric adhesive. The piezoelectric adhesive was successfully been embedded into a lap joint for both similar and dissimilar materials joints providing confidence for the material to be used as in-service, strain sensor for structural joints.

References

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