Latest achievements in the field of assembling metals and composites

ASTech International Conference MMP 2015
November 25th, Deauville
WHO WE ARE

SME dedicated to materials

- Anaysis, Testing, Audit, Expertise
- Contractual Innovation Studies (Bonding, coatings, composites, etc.)
- Proprietary Technologies
- Professional Training
SOME FIGURES

- 55% ASD
- 20% HEALTH
- 10% ENERGY
- 15% OTHER

- >1000 Customers (20% export)
- >50 patents following studies
- 10.5M€ turnover in 2014
- 50% of Turnover in contractual R&D

- 80 employees (PhDs, Engineers, Technicians)
- 7000m² fully equipped laboratories
  - 18 proprietary patents
QUALITY

- ISO 9001 Certification
- COFRAC ISO 17-025 Accreditation
  "Tests on Composites, food contact materials, medical devices »
- COFRAC ISO 17-020 « EcoTechnologies Verification » Accreditation
- Fire Testing Certification : FAR25
- NADCAP (NMMT) Accreditation
- SAFRAN Qualification (FAL518)
- AIRBUS Qualification
- GE Qualification
Agreed training center since 2001

- Numerous training programs available (Inter and intra)
- Various topics addressed: bonding, polymers, testing, regulation, etc.
- Graduating Trainings (EWF): Bonding for bonders and specialists

Some references
BONDING – Our core expertise

RESEARCH AREAS

- Adhesion
- Biobased materials
- Processes
- Durability
- Structural adhesives
- NDT
- Debonding on demand
- Smart adhesives
- Structural Health Monitoring

COMPETENCES

Formulation
- Established expertise in debonding on demand
- Development of customized formulations (conductive, fire resistant, REACH compliant, biosourced)

Benchmarking & Process development
- Benchmark and selection of best bonding solutions
- Production of bonded assemblies (test coupons and products)
- Development & qualification of bonding systems and processes

MAIN EQUIPMENT

- Bonding and surface preparation labs
- Table-top surface treatment stations (chemical) and plasma activation systems
- Planetary mixers (2x250g and 2x830g capacity)
- Dissolvers equipped with vacuum chamber
- 3-roll mill
- Bonding jigs
- Dosing and adhesives dispensing systems
- Curing ovens
- UV Fusion bench
- Dynamometers (static and fatigue, 100N to 250kN)
- METRAVIB DMA+150
- Climatic chambers
- Ultrasonic NDT

REFERENCES

MICHELIN, FIAT AUTO, SAFRAN, AIRBUS DEFENSE & SPACE, THALES, TECNIP, in various industry sectors (luxury, space, defense, transportation)
Bonding: Pros & Cons

Ever increased use of joining of dissimilar materials in new industrial developments

Bonding is a key solution identified in technological roadmaps of major aircraft manufacturers, since bonding means

- Lightness
- Better load distribution (compared to other joining techniques)
- Less impact on substrates (curing temp, no drilling)
- Good sealing

But several challenges exist
- E&T conduction
- Debonding on Demand
- Limited temperature resistance (polymeric materials)
- NDT
- Surface treatments
- Durability
Bonding: Pros & Cons

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Adhesives: insulative materials

Formulation mandatory to get electrical or thermal conductivity

Numerous products available on the market but they are:
- Expensive (costs of fillers)
- Dense (fillers)
- Not suitable for use in structural applications

There is a need for new cheap adhesives, with lower density and better mechanical strength

eT-BOND Project (11th FUI Call)
E&T CONDUCTIVITY

e&T conductive structural adhesives

eT-Bond National Project (end users: AIRBUS DS, THALES)
## BONDING – KEY PROJECTS

### E&T CONDUCTIVITY

**e&T conductive structural adhesives**

*eT-Bond National Project (end users: AIRBUS DS, THALES)*

<table>
<thead>
<tr>
<th></th>
<th>Raw adhesive</th>
<th>Rescoll Metal based Adhesive tech</th>
<th>Rescoll Cabon based Adhesive tech</th>
<th>Rescoll Ceramic based Adhesive tech</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal conductivity</strong></td>
<td>0.2 W/m.K</td>
<td>Up to 4 W/m.K</td>
<td>Up to 4 W/m.K</td>
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</tr>
<tr>
<td><strong>Electrical conductivity</strong></td>
<td>insulative</td>
<td>Up to $10^5$ S/m</td>
<td>Up to 1 – 10 S/m</td>
<td>Insulative</td>
</tr>
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</table>
## E&T CONDUCTIVITY

**e&T conductive structural adhesives**  
*eT-Bond National Project (end users: AIRBUS DS, THALES)*

<table>
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<tr>
<th></th>
<th>Electrical Conductivity S/cm</th>
<th>Thermal Conductivity W/mK</th>
<th>Lap Shear Strength MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specs for Thermal Adhesive</strong></td>
<td>$1.10 \times 10^{-5}$ to $1.10 \times 10^{-3}$</td>
<td>$&gt;4$</td>
<td>$&gt;9$</td>
</tr>
<tr>
<td><strong>Base Material</strong> (unmodified adhesive)</td>
<td>$1 \times 10^{-15}$</td>
<td>$0.2$</td>
<td>$24$</td>
</tr>
<tr>
<td><strong>Thermal Adhesive</strong></td>
<td>$6$</td>
<td>$4.4$</td>
<td>$10$</td>
</tr>
</tbody>
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</thead>
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<tr>
<td><strong>Specs for Structural Adhesive</strong></td>
<td>$&gt;100$</td>
<td>$&gt;0.8$</td>
<td>$&gt;15$</td>
</tr>
<tr>
<td><strong>Base Material</strong> (unmodified adhesive)</td>
<td>$1 \times 10^{-15}$</td>
<td>$0.2$</td>
<td>$24$</td>
</tr>
<tr>
<td><strong>Structural Adhesive</strong></td>
<td>$300$</td>
<td>$1$</td>
<td>$19$</td>
</tr>
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</table>

*2 adhesive formulations validated by end users and now part of STRUCTIL’s port-folio*
INDAR (INnovative Dismantling Adhesives Research)

Who needs to debond on command?

Many applications, at different product stages

- Maintenance
  - Replacement of worn parts
  - Upgrade of components
- End of life
  - Sorting-recycling of dissimilar bonded assemblies
  - Recovering of parts for the second-hand market
- Temporary Fixing
  - Machinining
  - Release on command (in flight-space applications)
  - Proof tests
  - Bonding of sensors (on planes, cars, …)
- Safety
  - Vents with restricted access (instead of screwed panels)

Requirements for a debondable structural adhesive

Processing
- Similar to adhesives used for the application
  - No specific tool/machine needed
  - No shelf life or gel time limitation

Life in service
- Similar to standard adhesives
- No anticipated debonding of the parts or depletion of the adhesive strength of the assembly
- Ageing performance and durability should remain unchanged

Debonding step
- Easy and unambiguous triggering (i.e. activation must be simple and reliable)
- As fast as possible (depending on the parts to disassemble)
- Clean substrates surfaces after debonding (easier re-use, recycling of the parts)

Main idea: How to find a compromise between durability and the release function?
INDAR (INnovative Dismantling Adhesives Research)

- Patented process for dismantling of an adhesive joint

- Bonding operation: No modification of shelf life and ageing of the adhesive formulation (H7, etc.)

- Thermal activation: Adapted and localized energy delivery Scale 1 test of industrial energy sources

- Dismantling: Dismantling of scale 1 samples: backlite, PP skin and spoiler bonded on an SMC frame. Clean surfaces after dismantling: easier reuse & recycling.

3 Temperature ranges

Compliant with various adhesive types
INDAR (INnovative Dismantling Adhesives Research)
Development of a structural debondable adhesive for ground testing of GAIA SiC structuree

Ceramic bonded on metal alloy with 2K epoxy (industrial reference modified with INDAR)

<table>
<thead>
<tr>
<th>Shear strength in MPa</th>
<th>Pull out strength in MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>After thermal activation</td>
</tr>
<tr>
<td>Reference</td>
<td>Reference</td>
</tr>
</tbody>
</table>

Training - Transfert
Process qualification and ground testing
INDAR (INnovative Dismantling Adhesives Research)

**Bonds that debond...**
An ecoconception of cars for further environmental friendly dismantling

A European Project supported within the Sixth Framework Programme for Research and Technological Development

Tempered glass bonded on metal with 1K polyurethane (industrial reference modified with INDAR)

<table>
<thead>
<tr>
<th>Pool failure type</th>
<th>Initial</th>
<th>After thermal activation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>Cohesive in adhesive</td>
<td>Cohesive in adhesive</td>
</tr>
<tr>
<td>INDAR</td>
<td>Cohesive in adhesive</td>
<td>Adhesive between adhesive &amp; glass</td>
</tr>
</tbody>
</table>

**Pull out strength in MPa**

- **Reference**
- **INDAR**

PP bonded on SMC with 1K polyurethane (industrial reference modified with INDAR)

<table>
<thead>
<tr>
<th>Shear strength in MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,5</td>
</tr>
<tr>
<td>Initial</td>
</tr>
</tbody>
</table>

- **Reference**
- **INDAR**

**More details: JEC COMPOSITES MAGAZINE – ISSUE #46 – January-February 2009**

- No visual degradation or deformation of the PP substrate
- Clean surface of the SMC substrate
INDAR (INnovative Dismantling Adhesives Research)

Debonding, a challenge not only for adhesives but also for paints!

Fourmi Project (2012-2015)

- Selective removal of the topcoat
- 100% solid wastes
- Easy recovering of the clean and non-damaged epoxy primer

Stripping: slow and dangerous process
BONDING – KEY PROJECTS

Development of Room Cure 2 Component Epoxy Adhesives with Extended Service Temp

Adhesives are polymers: limited high temperature resistance
Generally, the higher the curing temperature the higher the thermal resistance ($T_g$)

However:
- Several components of top class epoxy formulations may not be REACH compliant in the near future
- Many applications allow limited temp curing (<80°C), especially in ASD but wide service temperature range (eg: -90 to +150°C)

Need for better understanding of the interaction between curing conditions, adhesive composition and final thermomechanical properties

New adhesive formulations based on up-to-date components (resins, hardeners, tougheners, etc.)
Development of Room Cure 2 Component Epoxy Adhesives with Extended Service Temp

Relationship between network chemical structure and thermomechanical properties of the epoxy adhesives:

- **Curing conditions**: 23°C / Température
  - impact on thermomechanical properties
- **Components**
  - Resins: DGEBA, novolacs, …
  - Hardeners: polyamidoamines, polyetheramines, …

![Image of chemical structure]

**Study on « Tougheners »:**

- Core-Shell Rubber
- Block Copolymers (CTBN and others)
- Nanosilica

![Image of Lap Shear Strength]

LSS after 7 days @ 23°C

-90°C | 25°C | 90°C
---|---|---
Non modifié | | |
Renforcé | | |
Development of Room Cure 2 Component Epoxy Adhesives with Extended Service Temp

**Example of Results**

- **Curing conditions**: 23°C / Température (<80°C)
- **Gel Time >60min @ Room Temp**
- **Typical peel resistance >50N/cm @ Room Temp**
- **LSS > 10MPa between -70 and +150°C (on chemically etched 2024 Al)**
BONDING – KEY PROJECTS

COMPOCHOC (19th FUI Call)

Laser Shock NDT
Generation of localized traction loads
- Quantitative NDT
- Detection of kissing bonds

Experiments
1. Identification of debonding levels
2. Characterization of the assembly response

SIMULATIONS
1. Validation of models
2. Complete understanding and control of phenomena

OPTIMISATION
1. Definition of optimum shock configurations per assembly
2. Definition of laser parameters

Traction
- Strong interface ➔ No damage
- Weak interface ➔ Interface failure

Shock Wave
Free Surface
CONCLUSIONS

BONDING: *a key technology for joining of dissimilar materials*

But new assemblies need to optimize synergies of materials benefits (strength, lightness, conductivity, fatigue resistance, etc.), *adhesives needs to be multifunctionnal*

Stronger regulation pressure on materials manufacturers, especially adhesive formulators. Risk of *obsolescence of old high performance formulas* in the near future

More regulatory pressure on goods manufacturers regarding end of life

- Needs for recycling, especially new and widespread dissimilar assemblies
- Easier recovery/maintenance of parts is targeted to extend product life span

Debonding on command gives an open choice to engineers and designers for materials assembling: adhesive may be considered for applications where lack of reversibility is a No-Go

*In a few words, future multifunctionnal structural adhesives will bring more service performance/reliability and complete loss of adhesion by the push of a button!*