TKH-Technical Information Sheet

Dispersion Wood Glues

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Introduction

Until the 50s of the 20th century, only aqueous glues on plant/animal basis (e.g. bone glues) were used for gluing of wood. With the emergence of polymer chemistry, they were replaced by dispersion glues on a polyvinyl acetate basis (PVAc).

1. Characterization of dispersion wood glues

PVAc wood glues, frequently also designated as woodworker white glues, are produced by polymerization of vinyl acetate and rank among thermoplastic adhesives. Today, modern wood glues are mostly solvent-free. For MFFT-adjustment, film forming agents are added.

1.1. Parameters

The most significant parameters of PVAc wood glues are summarized in the following table:

Table 1: Physical parameters of wood glues

Characteristics	Measured parameters / methods	Unit
Solids content	DIN ISO 1625	%
pH-value	DIN ISO 976	
Viscosity	DIN EN ISO 2555	mPa*s
Minimum film-forming temperature (MFFT)	DIN ISO 2115	°C

Beside the parameters mentioned above, there exist several significant application-related characteristics of wood glues. In some cases at least part of these are listed in the technical product data sheets.

Table 2: Important characteristics of wood glues		
Parameters	**Measured parameters/methods**	**Unit**
Open time	Often divided into open and closed waiting time, mostly determined by manual testing under standardized conditions	minutes
Setting speed	Bond strength after defined pressing time under standardized conditions	N/mm²
Min. pressing time	Pressing time until required min. strength is reached under the given conditions	minutes
Water resistance	Bond strength after exposure to water under standardized conditions (EC standards)	N/mm²
Thermal stability	Bond strength at higher temperatures under standardized conditions (EC standards)	N/mm²
Creep stability	Resistance against cold flow under static load (EC standards)	days
Pot life (for 2-component systems)	Processing time of 2-component materials after hardener is added	Minutes, hours, days

The following table contains the most important European standards for PVAc wood glues.

In addition, there is a range of other standards for wood glues in non-European countries, the most significant in the US (ASTM standards) and in Japan (JIS or JAS standards).

Table 3: Valid standards for wood glues in Europe		
Standard	**Title**	**Valid version dated**
EN 204	Classification of thermoplastic wood glues for non-structural applications	September 2001
EN 205	Adhesives – wood glues for non-structural applications – determination of adhesive strength of longitudinal bonds with tensile tests	March 2003
EN 14257	Adhesives – wood glues - determination of adhesive strength of longitudinal bonds with tensile tests and heat exposure (WATT'91);	September 2006
EN 14292	Adhesives – wood glues – determination of resistance to static stress and heat exposure	September 2005
EN 14256	Wood glues for non-structural applications – test method and requirements for resistance to static stress;	October 2007

1.2 Classification of wood glues

In Germany, wood glues are normally classified according to their resistance to water. According to EN 204, four stress classes are defined (D1, D2, D3 and D4).

Table 4:
Classification of thermoplastic wood glues according to their water resistance (EN 204)
Tests have to be carried out with Test specimen prepared according to EN 205

Stress class	Storage life	Required bond strength
D1	**D1-1** storage 7 days at standard ambient conditions*	> 10 N/mm²
D2	**D2-1** storage 7 days at standard ambient conditions* **D2-2** storage 7 days at standard ambient conditions* storage of test specimen in cold water (approx. 20 °C) for 3 hours storage 7 days at standard ambient conditions*	> 10 N/mm² > 8 N/mm²
D3	**D3-1** storage 7 days at standard ambient conditions* **D3-3** storage 7 days at standard ambient conditions* storage of test specimen in cold water (approx. 20 °C) for 4 days **D3-4** storage 7 days at standard ambient conditions* storage of test specimen in cold water (approx. 20 °C) for 4 days storage 7 days at standard ambient conditions*	> 10 N/mm² > 2 N/mm² > 8 N/mm²
D4	**D4-1** storage 7 days at standard ambient conditions* **D4-3** storage 7 days at standard ambient conditions* storage of test specimen in cold water (approx. 20 °C) for 4 days **D4-5** storage 7 days at standard ambient conditions* storage of test specimen in boiling water (approx. 20 °C) for 6 h storage of test specimen in cold water (approx. 20 °C) for 2 h	> 10 N/mm² > 4 N/mm² > 4 N/mm²

*Standard ambient conditions: 23 °C / 50% rel. humidity (or 20 °C, 65% rel. humidity)

1.3 EPI systems

Adhesives with special features, up to now mostly widely used in Asia, are so-called EPI systems (Emulsion-Polymer-Isocyanate), utilizing approx. 15% isocyanate (mostly MDI) as hardener. These systems, a kind of transition product to thermosetting adhesives, customarily have very short pot lives and are applied mechanically.
With EPI systems, extremely high water and heat resistance is achieved.

2. Areas of application

PVAc wood glues are widely used in industry, by professionals and in the consumer sector. The list below gives an overview of the major areas of application.

- Furniture manufacturing (indoor use)
  - Veneering of wood and timber products.
  - For plank joints and block gluing of hard- and softwood.
  - For gluing of dowels, frames and corpuses and other assembly gluing.
  - For veneer finish, e.g. fleece lamination, veneer doubling, fleece impregnation.
  - Surface gluing of timber products with HPL, CPL and other suitable coating materials.
  - For thermo-lamination of timber products with decorative films.
- Furniture in wet rooms (bath, kitchen, outside use)
  - For manufacture of furniture and built-in components for baths, kitchens and other wet rooms, use D3 or D4 systems.
- Window and door manufacturing
  - For the lamination of window frames manufacture and window corner joints. Here special requirements, such as heat and water resistance have to be fulfiled.
- Installation of parquet and laminate floors
  - Preferably use D3 glues for joint gluing when installing parquet and laminate floors (e.g. tongue and groove gluing).
  - Moisture sealing of joints.

2.1. Other applications

- Stairways and stairway handrails (made from wood), interior work with timber materials.
- Gluing for outdoor applications with D4 systems, only with adequate surface protection. Glued joints shall not be exposed to outdoor weathering.
- Fabrication of drywall.
- Repair gluing of timber materials.

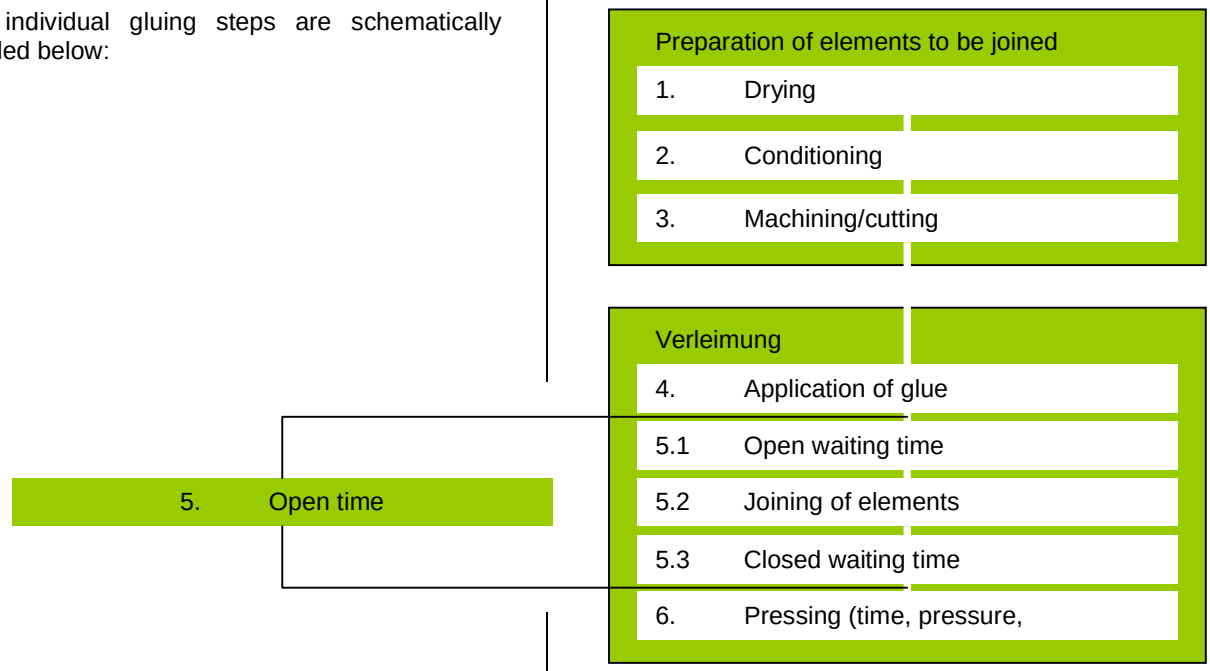
3. Installation systems and methods

In line with the variety of application areas, there is a wide range of different application methods for PVAc wood glues:

Adhesive applications	Adhesive application systems	
	Manual application method	**Automatic application method**
Gluing of dowels	– apply into dowel hole using a bottle – apply using a pressure device	– dowel injection device – injection with batching device (pressure device)
Veneer gluing	– notched trowel – glue application roller	– gluing machine **s** two/four roll mill
Groove/tenon gluing	– spatula perforated on both sides – pressurized device with groove/tenon roller – sprocket – paint brush, trowel	– automatic batching device with spatula perforated on both sides
Scantling manufacture	– paint brush – trowel – pressurized device with surface rake – delivery tank with bead application – delivery tank with roller	– two roller application – bead casting method – bead/nozzle application method – automatic batching device with multiple bead application
Plank joint gluing	– paint brush – multiple nozzle swivel blade – roller application – delivery tank	– automatic feed **s** multiple nozzle swivel blade **s** rake **s** roller
Surface gluing	– notched trowel – glue roller, e.g. Gupfo roller	– gluing machine **s** two roll mill **s** four roll mill **s** .....
Film lamination /surface	– glue roller, e.g. Gupfo roller	– gluing machine **s** two roll mill **s** four roll mill **s** .....
Frame gluing	– glue bottle	
HF gluing	– notched trowel – roller	– gluing machine – .....

4. Process/sequence of wood/timber material gluing

The individual gluing steps are schematically detailed below:



4.1. Drying/wood moisture

Wood is a natural product and absorbs moisture from the environment and also emits it. This fact has a significant effect on gluing, especially the gluing of solid wood and must consequently be taken into consideration.
Air-seasoned wood reaches a wood moisture of approx. 15 – 20%, depending on climatic conditions. When wood is used indoor in living areas, a wood moisture of approx. 8% is ideal. This is also the moisture content referred to in processing directions given in data sheets. Wood with a higher moisture content require longer pressing times, since it takes longer for the wood to absorb the water contained in the dispersion.

4.2. Conditioning

Wood elements to be joined shall always have the same wood moisture content with a maximum tolerance of 2%. Otherwise the different shrinkage and swelling behavior during moisture equilibration will lead to stress which will not only affect the glue joint but can also lead to deformation of the workpiece. To avoid this, the workpieces must be thoroughly conditioned before gluing (temperature and moisture equilibration). The required minimum conditioning period also depends on type and dimensions of the workpiece.
Before each gluing operation, wood moisture shall be measured with the appropriate measuring tools.

Besides conditioning of the timber material, the minimum film formation temperature (MFFT) of the adhesive must be considered. MFFT is the minimum temperature a dispersion requires during the setting process to form a film corresponding to the properties of the adhesive.
During processing, ambient, adhesive and workpiece temperature must comply with the specifications provided in the technical data sheet. When the temperature is too low, no film is formed. The dispersion only dries and forms a white layer which can not develop the required strength.

4.3. Machining/cutting

Machines and tools must be adjusted to achieve a good fit and surface quality during machining. Plane knocks, blunt and worn tools lead to an inaccurate fit and consequently cause imperfect glue joints. Burning of the cutting edges caused by blunt tools prevent regular setting of the adhesive, consequently reducing strength.
Wood shall preferably be glued shortly after machining/cutting so that surfaces shall not change again. This is of particular importance with wood types containing resins and oils such as teak, rosewood and rubberwood.

4.4. Application of adhesive

The viscosity of PVAc wood glues is adjusted to permit different application methods. It is important that the glue is applied evenly. Quantity of glue applied depends on absorbency and fit of

the wood or workpieces and normally ranges between 100 and 250 g/m². For some wood types, a one-sided application is sufficient; when working with solid wood or woods containing oils and resins, double-sided application is recommended. In any case, manufacturers' recommendations for their products must be followed.

4.5. Open time

Wet life or open life according to DIN 16920 is the period "after application of the adhesive during which wet bonding is possible", i.e. the time between application of the adhesive and the time pressure is applied.
This includes the open as well as the closed waiting time and depends among others on thickness of applied layer, absorbency of the elements to be joined, ambient and workpiece temperature as well as air humidity and velocity. The recommended times are specified in the technical data sheets of each product.

4.5.1. Open waiting time

Open time is the time from application of the adhesive until joining of the parts (DIN 16920 and EN 923: 1996). Some manufacturers also define open waiting time as open time according to EN 923: 1996. Since definitions are not completely clear, we recommend to contact the adhesive manufacturer in case of doubt to clarify if the open time indicated in the datasheet is equal to open waiting time or if the specification refers to the sum of open and closed waiting time.

4.5.2. Joining of the elements

The workpieces to be glued must be joined during the open time. Make sure to avoid any contamination of the surfaces to be joined.

4.5.3. Closed waiting time

According to DIN 16920 as well as to EN 923:1996, closed waiting time is defined as the time after joining of the elements until the required pressure is reached. Closed waiting time is part of the open time.

4.6. Pressing (time, pressure applied, temperature)

The minimum pressing time depends on wood type and press temperature. Solid wood and wood containing oils and resins require longer pressing times.
Increase in temperature results in a decrease of the minimum pressing time. Pressure must be sufficient to guarantee required fit of the joints. The specific pressure depends on wood type and ranges between 0.2 and 1.5 N/mm². If pressure is too high, glue might penetrate into the substrates and consequently lead to defective bonds. Temperatures and pressing times are normally specified in the technical data sheets.

5. Failure analysis

To facilitate inquiry into causes for defective bonds, the following table was prepared, listing the most common causes for defective bonds as well as corrective measures.

Failure analysis		
Appearance	**Failure**	**Corrective measure**
Glued joint notably visible. In uneven areas of parts to be joined, hardened adhesive partly shown as glossy film.	Pressure too low. Fit of elements insufficient.	Increase pressure. Improve fit of elements.
Joint opening. In parts, adhesive film is pulled apart.	Pressing time insufficient.	Increase pressing time and temperature. Reduce wood moisture if necessary.
Adhesives which normally form transparent film after hardening, have a white appearance.	Temperature below MFFT.	Adjust adhesive, material and ambient temperature.
Joint opening. Joined elements insufficiently wetted. No glue escapes from joints during application.	Insufficient glue quantity.	Increase adhesive quantity until glue escapes evenly from joint.
Joint opening. Partially, adhesive film is pulled apart. Frequently with HF gluing.	Temperature too high.	Decrease temperature, lower HF time and cooling down time.
Joint opening. Adhesive takes to long to harden. Pressing times increase.	Wood moisture too high.	Reduce wood moisture and increase pressing times.
Joint opening. No wetting of the surfaces. Adhesive discolored.	Woods containing oils and resins.	Only glue freshly planed wood. Clean surfaces with appropriate solvents, complying with safety instructions. Perform gluing test.
Joint opening. With one-sided application, second element insufficiently wetted.	Open time exceeded.	Check wetting with iodine test. Observe open time. Increase adhesive quantity. Avoid air movement over open glue joint. Protect open glue joint from thermal stress.

6. Discoloration

Wood discoloration is a change in the natural color of the wood. There are several causes for discoloration.
Discoloration of wood is either caused by fungal decay (e.g. bluing, brown rot, pocket rot) or other physiological or chemical influences (e.g. weathering, water intake, drying, contact with iron or iron ions, UV irradiation, changes of pH value).
In addition, some discoloration may be caused by natural substances contained in the wood such as humic or tannic acids. This occurs especially with heartwood.
Any unwanted discoloration of wood can be minimized during processing by avoiding contact with iron, selection of the appropriate adhesive system as well as compliance with adhesive manufacturers' instructions.
Useful information regarding these issues can also be found on the homepage of the Federal Research Institute for Rural Areas, Forestry and Fisheries (www.vti.bund.de).

7. Environmental and safety aspects

7.1 Environmental aspects

PVAc wood glues, like almost all polymers – are non-biodegradable. They remain in the environment or rather the abiotic or biological degradation is very slow. However, they are not classified as toxic to the environment nor do they result in bio-accumulation. Consequently, dispersion wood glues are of lesser importance from an environmental protection viewpoint.

7.1.1 Emissions from PVAc wood glues

On account of their composition, modern PVAc wood glues are very low in emission. Besides residual monomers and additives in the ppm-range, mainly film forming additives for MFFT adjustment need to be mentioned. Their content might amount to up to 3% of the glue product. Because of their low volatility and since the glue joint is mostly covered, the finished workpiece hardly emits any pollutants, i.e. barely measurable quantities.

7.2 Safety aspects

7.2.1 One-component glues

Vinylacetate polymers and copolymers in hydrous systems are inert from a biological viewpoint and chemically indifferent. There are certain health-related issues on due to the preservatives used in those systems, required as a protection against colonization.
Most preservatives (biocide substances) are sensitizing substances (Xi, R 43 – sensitizing through contact with skin). The low concentration of biocide substances required for preservation, however, is rather unlikely to induce allergies. However, allergies might be triggered in persons already sensitized. Wearing protective gloves will virtually exclude this hazard.
Based on our current state of knowledge, other additives and residual monomer fractions of polymers are of lesser importance.

7.2.2 Two-component systems

7.2.2.1 Metal salt curing agents

Aluminum chloride is classified as caustic (C, R34), however, in low proportions (<3%) no irritations are to be expected.
Aluminum nitrate x 9 H2O is classified by manufacturers as flammable and irritant (O, Xi, R8, R36/38). However, on account of the low proportion in wood glue (<3%), no flammable properties or health related effects are to be expected.

7.2.2.2 Isocyanate-based curing agents

The assessment of health issues depends on the hardener system. Normally, HDI- or MDI-based hardeners are used.
Because of their volatility and the related exposure scenario, monomer diisocyanates are not used in their original form but rather exclusively in the form of high-molecular, low volatile polyisocyanates. These polyisocyanates only contain low quantities of the original isocyanate as residual monomer. MDI, however, is an exception, which can be used without modifications on account of its low volatility.
Isocyanates are reactive compounds. As for their toxicological characteristics, irritation potential for skin, eyes and respiratory system as well as a certain sensitizing potential must be considered, always based on the type of isocyanate and application method. As a consequence, allergic skin reactions may occur after repeated contact with the substance. Overexposure to diisocyanates by inhalation may lead to sensitization of the respiratory tract with asthma-like symptoms. While sensitization is a consequence of a single or repeated overexposure, however in persons already sensitized, subsequent allergic reactions can already occur at considerably lower concentrations. People suffering from allergies, asthma and other diseases of the respiratory system shall not perform tasks involving products which contain isocyanates.
Typically, prescriptive limits for diisocyanates in the workplace are not exceeded when using aerosol-producing application methods (e.g. with the exception of spray application and heat hardening), provided adequate airing of the rooms is ensured. Under such circumstances, low-volatile polyisocyanates do not contribute to respiratory tract exposition.
Skin exposition is prevented by wearing protective gloves. See specifications in safety data sheets issued by manufacturers. As regards industrial safety and monitoring, the regulations of TRGS 430 Isocyanates- Exposition and Monitoring – apply.
Properly hardened dispersion wood glues are inert (fully polymerized synthetic resins) and are physiologically safe.

Annexes

Annex 1:
Values for equilibrium moisture

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 of various wood types

Wood type	Timber: degree of shrinkage from fresh to oven-dry condition				Differential swelling in % per 1 %	
	Gross density g/m³	Lengthwise in %	radial in %	tangentially in %	radial	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

References for both tables:

1. Oskar Toscha, "Grundlagen der handwerklichen Holzverleimung", Publisher: Hans Rösler KG, Augsburg

2. U. Lohmann, "Holzlexikon", 4th edition 2003, Publisher: DRW, Leinfelden-Echterdingen