Session: Processing
Presentation by: Erwin Honcoop, *Croda Smart Materials*

Title: **Biobased sound and vibration-reducing materials in railway systems**

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Curriculum:
Erwin Honcoop is Research & Technology Specialist Smart Materials & Antimicrobial Technology within Croda.
He is a science graduate with specialization on polymer chemistry.
In addition, he has completed a post-doctoral course in Coating Technology from the foundation of Polymer Technology in the Netherlands and holds a degree on Coating Technology.
Worked in the industry as R&D development chemist and Application / Technical service specialist in Europe, Asia and US.

Abstract:
Polyurethanes have been used for many years to produce high-performance materials.
One of the reason the polyurethanes are used in sound and vibration reducing materials like railway fastening systems.
These systems based on isocyanates require special attention to occupational safety when being used. Another driver is the search for environmentally friendly systems
Taking this as a background, a project between Wageningen Food & Biobased Research, Edilon)(sedra and Croda was designed to develop a new system preferably from biomass.

Several potential alternatives for isocyanate chemistry were evaluated. Final elastomer performance has been studied and compared to the currently used polyurethane elastomers. A system has been developed in which no isocyanate is used and contains bio-based polyols. The developed system is currently being optimize in a way that we can meet all the specific mechanical requirements.

Bio based sound and vibration-reducing materials in railway systems

BPM MAGIC

Innovation you can build on™

WAGENINGEN UNIVERSITY & RESEARCH

edilon)(sedra

CRODA

BPM – Magic project team

WAGENINGEN UNIVERSITY & RESEARCH

- Rolf Blaauw
- Willem Vogelzang
- Rutger Knoop
- Guus Frissen

edilon)(sedra

- Gerrien van der Houwen
- Joost Kerkhoven
- Sfefan Koteris

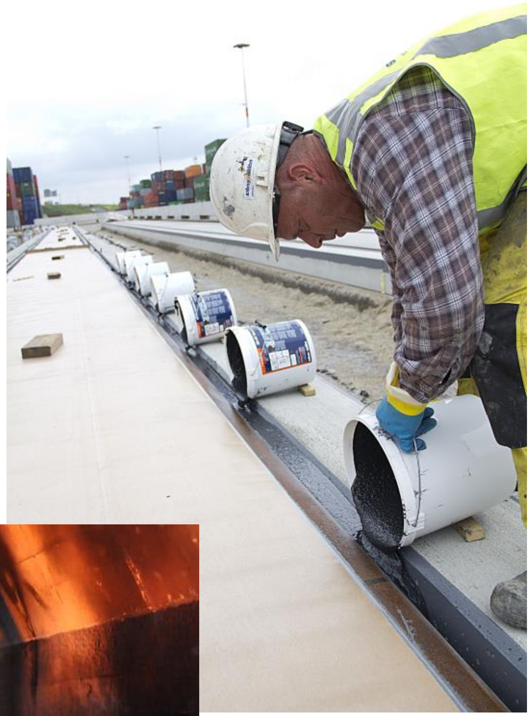
CRODA

- Hans Ridderikhoff
- Erwin Honcoop

Current state of technology in railway fastening

- Polyurethane elastomers
    - Mixed on site
    - 2 component system

- Market demand and future
    - Polyurethanes are petroleum based: trend to go bio based
    - Safety worker
        - Isocyanates
        - Amines
    - Safety during calamities
        - Formation of toxic gases.



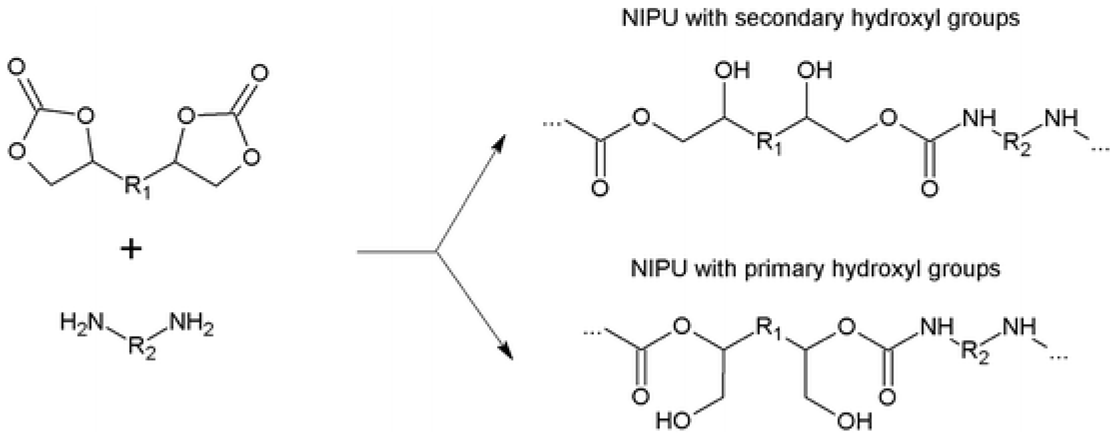
Project objective

- Develop new resins from biobased materials which exhibit elastomeric properties in line with the current polyurethane system.

- Preconditions:
  - Adhesion to concrete, steel, bitumen. Preferably without primer
  - Non-hazardous labelling of the components (only GHS05 & GHS09)
  - Renewable min 80% (if economically viable)
  - Mechanical & physical performance.
    - Pourability
    - Elasticity
    - Moisture resistance
    - reactivity
  - Price

Available Chemistries

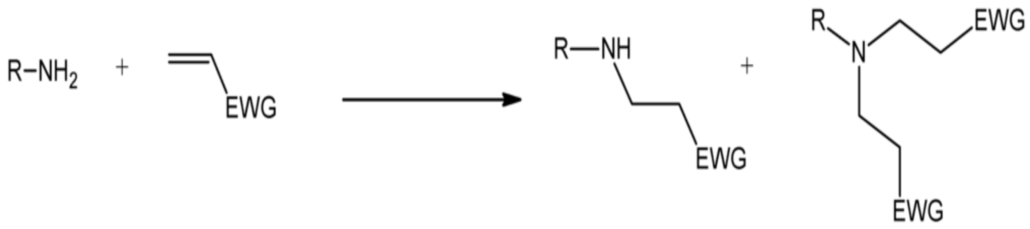
- Literature / market research
  - NIPU
    - Reaction carbonate + polyamines
    - Croda’s Dimerdiamine
  - Aza-Michael addition polymer
    - Reaction polyfunctional acrylate + polyamines
    - Croda’s Dimerdiamine
    - Acrylated epoxidised soybean oil (AESO)



- Avoiding above isocyanate based prepolymers

  Acrylated oleochemicals

  Biobased polycarbamates and aldehydes



Aza-Michael addition polymer

- Screening the opportunities for the Aza-Michael addition curing
  - Acrylated epoxidised soya oil (AESO) + dimerdiamine (DDA)
    - Elastomer : sticky, fragile due to blend ratio → elastomer : non sticky
  - Range of high functional acrylates + dimerdiamine

  - First mechanical testing: Tensile properties

	Stiffness (MPa)	Tensile strength (MPa)	Elongation (%)
Reference (target / including fillers)	2.75	> 1	> 150
AESO / DDA	7-8	1.1	16
High functional acrylate / DDA	15	1.4	11

Back to the drawing board

- Pros and cons of the different curing chemistry
  - NIPU literature
  - Aza-Michael experiments

	NIPU	Aza-Michael	comments
Reactivity	+/-	+	
Viscosity reactants	+/-	+	Carbonates often solid
Availability reactants	-	+	Limited range carbonates
Toxicity	+/-	+/-	Polyamines (labelling)
Material properties	+	+/-	Aza-Michael : low elongation at break

- Aza-Michael seems more promising → need to improve the properties

Improving the mechanical properties Aza-Michael addition polymer

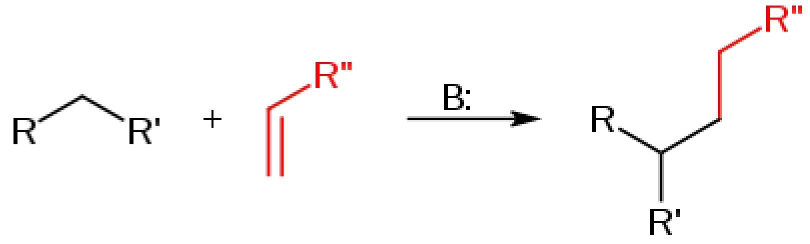
- Different combinations acrylates and diamines
  - Diacrylates / triacrylates / acrylic resin / AESO
  - Dimerdiamine / Jeffamines / cyclic diamines

	Stiffness (MPa)	Tensile strength (MPa)	Elongation (%)
Reference (target / including fillers)	2.75	> 1	> 150
Acrylic resin / DDA	0.3	0.1	55
Acrylic resin & AESO / DDA	7	1.1	20
Acrylic resin & AESO / DDA & Jeffamine	3	0.6	20

- AESO helps with the stiffness but…… still below the target properties
- Literature check for inspiration.

New curing route *carbon*-Michael addition

- *Carbon*-Michael addition
  - New product(s) synthesised based on bio based polyols
  - Curing the acrylic resin with the new products



	Stiffness (MPa)	Tensile strength (MPa)	Elongation (%)
Reference (target / including fillers)	2.75	> 1	> 150
Acrylic resin / product A	1.4	1	141
Acrylic resin / product B	1	0.5	124

- Range of ratios have been screened to see the effect on properties

Influence of fillers on the *carbon*-Michael addition based elastomer

- *Carbon*-Michael addition based elastomer
  - Rubber granules
  - $CaCO_3$

	Stiffness (MPa)	Tensile strength (MPa)	Elongation (%)
Reference (target / including fillers)	2.75	> 1	> 150
Acrylic resin / product A	1.4	1	141
Acrylic resin / product A + 20 wt% rubber	2.3	0.6	56
Acrylic resin / product A + 20 wt% $CaCO_3$	1.9	1	155
Acrylic resin / product A + 30 wt% $CaCO_3$	2.6	1.2	173

Carbon-Michael vs AZA-Michael addition

- *Carbon*-Michael
  - Faster
  - Lower stiffness, tensile strength slightly lower but high elongation at break
  - Addition of $CaCO_3$ improves mechanical properties
  - New product expected to be more “label-friendly”

- Next improvement targets
  - Adhesion to substrates
  - Tear strength
  - Increase renewable content (if economically viable)

Latest results

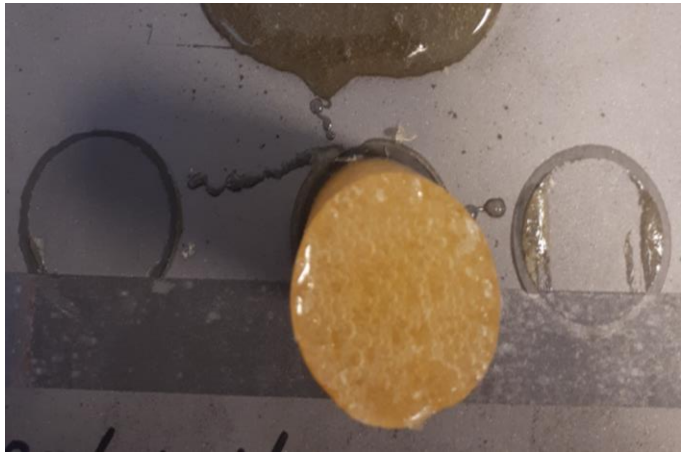
- *Carbon*-Michael addition based elastomer

	Stiffness (MPa)	Tensile strength (MPa)	Elongation (%)	Tear strength (N/mm)
Reference (target / including fillers)	2.75	> 1	> 150	> 12
Acrylic resin / product A	1.4	1	141	9.7
Acrylic resin / product C	9.4	2.1	82	19.1
Acrylic resin / product D	4.4	1.4	47	tbd
Acrylic resin / product E	31	2.7	66	32
Acrylic resin / product A+C	tbd	tbd	tbd	20.3

- Going in the right direction with interesting properties

Adhesion of the elastomer

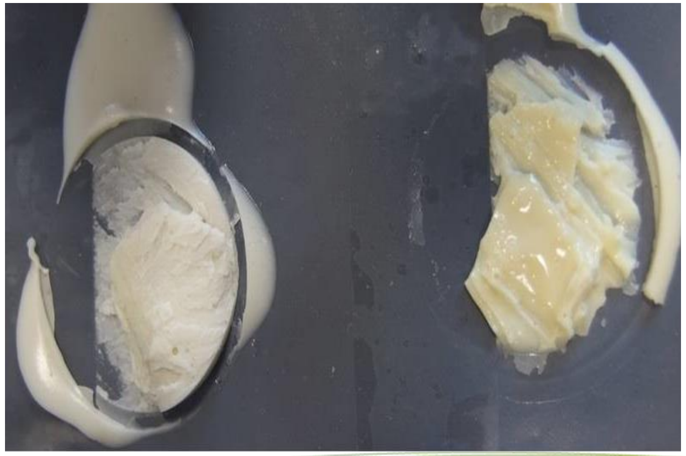
- Aza-Michael based elastomer
  - Adhesive failure on steel



- *Carbon*-Michael based elastomer

  Cohesive failure

  Formulation looking still “lumpy”
  - Compatibility?



Conclusions & Next steps

- Elastomer has been developed free of isocyanates with mechanical properties close to a polyurethane elastomer

	Stiffness (MPa)	Tensile strength (MPa)	Elongation (%)	Tear strength (N/mm)
Reference (target / including fillers)	2.75	> 1	> 150	>12
Acrylic resin / product A	1.4	1	141	9.7
Acrylic resin / product A + 20 wt% $CaCO_3$	1.9	1	155	tbd

- Optimisation of the formulation
- Check IP
- Investigation of a possible field test
- Investigation of the use of *carbon*-Michael addition in non elastomeric applications

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- Hans Ridderikhoff
- Erwin Honcoop