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Requirements of sealed joint systems for demanding applications – an engineering perspective

Professor Allan Hutchinson
Head, Joining Technology Research Centre

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Sealed Joint Systems

A sealant is required to fill gaps, to stick to the relevant surfaces and to accommodate movement; few sealants are required to transmit stress.

Sealed joints generally comprise:
- substrates (e.g., aluminium, glass, concrete, masonry)
- a primer (e.g., a silane or an isocyanate dissolved in solvent)
- the sealant itself (a polymer base with additives such as pigments, fillers and catalysts)
- a backing material, bond-breaker tape, or similar
Sealed Joints in Building Facades

A modest 10-storey office block may have >5km of joints

A tall building may have >50km of joints

RESEALING will be necessary within the lifetime of a building –a very difficult and expensive operation
Requirements of Sealed Joints in Building Facades

Accommodate MOVEMENT
Accommodate building tolerances
Stick to relevant surfaces, including residues in the case of resealing
Cure as appropriate
Barrier to air/water/other fluids
Aesthetically pleasing
Be durable
Be amenable to resealing
(Resist fire)
Sealed Joints in Building Facades

London – daily movement of typical butt joint in aluminium cladding
Typical Causes of Failure

- Inappropriate joint design (bead too narrow or too deep, lack of allowance for magnitude and frequency of movement)
- Incorrect specification of sealant type
- Poor adhesion to substrates/lack of priming
- Adhesion to backer rods, causing 3-sided adhesion
- Joint movement during cure
- Curing issues
- Workmanship
- Poor access to joints during application
- Lack of control of working environment
- Time pressures on completion
- Aesthetic problems, eg staining
Aerospace

- Sealing of aircraft integral fuel tanks and test method development
- Optimisation of composite structures
- Development of next generation all composite airframes

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Automotive

- Modelling of joints and sub-structures
- Behaviour and modelling of Self-Fiercing Rivet (SPR)/Adhesive hybrid joints
Aircraft Sealants

- Corrosion Inhibitive
- Conductive
- Aerodynamic Smoothing
- Windshield and Canopy
- Integral Fuel Tank
- High Temp.
- Access Door
The Aircraft Wing

Inside the wing showing the skin, stringers and ribs
Integral Fuel Tank Sealing

100kg of sealant per wing
Total fuel volume 100,000 to 150,000 litres

Typical interfay, fillet and overcoat applications
Requirements for Integral Fuel Tanks on Commercial Aircraft

Sealant systems (sealant/primer/skin material) must resist a combination of structural loading, fuel inertia, tank pressures, thermal cycling and chemical effects

- Ground loads and flight loads, leading to aluminium skin stresses of up to 120MPa at 5Hz
- Pressure changes (typically 0.25 bar but spikes of 2.5 bar during high G manoeuvres for commercial airframes with aluminium tanks)
- Temperature changes (-55 to +55C)
- Chemicals (kerosene-type jet fuel, water, de-icing fluids, hydraulic oils, biological contamination, corrosion products)
- Wet/dry cycles
- Low density (1g extra leads to an additional 1l of fuel used per annum)
Experience with Integral Fuel Tanks

Preferred sealant material is a two-part, manganese-dioxide cured, liquid polysulfide

Problems
- Tank design makes sealing difficult with many complex joints
- Surface preparation and priming is difficult
- Application of sealant during initial assembly and subsequent repair is difficult to achieve consistently
- Ageing of sealed systems
- Dynamic loading
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Automotive

- Modelling of joints and sub-structures
- Behaviour and modelling of Self-Fiercing Rivet (SPR)/Adhesive hybrid joints
- Static, dynamic and noise, vibration and harshness (NVH) behaviour of vehicle panels and jointed components

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Materials and Surfaces
Noise, Vibration and Harshness (NVH)
Low NVH Roof Solutions

Prototype roof sections in polypropylene/glass, representative for stiffness and NVH testing, bonded to a BIW with low modulus PU adhesive/sealant.
Requirements of Semi-structural Sealant

- Bond to painted steel and polypropylene
- Allow rapid application
- Fast curing
- $E: 1\text{-}3 \text{ MPa};$ lap shear strength $\sim 1.5 \text{ MPa}$
- Confer composite structural action to vehicle body
- Absorb vibration and contribute to acoustic damping
- Transmit shear, tensile and torsional stresses
- Accommodate thermally-induced movements (-40 to +80°C)
- Be durable for design life (c. 13 years)
- Resist a variety of fluids
- Be paintable
- Allow repair/disassembly
Common Themes

- Products that are easy to (mix and) apply
- Training in application and workmanship
- Working environment
- Quality control
- Use performance-based testing, eg ISO 11600 for construction sealants
- Lack of understanding of joint design principles
- Lack of understanding of sealant technology
- Lack of assessment of sealed joint performance requirements
- Think in terms of sealed joint systems
The Future

CONSTRUCTION
• Better workmanship
• Better training
• Better education of designers and specifiers
• More durable products
• Products that enable resealing
• Joint designs that enable resealing
• Performance-based test methods that allow *systems* to be evaluated

AEROSPACE
• Low density
• Sprayable
• Deal with greater temperature extremes
• Deal with greater movement extremes
• Stick to polymer composites and exotic metal alloys
• Performance-based test methods that allow *systems* to be evaluated under simulated real life conditions
Testing Services

The Joining Technology Research Centre (JTRC) at Oxford Brookes is recognised as one of the leading establishments in the UK today offering a comprehensive range of testing and consultancy services for adhesive bonding, adhesion in engineering and sealants used in building construction. It has a fully equipped test facility capable of testing to national and international standards.

Please click on the links below for further information on our main areas of expertise:

- QC testing for the construction industry
- Materials testing of adhesives, composites and bonded joints
- Sealant testing
- Consultancy

JTRC undertakes consultancy and short- and long-term research contracts in all areas of adhesion, adhesive bonding and sealant technology, and failure analysis. For an initial discussion please contact us at jtrc@brookes.ac.uk