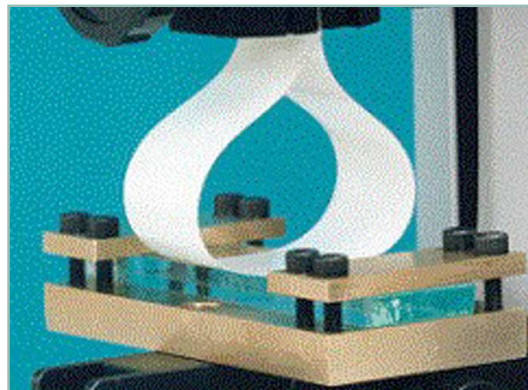


NPL Materials Centre

Performance of Adhesive Joints

Technical Overview

The provision of accurate engineering properties data and the availability of reliable materials models and failure criteria for adhesives are essential for accurate Finite Element (FE) design simulations of bonded structures. Progress had been made on establishing techniques for obtaining design data in an earlier programme. Two projects within this Performance of



Adhesive Joints programme continued the investigation of methods for designing structures bonded with *Flexible Adhesives* and *Rubber-Toughened Adhesives That Deform Through Cavitation*. A further project disseminated best practice to industry.

Greater understanding of how to represent toughened adhesives in elastic-plastic material models has led to the development of new functions to characterise large-strain plastic yielding by cavitation of the rubber phase. New and improved test methods for accurately obtaining the required material properties have been developed and used to obtain the properties of structural adhesives over ranges of temperature and strain rate.

The hyperelastic properties of flexible adhesives required the development of uniaxial, planar and biaxial test methods that provide the input data suggested by the FE software manuals. Flexible adhesives were found to be compressible and therefore methods for determining volumetric properties were required. Validation of the use of hyperelastic material models for predicting joint performance demonstrated that it was possible to obtain all the required test data from the uniaxial tension test alone with little loss of prediction accuracy.

The properties of bulk adhesive materials were compared to strengths obtained from a variety of joint tests in order to investigate likely failure criteria. The strengths of adhesive systems depend on the rate and temperature at which they are deformed. Correlations can be made between joint strength and bulk tensile strength.

Industrial Partners

- 1 3M (UK) Ltd
- 1 ADCON
- 1 AEA Technology
- 1 Alcan International
- 1 BAe Systems
- 1 Celestion International
- 1 Corus
- 1 Cytec Aerospace
- 1 Evode
- 1 Ford Motor Company Ltd
- 1 Gurit-Essex
- 1 Henkel Surface Technologies
- 1 Jaguar
- 1 Industrial Adhesives
- 1 Loctite (UK) Ltd
- 1 Pira International
- 1 Permabond
- 1 Polymer Advisory Link Service
- 1 Risk Statistical Consulting
- 1 SATRA
- 1 Taywood Engineering
- 1 TWI
- 1 Vantico
- 1 Xyratex

Project Outputs

Reports

NPL Report CMMT(A)262	Rate and temperature dependent properties of a flexible adhesive
NPL Report CMMT(A)285	Evaluation of hyperelastic finite element models for flexible adhesive joints
NPL Report MATC(A)286	Measurement methods for obtaining volumetric coefficients for hyperelastic modelling of flexible adhesives
NPL Report MATC(A)23	Hyperelastic properties of a polyurethane adhesive
NPL Report MATC(A)36	Failure of flexible adhesive joints
NPL Report MATC(B)29	Effects of moisture on the mechanical properties of M70 Adhesive
NPL Report CMMT(A)289	An elastic-plastic model for the non-linear mechanical behaviour of rubber toughened adhesives
NPL Report CMMT(A)293	Analysis of joint tests on an epoxy adhesive
NPL Report CMMT(A)40	Comparison of the measured and predicted deformation of an adhesively bonded lap-joint specimen
NPL Report MATC(A)27	Strength of adhesive joints: a parametric study
NPL Report MATC(A)43	Temperature dependence of the properties of an epoxy adhesive

Measurement Notes

CMMT(MN)057	Preparation of bulk adhesive test specimens
MATC(MN)11	Size effects on the performance of flexible adhesive joints
MATC(MN)02	Loop tack Measurements
MATC(MN)09	Tensile testing of adhesive butt joint specimens
MATC(MN)10	Geometric and material property effects on the strength of rubber-toughened adhesive joints

Good Practice Guides

NPL GPG No 45	Characterisation of flexible adhesives for design
NPL GPG No 47	Preparation and testing of adhesive joints
NPL GPG No 48	The use of finite element methods for design with adhesives

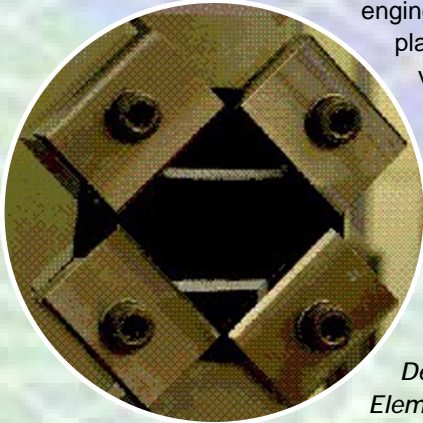
The above reports, together with the 50 technical reports and three Good Practice Guides produced in the earlier Performance of Adhesive Joints programme, are being released on a single CD-ROM. (PAJCD1). This will bring together findings covering the lifecycle of adhesive joints from design through processing to long-term durability.

These reports can be purchased from the NPL e-Store (www.npl.co.uk/e-store) quoting the relevant reference number.

Programme Achievements:

Three new measurement methods leading to one draft standard

Measurement methods for quantifying the hyperelastic properties of flexible adhesives and plastic yielding behaviour of rubber-toughened adhesives have been developed to obtain engineering properties needed for Finite Element design methods. Biaxial and planar tension test methods for hyperelastic adhesives were developed and validated. New test methods were established for determining volumetric properties of flexible adhesives. Improved butt-joint test methods have been developed to study plastic yielding behaviour in toughened adhesives. An improved standard method for the thick-adherend shear test has been adopted by ISO. These new tests help industry to obtain more accurate materials properties



Three codes of best practice

NPL Good Practice Guides on *Characterisation of Flexible Adhesives for Design, Preparation and Testing of Adhesive Joints* and *The Use of Finite Element Methods for Design with Adhesives* have been produced to complement earlier guides on Preparation and Testing of Bulk Specimens of Adhesives, Durability Performance of Adhesive Joints and Adhesive Tack. These guides give practical advice on testing and analysis for engineering properties of adhesives.

Two measurement notes

Five measurement notes issued covering preparation of bulk test samples, tack testing, butt-joint tension, and scaling effects in joints.

Two new products

A novel prototype test frame has been made that enables the imposition of an equibiaxial stress on flexible test specimens using a standard tensile test machine. The frame is being promoted to industries using 'soft' materials such as footwear and packaging as a low-cost method of obtaining biaxial data. New mathematical functions have been developed to characterise the cavitation of rubber particles

in toughened adhesives and these are being implemented in a Finite Element Analysis package. The new models will help the automotive industry design safer lightweight vehicles

Results widely and effectively disseminated

Over 6,000 companies have received information on the programme through articles in NPL newsletters such as 'Materials Measurement' and 'Plastics and Adhesive News'. Eight UK companies took part in a round-robin and on-site training exercise aimed at improving reliability of joint test measurements. Some 40 organisations have either visited NPL or been visited by NPL in connection with the Performance of Adhesive Joints programme, receiving advice on the use of adhesives. An Industrial Advisory Group with over 20 members met twice a year during the programme.

Presentations were made at a number of conferences and meetings including Adhesion '99 (Cambridge 1999), FASTENEX 2000 (Coventry 2000), Structural Adhesives in Engineering VI (Bristol 2001), 39th International Conference on Adhesion and Adhesives (Oxford 2001) and Pressure Sensitive Adhesives (London 2001). A one-day workshop on Adhesives - Testing and Design attracted over 20 delegates from 16 companies. Articles from the programme have appeared in magazines such as Materials World, Adhesives Technology, Professional Engineering and European Coatings.

Programme Partners

The PAJex programme (and its predecessors) has done the adhesive bonding community a great service through addressing the properties of adhesives and joints from a fundamental and independent perspective. The knowledge gained will lead to more meaningful testing protocols and soundly based standards. Even the best test is of limited value if it is not properly carried out, and as ever, the comparative trials and round robin exercises in the programme have been useful in identifying good (and bad) practice.

- Steve Abbott (SATRA Footwear Technology Centre)

Reliable failure criteria for adhesive joints will significantly assist in our efforts to establish cost effective bonding systems with a balanced range of properties.

- John Hunter (Alcan)

The work in this report and the other reports from that series have been used to develop a new material model for an adhesive which we have put into a new FE code. These material models are being used now for a new vehicle being developed in the UK for manufacture in the UK. This vehicle uses new materials and joining methods extensively. We have invested considerably in further developing the results reported by NPL into methods which we are applying on this vehicle and proving them for future vehicles. Without the NPL work, we would have major issues in using adhesives in some locations on this vehicle, because we would not have been able to predict the behaviour of the adhesive under an impact load.

- Roger Davis (Ford)

Further Work:

Technical themes of the Performance of Adhesive Joints programme continue to be developed in the Measurements for Material Systems programme. Two projects 'Interfacial Adhesion Strength' and 'Fatigue and Creep in Joined Systems' maintain NPL's research into improving testing and design practice for adhesives and bonded systems. There are still opportunities to become actively involved with these projects. For further information contact NPL.

Programme Management

This work was funded by the DTI Materials Measurement programme and managed by NPL under the guidance of the adhesives industrial advisory group chaired by Dr Gareth McGrath (TWI)

If you would like any further information on this or any other work at NPL please contact:

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