Polyurethane resin solutions for wind turbine blades

Technical information for the Americas,
Europe, Middle East and Africa

covestro

Polyurethane resin solutions for wind blades

Baydur® and Desmodur® high-strength infusion resin system

Our two-component polyurethane resin system composed of **Baydur® 120V2** and **Desmodur® 44CP23** is specially designed for the fabrication of wind turbine rotor blades by the vacuum infusion process. This system offers the following key benefits:

- **Very low viscosity at room temperature**
- **Fast curing at elevated temperature**

A polyurethane resin system for wind blades

Application

Very low viscosity resin system for processing of glass and carbon fibers, suitable for the production of components with intended exposure to high static and dynamic load.

Advantages

The low viscosity and long pot-life make this resin system especially advantageous for the vacuum infusion process, including parts with complex geometry and long infusion paths.

Characteristic	Specification
Resin type	Two-component polyurethane resin system: Polyol – **Baydur® 120V2** and Isocyanate – **Desmodur® 44CP23**
Purpose/Application	Specially designed for the vacuum infusion process, in particular for the fabrication of rotor blades for wind turbines
Features	Very low viscosity at room temperature Fast curing at temperature above 80 °C
Conditions for processing	Between 15 °C and 35 °C

Appropriate industrial safety regulations must be observed and followed for the handling of polyurethane resins and their components.
(See ISOPA's Walk the Talk guidelines: https://www.isopa.org/product-stewardship/walk-the-talk/)

Resin specification

Liquid mixture of **Desmodur® 44CP23** and **Baydur® 120V2**

Property	Unit	Desmodur® 44CP23	Baydur® 120V2	Mixture	Standard	Remarks
Density	g/cm³	1.23 ± 0.05	1.03 ± 0.05	1.11 ± 0.05	Internal	at 25 °C
Viscosity	mPas	160 ± 50	35 ± 10	60 ± 10	Internal	at 25 °C
NCO content	% by wt.	30.8 ± 1.0	N/A	N/A	Internal	
OH value	mg KOH/g	N/A	357 ± 10	N/A	Internal	
Mixing ratio	by weight by volume	88 74	100 100	Index: 102		

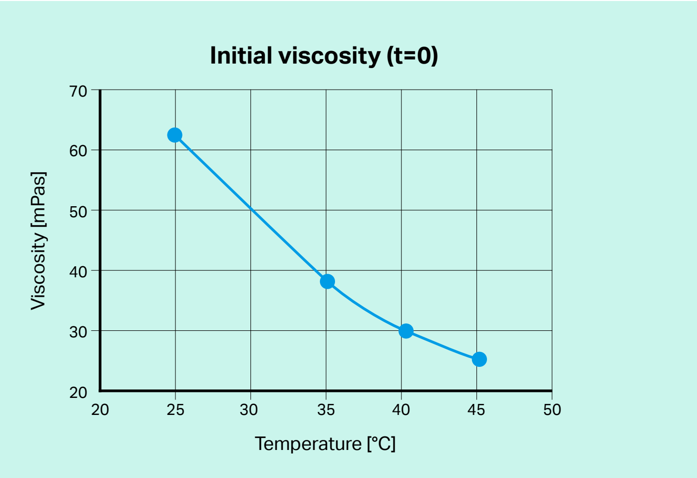
Isocyanate component: **Desmodur® 44CP23**
Polyol component: **Baydur® 120V2**

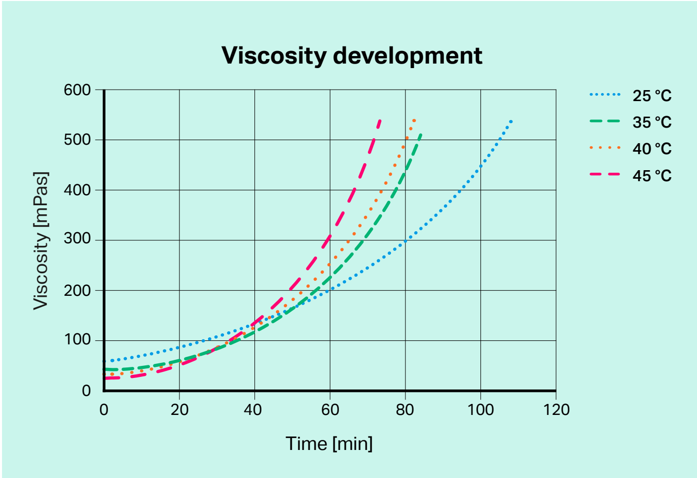
Viscosity of the mixture

Isothermal, at different processing temperatures

Processing viscosity

The initial viscosity of freshly mixed resin ranges from approximately 38 mPas at 35 °C to approximately 62 mPas at 25 °C. Higher temperatures reduce the viscosity of the mixture but shorten its pot-life. The viscosity of the mixture builds up with time. The resin cures at elevated temperatures, rapidly reaching its gel point.

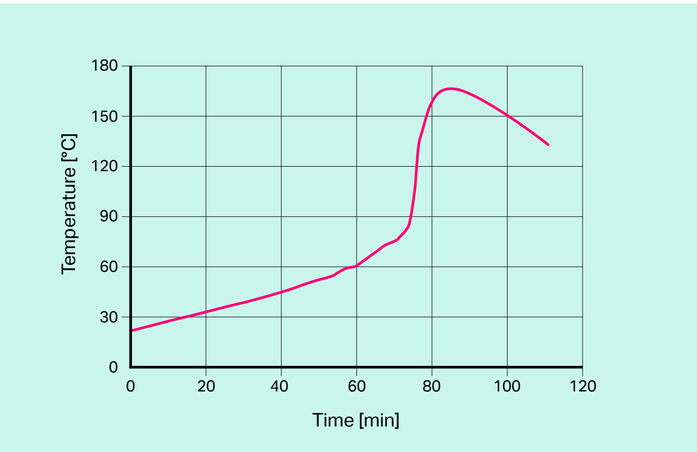




Viscosity measured with Brookfield DV2T viscometer with small sample adapter (approximately 7 g of resin).

Exothermic heat and temperature development

Temperature increase for a sample of resin mixed in an open bucket



The temperature of the resin increases slowly after mixing due to the exothermic nature of the polyurethane reaction. The typical temperature development of the resin, when mixed in an open bucket (non-adiabatic) allows for a long pot-life and avoids critical hot spots during infusion and curing.

Example:

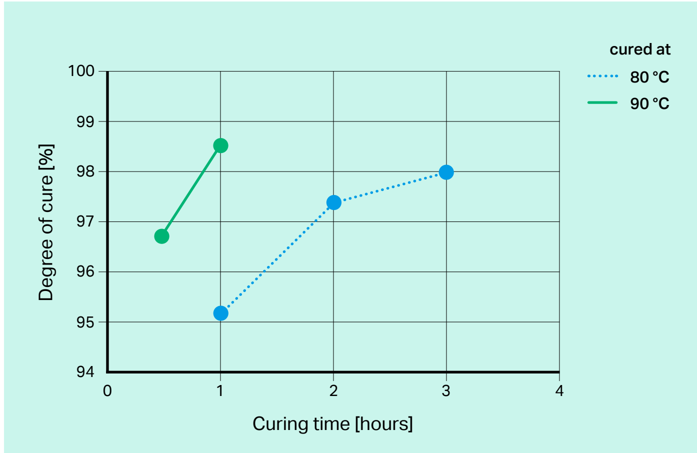
- Sample size: 1 kg
- Bucket volume: 1.5 l
- Initial/external temperature: 23 °C
- Max. temperature: 168 °C at 85 min

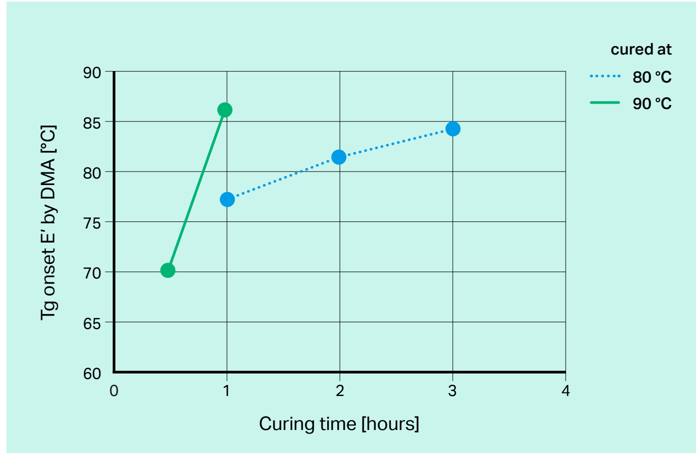
Cure and evolution of mechanical properties

Degree of cure and Tg development of the resin

Degree of Cure (DOC) by DSC: The determination of the degree of cure using DSC may be based on the relation between the residual enthalpy of a cured material to the total enthalpy of the resin system.

Tg by DMA: DSC is widely used for Tg-determination in industry, however Tg-determination of the PU-infusion resin by DSC is difficult because the transition is very wide. Instead, Tg-determination by DMA is possible.





Note: These techniques were implemented by Covestro for characterization of the polyurethane resin.
For additional support about materials properties and characterization techniques, please contact our technical experts.

Directions for processing

Drying

Moisture in the resin components and in the reinforcing material must be kept at a minimum as this may cause foaming of the resin. Drying of the reinforcing material is a crucial step that may be achieved by several methods including vacuum, heating and by use of drying agents.

Degassing of the resin: The resin components must be degassed individually before mixing, or directly after mixing under <10 mbar vacuum and constant stirring for approximately 15 minutes. The temperature of the resin while degassing may not exceed 30 °C.

Drying of the reinforcing material and the lay-up: The reinforcing material and construction lay-up must be thoroughly dried before infusion. Typical examples of drying an 80-layer glass reinforcement lay-up of 1.7 m² may include:

- **Vacuum drying:** After lay-up and bagging, vacuum of <10 mbar and temperature of 35 °C may be applied to the entire lay-up for at least 90 min to dry the reinforcement. It is suggested to keep the temperature no lower than 30 °C and no higher than 40 °C to minimize the time of drying and eliminate any delay before infusion (i.e., waiting time for cooling).

- **Using a drying agent:** After lay-up and bagging, vacuum may be applied to the entire lay-up to dry the reinforcing material. To accelerate the process, a drying agent like nitrogen or dry air may be introduced into the lay-up via a VAP® membrane (vacuum applied via resin canal). Drying of the lay-up is typically complete after 45 min at 25 °C and 10 Nl/min of nitrogen.

Note: Covestro's polyurethane resin is not particularly designed for working with hygroscopic components like balsa wood.
For additional support regarding materials compatibility and processing, please contact our technical experts.

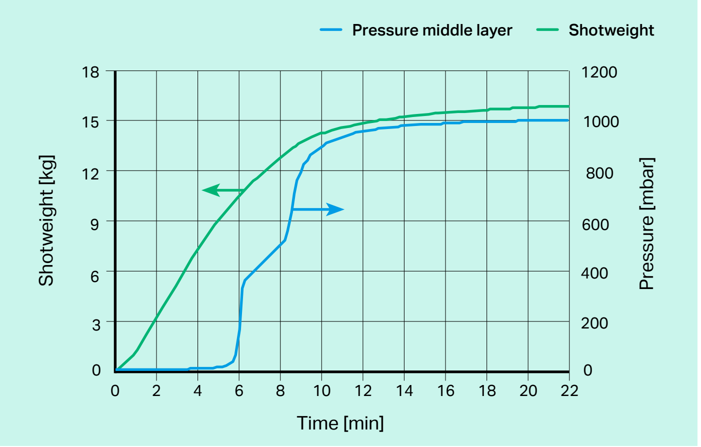
Infusion

Infusion may start directly after drying the reinforcement lay-up. The resin components must be thoroughly degassed under vacuum before processing to avoid formation of gas bubbles in the composite. The specified mixing ratio must be observed as exactly as possible, and the components must be fully mixed before infusion.

Conditions for infusion:
- Temperature of mixed resin: Min. 15 °C and max. 35 °C
- Temperature of lay-up (after drying): Max. 35 °C

Example: Infusion of a dry 60-layer UD-glass reinforcement lay-up equivalent to a spar cap segment of 1 x 0.5 m^2

Temperature of the resin: 25 °C
Temperature of the lay-up: 35 °C
Pressure in the lay-up: <10 mbar
Infusion pressure: atmospheric
Infusion time: 23 min



Note: Covestro recommends a closed direct infusion process with the use of suitable equipment (i.e., direct infusion machine). For additional support regarding equipment and processing, please contact our technical experts.

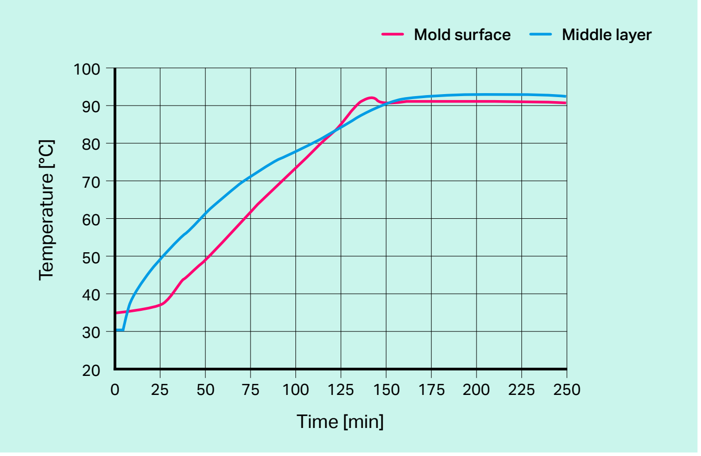
Curing

Due to its relatively low exothermic heat, curing of Covestro's polyurethane resin can start directly after infusion. The following curing conditions ensure high degree of cure and therefore the best mechanical properties offered by the resin.

Conditions for curing:
- Curing temperature (target): between 80 °C and 100 °C
- Heating rate: 0.5 – 1 K/min
- Curing time (after target temperature is achieved):
  at 80 °C ➔ min. 3 hours
  at 90 °C ➔ min. 1 hour

Example: Curing of an infused 60-layer UD-glass reinforcement lay-up equivalent to a spar cap segment of 1 x 0.5 m^2

Target temperature: 90 °C
Heating ramp: 0.5 K/min
Curing time: 2 hours



Note: Covestro recommends natural cooling and demolding below 60 °C to conserve the mechanical properties and dimensional fidelity of the parts. For additional support regarding processing and material properties, please contact our technical experts.

Neat resin properties

Values for an exemplary sample cured for 3 hours at 80 °C

Property	Unit	Value	Standard
Density, cured	g/cm³	1.209 ± 0.001	DIN EN ISO 1183-1
Volume shrinkage	%	7.38 ± 0.11	DIN EN ISO 3521
Water absorption (after 168 h)	%	0.59 ± 0.02	DIN EN ISO 62
Tensile strength	MPa	80.3 ± 0.2	DIN EN ISO 527-2
Tensile E-modulus	MPa	3441 ± 18	DIN EN ISO 527-2
Tensile maximum strain	%	5.38 ± 0.23	DIN EN ISO 527-2

Property	Unit	Value	Standard
Tensile strength (at -40 °C)	MPa	68.5 ± 7.5	DIN EN ISO 527-2
Tensile E-modulus (at -40 °C)	MPa	4683 ± 77	DIN EN ISO 527-2
Tensile maximum strain (at -40 °C)	%	1.70 ± 0.23	DIN EN ISO 527-2
Flexural strength	MPa	134.6 ± 0.6	DIN EN ISO 178
Flexural E-modulus	MPa	3458 ± 28	DIN EN ISO 178
Flexural maximum strain	%	6.63 ± 0.48	DIN EN ISO 178

These are the properties of one neat resin sample cured for 3 h at 80 °C, measured at ambient conditions, unless stated differently.

Reinforced resin properties

Values for an exemplary sample cured for 3 hours at 80 °C

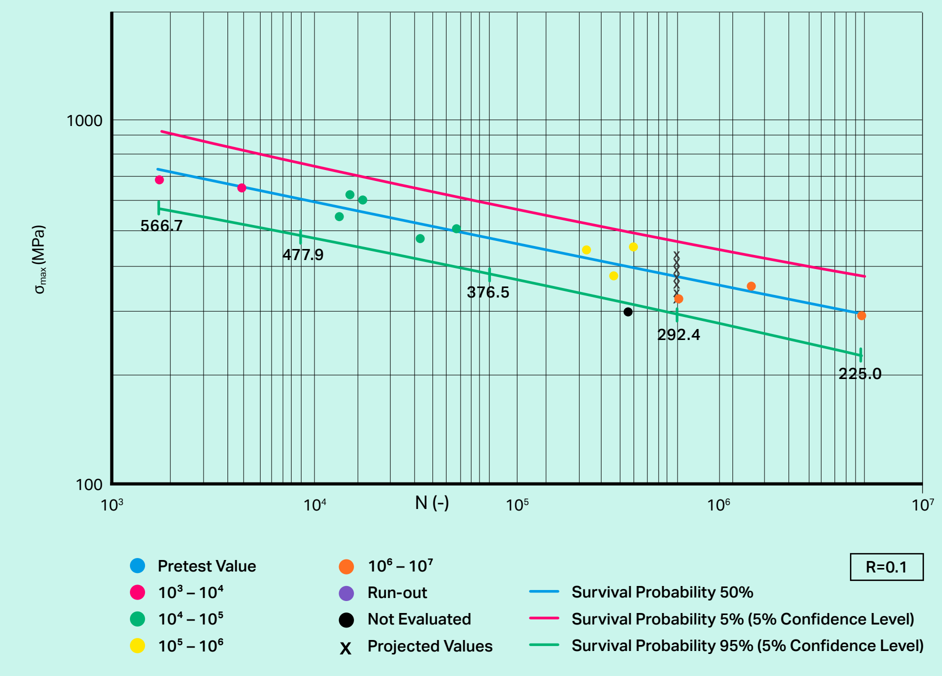
Glass reinforcement: 4 layers of UD E-glass (1200 g/m²)
Carbon reinforcement: 2 layers of UD Carbon Fiber (880 g/m²)

Property	Unit	Glass	Carbon	Standard
Fiber content (weight)	%	73.4 ± 0.1	66.1 ± 1.2	DIN EN ISO 1172 / 2564
Fiber content (volume)	%	57.0 ± 0.1	57.3 ± 1.3	DIN EN ISO 1172 / 2564
Tensile strength 0° to fiber	MPa	1074 ± 50	1688 ± 87	DIN EN ISO 527-5A2
Tensile E-modulus 0° to fiber	GPa	44.4 ± 0.7	119.6 ± 5.5	DIN EN ISO 527-5A2
Tensile maximum strain 0° to fiber	%	2.75 ± 0.09	1.33 ± 0.07	DIN EN ISO 527-5A2
Tensile strength 90° to fiber	MPa	59.5 ± 3.9	–	DIN EN ISO 527-5B
Tensile E-modulus 90° to fiber	GPa	14.4 ± 0.2	–	DIN EN ISO 527-5B
Tensile maximum strain 90° to fiber	%	0.45 ± 0.04	–	DIN EN ISO 527-5B
Tensile strength 90° to fiber (at -40 °C)	MPa	59.7 ± 4.6	–	DIN EN ISO 527-5B
Tensile E-modulus 90° to fiber (at -40 °C)	GPa	16.9 ± 0.4	–	DIN EN ISO 527-5B
Tensile maximum strain 90° to fiber (at -40 °C)	%	0.36 ± 0.04	–	DIN EN ISO 527-5B

These are the properties of one reinforced resin sample cured for 3 h at 80 °C, measured at ambient conditions, unless stated differently.

Reinforced resin properties: Fatigue

Values for an exemplary sample cured for 3 hours at 80 °C



Standard: ISO12107 (R=0.1)
Reinforcement: 8 layers of Ultra fatigue UD E-glass (1166 g/m²)
Fiber content (volume): 52.6 %
(weight): 70 %

σ_{max} @ 10^6 = 369.1 MPa
Slope = 9.4

Forward-looking statements

This brochure may contain forward-looking statements based on current assumptions and forecasts made by Covestro AG.

Various known and unknown risks, uncertainties and other factors could lead to material differences between the actual future results, financial situation, development or performance of the company and the estimates given here. These factors include those discussed in Covestro's public reports, which are available on the Covestro website at **www.covestro.com**.

The company assumes no liability whatsoever to update these forward-looking statements or to adjust them to future events or developments.

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[1] Please see the "Guidance on Use of Covestro Products in a Medical Application" document.

Edition: 2021 · Printed in Germany