Adhesive selection via an interactive, user-friendly system based on Symbolic AI

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Adhesives

widely used in industry

Not 1 adhesive suitable for all applications

Adhesive selection = crucial step in design process

Traditionally done by adhesive expert = time consuming + labor intensive process
Support tools

Websites

- Requires much manual work
- Limited functionality

Personal assistance adhesive suppliers

- Contact suppliers via contact form/phone
- Receive personal response

- Time consuming
- Only brand specific adhesives
- Takes couple of days

Expert systems

- Decision trees
- Selection tables
- Rule based expert systems

- Low maintainability + user unfriendly
- Limited expressiveness: complex relations not considered
- Limited number of adhesives / substrates

Our approach: Knowledge-Base System

Knowledge Base \[\leftrightarrow\] Multi-purpose reasoning engine \[\leftrightarrow\] User interface

**FO(·)**

- Extension of First-Order logic
- Very expressive, can capture everything
- Readable for people with engineering background
- Contains the knowledge of the domain experts
- **Formal** description of the knowledge: if expert leaves, knowledge is kept!

**IDP-Z3**

- Reasoning on knowledge
- Powerful and efficient
- Knowledge can be **re-used** for multiple purposes

**IDP web interface** (Interactive Consultant)

- Generic view of FO(·)
- User-friendly interaction with IDP-Z3
- Explainable!

1. \[\text{MaxAllowedStress} = \frac{\text{Load}}{\text{BondingArea}}\]
2. \[\text{MinBondStrength} \leq \text{BondStrength}\]
3. \[\text{AdhesiveFamily} \in \{\text{RadiationCuringAcrylates}\} \Rightarrow \text{SAUVTransparent} \lor \text{SBUVTransparent}\]

- Stress = Load / Area
- Bonding strength of the adhesive should be higher than the min required strength for the design
- For radiation curing acrylates: at least one of the two substrates should be UV transparent, to ensure proper curing.
1. Creation of knowledge Base:
   • Via 3 knowledge articulation workshops with 4-6 domain experts
   • 21 adhesive + 11 substrate parameters

2. Integration in interactive consultant tool
Interactive adhesive selector tool with

- 21 adhesive families
- 55 specific adhesives
- 31 substrate families
Adhesive selector

• In the interface, **any of the parameters** can be set

• The **consequences** are automatically derived and shown!

• The system can **explain** these consequences, increasing user-friendliness

• Tool is multi-purpose:
  ➢ Find list of suitable adhesives
  ➢ Find cheapest/strongest/most flexible adhesive
  ➢ Verify suitability of pre-owned adhesive
  ➢ Find a second substrate
  ➢ Explain *why* an adhesive is not suitable
  ➢ ...

![Adhesive selector interface](image)
Benchmarking

- Test industrial tool on industrial relevant case
- Compare resources + output adhesive expert with + without tool

Requirements

- Min. shear strength: 11 MPa at room temperature
- Dimensions bondline: 4842 mm x 202 mm
- Good shock + impact resistance
- Desired bondline thickness: 5 mm
- Temperature resistance in operation: -40°C till +80°C
- Range of allowable application temperatures: 18°C to 30°C
- Min. potlife of 60 min
- Max. time till handling strength 12h
- No oven curing possible
Results

Adhesive expert

1. Reasons on possible adhesive families
2. Suppliers of industrial adhesives are contacted
3. Technical datasheets compared
4. Make final selection

Selection tool

1. Fill requirements in selection tool
2. IDPs propagation inference performed after each value
3. Make final selection

MMA: Plexus MA 560-1

3 h

5 min

• Significant reduction in time to find adhesive
• Assumes significant large database of adhesives for selection tool
• Full market study not performed by adhesive expert
Future work

- Extend KB with more adhesives + substrates $\rightarrow$ automatic datasheet parsing

- Validation of selector tool on more industrial relevant use cases

- Convert KB to cDMN, a novel representation method which aims at being user-friendly

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<thead>
<tr>
<th>U</th>
<th>Support</th>
<th>MinElongation</th>
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<tr>
<td>1</td>
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<td>$0.5 \times \frac{\text{deltaLength}}{\text{BondThickness}}$</td>
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<tr>
<td>2</td>
<td>fixed</td>
<td>$\frac{\text{deltaLength}}{\text{BondThickness}}$</td>
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Conclusions

• Adhesive Selection knowledge was captured in FO(·) KB

• IDP-Z3 as reasoning engine & Interactive Consultant as interface

• Adhesive selector is multi-purpose: knowledge can be re-used

• Tool is sufficiently performant

• Tests on industrial use case showed potential
Thank you!

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