TKH- Technical Briefing Note 3
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Industrieverband Klebstoffe e.V.

Dispersion Adhesives

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Contents

Introduction

Until the 1950s, water-based adhesives made of animal or vegetable materials (e.g. bone glues) were commonly used for gluing wood. With the developments in polymer chemistry, these glues were replaced by dispersion adhesives which are primarily based on polyvinyl acetate (PVAc).

1. Characterization of dispersion adhesives

Dispersion adhesives, often also called white glues, are produced by polymerization of vinyl acetate or by copolymerization with other monomers. They are classified as thermoplastic adhesives. Nowadays, modern dispersion adhesives are mostly solvent-free. Some of them contain film-forming agents that are added to adjust the minimum film-forming temperature (MFFT).

1.1 Properties

The most important physical properties of dispersion adhesives are listed in the following table:

Table 1:
Physical properties of dispersion adhesives

Parameter	Measuring method	Unit
Solid content	DIN EN 827	%
pH-value	DIN ISO 976 DIN EN 1245	
Viscosity	DIN EN ISO 2555 DIN EN 12092	mPa*s
Minimum film-forming temperature (MFFT)	DIN ISO 2115	°C

In addition, several application-related properties are important for dispersion adhesives, some of which are also specified in the technical data sheets of the products (see table 2).

Table 2:
Important properties of dispersion adhesives

Parameter	Measuring method	Unit
Open time*	Often divided into open and closed waiting time; usually determined by manual tests under standardized conditions (DIN EN 16556)	Minutes
Curing time	Period of time until a certain minimum strength is reached	Minutes
Minimum pressing time	Pressing time until the required minimum strength is reached under the given conditions	Minutes
Water resistance	Tensile shear strength after exposure to water under standardized conditions (DIN EN 204)	N/mm²
Thermal stability	Bond strength at higher temperatures under standardized conditions (DIN EN 14257)	N/mm²
Creep resistance	Resilience to cold flow under static load (DIN EN 14256)	Days
Pot life (2-component systems)	Application time of 2-component systems after mixing the 2 components	Minutes, hours, days

*The term "open time" used in this Technical Briefing Note is based on a different definition than the official standard EN 923.
Also see TKH Technical Briefing Note 1.

Table 3 below contains the most important European standards for dispersion adhesives.

Additionally, there are several other standards for dispersion adhesives that are applicable in non-European countries. The most important ones are the ASTM standards in the USA and the JIS or JAS standards in Japan.

Table 3:
Important European standards for dispersion adhesives

Standard	Title
DIN EN 204	Classification of thermoplastic wood adhesives for non-structural applications
DIN EN 205	Adhesives – Wood adhesives for non-structural applications – Determination of tensile shear strength of lap joints
DIN EN 14256	Adhesives for non-structural wood applications – Test method and requirements for resistance to static load
DIN EN 14257	Adhesives – Wood adhesives – Determination of tensile strength of lap joints at elevated temperature (WATT 91)
DIN EN 14292	Adhesives – Wood adhesives – Determination of static load resistance with increasing temperature (HRT 92)
DIN EN 16556	Determination of the maximum open time for thermoplastic wood adhesives for non-structural applications

Table 4:
Classification of thermoplastic wood adhesives based on water resistance (DIN EN 204)

Stress group	Storage sequence		Required bond strength
D1	D1-1	7 days storage at standard ambient conditions*	> 10 N/mm²
D2	D2-1	7 days storage at standard ambient conditions*	> 10 N/mm²
	D2-2	7 days storage at standard ambient conditions* 3 hrs storage of test specimens in cold water (approx. 20 °C) 7 days storage at standard ambient conditions*	> 8 N/mm²
D3	D3-1	7 days storage at standard ambient conditions*	> 10 N/mm²
	D3-3	7 days storage at standard ambient conditions* 4 days storage of test specimens in cold water (approx. 20 °C)	> 2 N/mm²
	D3-4	7 days storage at standard ambient conditions* 4 days storage of test specimens in cold water (approx. 20 °C) 7 days storage at standard ambient conditions*	> 8 N/mm²
D4	D4-1	7 days storage at standard ambient conditions*	> 10 N/mm²
	D4-3	7 days storage at standard ambient conditions* 4 days storage of test specimens in cold water (approx. 20 °C)	> 4 N/mm²
	D4-5	7 days storage at standard ambient conditions* 6 hrs storage of test specimens in boiling water 2 hrs storage of test specimens in cold water (approx. 20 °C)	> 4 N/mm²
*Standard climatic conditions: 23 °C / 50 % RH (or 20 °C / 65 % RH)			

1.2 Classification of dispersion adhesives

In Germany, water-based wood adhesives are usually classified according to their water resistance. DIN EN 204 distinguishes between the four stress groups D1, D2, D3 and D4 (see table above).

1.3 EPI systems

A special product group are the so-called EPI systems (emulsion polymer isocyanates), which use approx. 15 % of isocyanate (usually MDI) as a cross-linking or curing agent. These systems, which can be seen as a transition to thermosetting adhesives, usually have very short pot lives and are applied mechanically. Compared to conventional dispersion adhesives, EPI systems achieve a significantly higher resistance to water and heat.
Also see: TKH-Technical Briefing Note 5 EPI-Adhesives

2. Application areas

Dispersion adhesives are widely used in industry, trade and the consumer sector. The following list provides an overview of the most important areas of application.

- Furniture manufacture (indoor use)
  - Veneering of wood and wood-based materials
  - Gluing board joints and block gluing of hardwood and softwood
  - Gluing dowels, frames and bodies as well as other applications of assembly bonding
  - Veneer finishing, e.g. fleece lamination, veneer doubling and fleece impregnation
  - Surface bonding of wood-based materials with HPL, CPL and other suitable coating materials
  - Thermal lamination of wood-based materials with decorative finishing foils or films
- Furniture exposed to moisture (bathrooms, kitchens, outdoor use)
  - For producing furniture and built-in parts for bathrooms, kitchens and other wet areas, it is recommended to use D3 or D4 adhesives.
- Window and door manufacture
  - For producing laminated window scantlings and window corner joints. Special requirements such as heat and water resistance must be observed.
- Installation of parquet and laminate
- D3 adhesives should preferably be used for installing parquet and laminate flooring (e.g. tongue-and-groove bonding).
  - Protection of joints against moisture

2.1. Other applications

- Stairs and banisters made of wood, interior finishing work with wood-based materials
- Bonding with D4 adhesives for outdoor use, but only with appropriate surface protection. The adhesive joints must not be exposed to the weather.
- Manufacture of plasterboards
- Repair bonding of wood-based materials
- Hobby and do-it-yourself woodwork

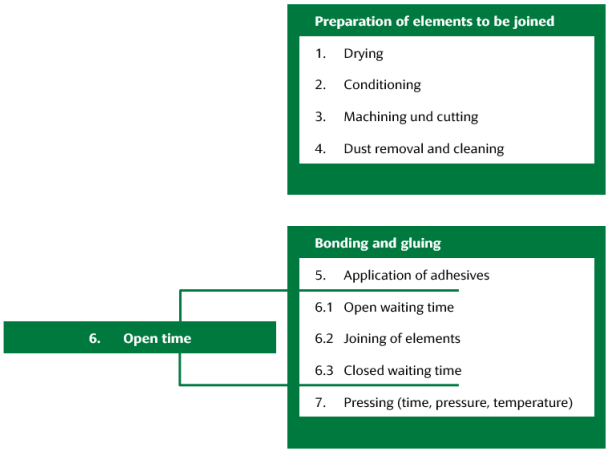
3. Application systems and methods

Due to the large variety of possible applications, there are also a number of different application methods for dispersion adhesives.

Possible applications	Adhesive application system / Manual application method	Automatic application
Dowel bonding	- Application by bottle into the dowel hole - Application by pressure device	- Automatic dowel injection by means of a dosing unit (pressure device)
Mortise-and-tenon joints	- Finishing spatula perforated on both sides - Pressure device with mortise/tenon roller - Chain wheel - Paint brush, trowel	- Automatic dosing unit with a finishing spatula perforated on both sides
Manufacture of window scantlings	- Paint brush - Trowel - Pressure tank with finishing spatula - Pressure tank with bead applicator - Pressure tank with roller	- Roller applicators - Nozzle applicators
Glue-laminated panels	- Paint brush - Multi-nozzle blade - Roller applicator - Pressure tank	- Roller applicators - Nozzle applicators
Surface bonding, e.g. bonding of films, veneers and decorative panels	- Notched trowel - Glue applicator, e.g. by the company GUPFO	- Roller applicators
Frame gluing, e.g. tables, chairs etc.	- Glue bottle - Paint brush	- Nozzle applicators

4. Gluing of wood and wood-based materials

The following illustration provides a schematic overview of the steps in the gluing process:



4.1. Drying process / wood moisture

Being a natural product, wood absorbs moisture and releases it back to the environment. The swelling and shrinking behaviour of wood depends very much on the changes in ambient moisture. This fact plays a significant role for the gluing of solid wood in particular and must therefore be duly considered.

Air-dried wood has a moisture content of approx. 15 - 20 %, depending on the climatic conditions. If the wood is used inside buildings in the living area, it is assumed to have a moisture content of approx. 8 %. This is also the moisture content often referred to in technical data sheets. Wood with a higher moisture content requires a longer pressing time, since it takes longer for the wood to absorb the water contained in the dispersion.

4.2. Wood conditioning

It is important that wooden parts to be joined always have the same moisture content with a max. tolerance of 2 %. Otherwise, the differences in shrinkage and swelling during equilibration of the moisture content can result in stresses that not only affect the glue joint, but can also cause deformation of the workpiece. To avoid this, the workpieces must be conditioned for a sufficiently long time before gluing (temperature and moisture equilibration). The minimum time required for conditioning also depends on the type of workpiece and its dimensions.

Before the start of bonding, the wood moisture should always be determined with the help of suitable measuring devices.

In addition to conditioning the wood, it is also necessary to observe the minimum film-forming temperature (MFFT) of the adhesive. MFFT is the minimum temperature required for dispersions to form a homogeneous film during the curing process.

During application, it must be ensured that ambient, adhesive and workpiece temperature comply with the specifications in the technical data sheet. If the temperature falls below the MFFT, no film of sufficient thickness will form. The dispersion will only dry and form an inhomogeneous, possibly flaky white layer that will fail to develop the required strength.

4.3. Machining and cutting

The machines and tools must be adjusted so that a good fitting accuracy and surface quality is achieved during machining. Plane marks and blunt or worn tools can lead to fitting inaccuracies and thus also result in poor glue joints. Burnt cutting edges caused by blunt tools prevent the proper curing of the adhesive, thus reducing the strength of the bond.

The wood should be glued as soon as possible after machining or cutting so that the surfaces cannot change again. This is particularly important for types of wood that contain resins or oils such as teak, palisander (rose-wood) and rubberwood.

4.4. Dust removal / cleaning

To achieve optimum bonding strength, it is necessary to remove any release agents and contaminants before joining the workpieces. The easiest way to remove dust from the surfaces is either by vacuuming, brushing or wiping it off with suitable cleaning agents.

4.5 Adhesive application

The viscosity of dispersion adhesives has been adjusted to allow the use of different application methods. The even and uniform application of the adhesive is essential. The amount of adhesive applied depends on the absorbency and fitting accuracy of the woods or workpieces to be joined and is usually between 100 and 250 g/m². For some types of wood, one-sided application is sufficient. Double-sided application is, however, recommended when working with hardwood or woods that contain resins and oils.

In any case, it is important to follow the manufacturers' recommendations for their products.

4.6. Open time

The wet time or open time is the period during which wet bonding is possible after the adhesive has been applied, i.e. the time between adhesive application and the start of pressure application.

The open time includes both the open and the closed waiting time. It depends, among others, on the thickness of the applied layer, the absorbency of the parts to be joined, the ambient and workpiece temperature, as well as on the air humidity and air speed. The standard times are indicated in the technical data sheets for the individual products.

4.6.1. Open waiting time

The open waiting time is the time from the application of the adhesive to joining the workpieces or parts. Some manufacturers refer to the open waiting time as "open time". Since the definition here is not entirely clear, we recommend contacting the adhesive manufacturer in case of doubt to clarify if the open time in the technical data sheet is identical with the open waiting time, or whether it has been defined as the sum of open and closed waiting time.

4.6.2. Joining the workpieces

The workpieces must be joined within the open time. It must be ensured that the surfaces are free of dirt or other contaminants.

4.6.3. Closed waiting time

The closed waiting time is defined as the time after joining the workpieces and the start of heat and/or pressure application. Heat and/or pressure are applied to initiate the crosslinking or curing process. The closed waiting time is part of the open time.

4.7. Pressing process (time, pressure, temperature)

The minimum pressing time depends on the type of wood and the pressing temperature. Hardwood and wood types that contain resins or oils require longer pressing times.

When increasing the temperature, the minimum time required for pressing is decreased. The applied pressure must be sufficiently high to ensure the necessary joint fit. The specific pressure is between 0.2 and 1.5 N/mm², depending on the type of wood. If the pressure is too high, the adhesive may soak into the substrate and then result in bonding failures. Temperature, pressing time and the required pressure are usually specified in the technical data sheet.

5. Fault analysis

The following table shows examples of how to avoid or troubleshoot bonding failures.

Appearance	Cause of failure	Correktive action
Glue joint is clearly visible. If the parts to be joined are uneven, the cured adhesive is afterwards partially visible as a glossy film.	Pressure too low. Insufficient fitting accuracy of the parts to be joined.	Increase the pressure. Improve the fitting accuracy of the surfaces to be joined.
Joint opening. In some areas, the adhesive film has been pulled apart.	Pressing time too short.	Increase pressing time and temperature. Reduce the moisture content of the wood if possible.
Adhesives that normally form a transparent film have a white color after curing.	Temperature below MFFT.	Adjust the temperature of the adhesive, the material and the room to the MFFT.
Joint opening. Insufficient wetting of the parts to be joined.	Insufficient amount of adhesive applied.	Increase the amount of adhesive until the adhesive runs out of the joint over its entire length.
Joint opening. In some areas, the adhesive film has been pulled apart. This mostly happens with high-frequency bonding.	The temperature is too high.	Lower the temperature. Decrease the HF time. Increase the cooling time.
Joint opening. The adhesive does not cure quickly enough. The pressing time has become longer.	Wood moisture is too high.	Reduce the wood moisture. Increase the pressing time.
Joint opening. Partially no wetting. Discoloration of the adhesive.	The wood contains oil and/or resin.	Only join freshly planed wood. Treat the surfaces with suitable cleaning agents (follow the safety instructions). Carry out test bonds.
Joint opening. One-sided application does not result in sufficient wetting of the second part to be joined.	Open time exceeded.	Proof of wetting can be done by an iodine test. Observe the open time. Increase the amount of adhesive. Avoid air movement around the open glue joint. Protect the open glue joint from thermal stress.

6. Discoloration

Wood discoloration, i.e. a change in the natural color of the wood, can have different causes.

Often, the discoloration is caused by fungal attack, e.g. by blue stain, brown rot or white rot fungi. However, it can also be due to other physiological or chemical influences, including e.g. weathering, exposure to water, drying, contact with metals or metal ions (especially iron or iron ions), UV radiation or a change in pH value.

Furthermore, discoloration can occasionally be caused by natural wood ingredients such as humic acids and tannins, especially when using heartwood.

The risk of unwanted wood discoloration can be minimized during application by avoiding contact with iron, selecting a suitable adhesive and observing the adhesive manufacturer's instructions.

Useful information on this topic can also be found on the homepage of Thünen-Institut für Holzforschung (Institute of Wood Research) in Hamburg. Please refer to http://www.thuenen.de/.

7. Environmental and safety aspects

7.1. Emissions from dispersion adhesives

Due to their composition, modern dispersion adhesives have very low emissions. These emissions are caused to a lesser extent by residual monomers and additives in the ppm range. Primarily, they are caused by the film-forming additives that are required for adjusting the MFFT. Their content may account for up to 3 % of the adhesive. But due to their low volatility, there are hardly

any measurable emissions from the finished workpiece. In addition, the glue joints are covered for the most part.

7.2 Safety aspects

All safety aspects involved in the use of an adhesive are addressed in the manufacturer's safety data sheet.

7.2.1 Biocidal agents

Vinyl acetate polymers and copolymers in aqueous systems are inert and chemically inactive from a biological point of view. Health-related issues can, however, arise from the use of preservatives in such systems. These preservatives are added to protect the adhesives from microbiological contamination (bacteria, fungi, yeasts).

Most preservatives (biocidal agents) are sensitizing substances (H317 "May cause an allergic skin reaction" or EUH208 "Contains <name of sensitizing substance>. May produce an allergic reaction"). Their dosage is therefore based on the principle: As much as necessary and as little as possible (see Argumentationspapier IVK). It is possible that an allergic reaction is triggered in people who are already sensitized. Wearing protective gloves can, however, help to virtually eliminate this risk.

Other additives as well as the residual monomer content of the polymers are of minor importance according to the current state of knowledge.

7.2.2 Two-component systems

7.2.2.1 Metal salt hardener

Metal salts are generally hazardous substances. It is therefore mandatory to follow the instructions for safe handling prescribed by law.

See the current safety data sheets issued by the adhesive manufacturers.

7.2.2.2 Isocyanate-based curing agents

Whether or not health-related issues need to be assessed depends on the curing agent used, its monomer content/concentration and the application conditions.

Normally, HDI- or MDI-based curing agents are used.

Isocyanates are reactive compounds. Due to their toxicological properties, it is necessary to take their irritant effect – above all on the skin, the eyes and the respiratory tract – as well as their sensitizing potential into account. These effects depend on both the type of isocyanate and the application method used. Repeated contact may result in allergic skin reactions. Overexposure to diisocyanates through inhalation can lead to respiratory sensitization with asthma-like symptoms. While sensitization is the result of single or repeated overexposure, subsequent allergic reactions can be triggered in already sensitized persons even at considerably lower concentrations. People suffering from allergies, asthma and other respiratory diseases should not be permitted to carry out work with isocyanate-containing products. This applies, in particular, to employees who are already sensitized to isocyanates.

Skin exposure can be prevented by wearing suitable protective gloves and work clothing. Information on this can be found in the manufacturers' safety data sheets. With regard to occupational safety and its monitoring, the regulations of TRGS 430 "Isocyanates – Exposure and Monitoring" apply.

As of 24 August 2023, substances or mixtures with a diisocyanate content of ≥ 0.1 % by weight are only allowed for industrial or commercial use after a training course has been successfully completed. This results from an amendment to the REACH Regulation.

For more information please refer to:
https://www.klebstoffe.com/diisocyanate/

Properly cured dispersion adhesives are inert (fully polymerized synthetic resins) and are physiologically safe.

Annex 1:
Values for the equilibrium moisture content

Relative humidity in %	Wood moisture in %
10	2,8
20	4,5
30	6,0
40	7,5
50	9,1
60	10,9
65	12,0
70	13,3
80	16,4
90	20,7
100	30,0
The values refer to a temperature of 20 °C..	

Annex 2:
Swelling and shrinkage values for different types of wood

Type of wood	Shrinkage values from fresh wood to kiln-dried wood				Differential swelling in % per 1 %	
	Bulk density in g/m2	Lengthwise in %	Radially in %	Tangentially in %	Radially	Tangentially
Maple	0,63	0,4	3,8	8,2	0,17	0,32
Birch	0,65	0,6	5,3	8,0	0,16	0,24
Beech	0,69	0,3	5,8	11,8	0,20	0,41
Spruce	0,47	0,3	3,6	7,8	0,19	0,36
Oak	0,69	0,4	4,3	8,9	0,18	0,34
Ash	0,69	0,2	5,0	8,0	0,17	0,28
Pine	0,52	0,4	4,0	7,7	0,19	0,36
Cherrywood	0,61	–	5,0	8,7	0,17	0,31
Larch	0,59	0,3	3,3	7,8	0,14	0,30
Walnut	0,68	0,5	5,4	7,5	0,18	0,33

Source references for the two tables:

1. Oskar Toscha, „Grundlagen der handwerklichen Holzverleimung“, Verlag: Hans Rösler KG, Augsburg
2. U. Lohmann, „Holzlexikon“, 4. Auflage 2003, DRW Verlag, Leinfelden-Echterdingen

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