TKH Technical Briefing Note 4

Version: October 2023

Industrieverband Klebstoffe e.V.

Hotmelt Adhesives

Published by Technischen Kommission Holzklebstoffe (TKH)
(Technical Committee on Wood Adhesives)
of Industrieverband Klebstoffe e.V., Düsseldorf

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Introduction

Hotmelt adhesives have become an integral part of modern wood and furniture industry. They are the only adhesive system that allows the application-specific adaptation of its properties to the application process. For instance, the application behavior can be precisely adapted to the respective requirements simply by increasing or decreasing the hotmelt temperature. This property makes hotmelt adhesives a perfect tool when it comes to automating work processes.

The objective of this Technical Briefing Note is to explain the wide variety of terms that processors or users of hotmelt adhesives are confronted with.

1. Terms and definitions

According to DIN EN 9231), a hotmelt adhesive (German: Schmelzklebstoff, French: colle thermo-fusible) is defined as an adhesive system that can be melted by the application of heat and develops cohesion (internal strength) through cooling.

Like all adhesives, a hotmelt basically consists of one or more polymers, supplemented by additives such as pigments or stabilizers. More information can be found in section 2.2 Chemical properties of adhesives.

Hotmelt adhesives are usually named after their base polymers:

Table 1:
Base polymers used for the production of hotmelt adhesives

Base polymer	Comments
Ethylene vinyl acetate (EVA)	Frequently used base polymer for standard applications
Polyolefin (PO)	Enables higher heat resistance than EVA
Polyamide (PA)	High heat resistance
Polyurethane (PUR)	Mostly reactive system with high resistance to heat and moisture
Polyester (PES)	Broad adhesion spectrum and long open time

Many systems can be formulated to be thermoplastic and chemically reactive.

Thermoplastic hotmelt adhesives are thermally reversible. With a sufficiently high heat input, they become flowable again. As a result, their internal strength, also called cohesion, is reduced. This property (sometimes desirable, e.g. for precoating) can be counteracted by linking the polymer molecules after the cooling process (chemical crosslinking). This virtually eliminates the reduction of cohesion at higher temperatures while the bonding strength of the hotmelt adhesive is retained. Such systems, which undergo chemical crosslinking reactions during or after cooling, are called reactive hotmelt adhesives.

In its molten state, the hotmelt adhesive is a **flowable mass**. Only in this state does it wet the surface of the substrates to be bonded and develop **adhesion** to them. However, a flowable mass can only transfer forces to a very limited extent as it has comparatively low **cohesion**. As a result of cooling, the hotmelt adhesive solidifies:

it becomes a solid, which then has a high cohesion for force transmission. The viscoelastic properties of the polymers then ensure that the adhesion is maintained despite the mechanical stresses built up during the cooling process.

2. Properties of adhesives

2.1. Physical properties of adhesives

The above explanation of the bonding process shows that when describing a hotmelt, it must be clearly distinguished whether one refers to the molten mass, the phase transition or the hotmelt in its solidified state. Most **application parameters** of hotmelts refer to the molten mass, whereas most hotmelt **selection criteria** refer to the solid state.

The molten mass is described by parameters that relate to a liquid (e.g. viscosity). By contrast, the solid is described with the help of mechanical parameters (e.g. shear modulus G). In between are the parameters that describe the phase transition between the two physical states (e.g. softening point).

Table 2:
Parameters for characterizing the molten mass

Parameter	Short form	Unit	Measuring method	Description
Viscosity	η	Pa·s	Rheometer	Describes the flow behavior under the application of force
Melt Flow Index	MFI	g/10 min	MFI meter	Further viscosity characteristic
Melt Volume Rate	MVR	ml/10 min	MFI meter	Further viscosity characteristic

Table 3:
Parameters for characterizing the phase transition

Parameter	Short form	Unit	Measuring method	Description
Softening point or softening range	SP SR	°C	Kofler bench[2]; ring and ball apparatus[3]	Visual behavior of the adhesive during heating

Table 4:
Parameters for characterizing the solid

Parameter	Short form	Unit	Measuring method	Description
Density	ρ	g/cm^3	Volumetric	Specific weight
Elastic shear modulus	G'	Pa	Rheometer	Storage modulus, describes the elasticity
Plastic shear modulus	G"	Pa	Rheometer	Loss modulus, describes the plasticity
Loss factor	tan δ		Rheometer	Describes the ratio of plastic to elastic properties

2.2. Chemical properties of adhesives

Hotmelt adhesives are multi-component systems which can be formulated with specific properties by combining different polymers and additives. As a result, it is possible to obtain, for instance, thermal or mechanical properties in hotmelt adhesives that are very different from those of the individual polymers. This is comparable to the material steel. By alloying its main component iron with other metals, properties are achieved that far exceed those of iron.

This process makes it possible to produce hotmelt adhesives that are virtually customized polymer alloys. The table below lists the main raw materials that are used for producing hotmelt adhesives.

Table 5:
Main raw materials used for the production of hotmelt adhesives

Name	Short form	Function, examples
Ethylene vinyl acetate	EVA	Base polymer
Polyolefin	PO	Base polymer
Polyamide	PA	Base polymer
Polyurethane	PUR	Base polymer
Polyester	PES	Base polymer
Filler		E.g. chalk, barite
Prepolymer		Crosslinking component, e.g. isocyanate
Resin		Tackifier, e.g. natural resins or petrochemical resins
Additive		E.g. stabilizers, pigments, waxes

The somewhat vague term **resin** may need to be explained: In common parlance, resins are those polymers that are mainly responsible for building up adhesion in the melt. Compared to the base polymers, they are usually low-molecular compounds.

In this context, the word **filler** should not be understood as a synonym for "cheap material to reduce the price". Fillers have a considerable impact on the rheology and structure of adhesives and therefore contribute significantly to their profile. During road construction, for instance, the gravel added to the asphalt is not used to extend the bitumen, but to ensure the stability of the road surface.

3. Properties of the substrates

The properties of a bond are not only influenced by the adhesive, but also by the respective substrate. When analyzing the properties of a bond, it is therefore necessary to not only consider the adhesive properties but the bond as a whole. It is the bonded system that is important, not its individual components (adhesive and substrate).

3.1. Physical properties of materials

Table 6 below lists those properties of furniture edge-bands that cause particularly high physical stresses for an adhesive bond.

The last column "Test" is meant to indicate that, at least as a comparative test, the behaviour of the edgebands allows an assessment of the stresses to be expected when exposed to high temperatures over a prolonged period of time.

Table 6:
Properties of furniture edgebands that can cause particularly high stresses for adhesive bonds

Problem	Source	Effect	Test
Internal stress	Material property	Constant load acting on the adhesive. Occurs with increasing temperatures.	Behavior of the edgeband in the heating cabinet
Frozen-in mechanical stresses	Manufacturing process (e.g. extrusion, calendering, radius of the edgeband roll)	Often only has an effect after a long time.	Behavior of the edgeband in the heating cabinet
Degree of condensation	Manufacturing process	Internal stress. Water resistance, behavior under the influence of moisture	Behavior of the edgeband in the heating cabinet

When bonding a thermoplastic edgeband with a purely thermoplastic hotmelt adhesive to a chipboard, the following observation can be made: When tempera-tures rise above room temperature, both the hotmelt and the edgeband tend to become softer. The bond will hold as long as the adhesive is able to compensate or transfer the mechanical stresses occurring at this temperature.
The stress acting on the adhesive is determined by the tensions in the substrate (edgeband and chipboard). For example, edge material that tends to shrink at high temperatures (shear stress due to material properties) or edge material that curls up due to frozen-in mechanical stresses will cause mechanical overload for some adhesives. In everyday language, this is called "heat resistance" until shortly before the bond fails.

Another example is a water-insoluble hotmelt adhesive. It will not be able to hold an edgeband to a chipboard swelling in water if the top layer of the board becomes detached when exposed to water.

The two examples show that heat resistance and water resistance are typical properties of the bond and not of the adhesive itself. This must be considered when analyzing the requirement profile.

3.2. Chemical properties of materials

The base material is also used for naming the coating materials and edgebands. Table 7 lists some of the materials commonly used today without making a claim to completeness.

The different chemical compositions of the materials result in different properties. With regard to the bonding process, for example, the surface energy is an essential property that shows physically, but has its origin in the chemical properties. If the surface energy of the substrate does not match the surface tension of the hotmelt adhesive, there will be no sufficient wetting. As a result, adhesion will be reduced or simply non-existent.

Wood and wood-based materials can normally be bonded without special pretreatment as long as their bonding surfaces are free of dust, grease and oil. Plastics or metals, on the other hand, often require pre-treatment to improve adhesion. For this reason, manufacturers will sometimes apply adhesion promoters (e.g. primers), which then form the actual contact surface with the adhesive.

Table 7:
Base materials for coating materials and furniture edgebands

Name	Application
ABS (acrylonitrile butadiene styrene)	Edges, surfaces
PVC (polyvinyl chloride)	Edges, surfaces
PP / PE (polypropylene / polyethylene)	Edges, surfaces
PET / polyester	Edges, surfaces
Aluminum	Edges, surfaces
Laminates	Edges, surfaces
Veneers / solid wood	Edges, surfaces
Chipboards / plywood	Carrier material
Fiberboards MDF / HDF	Carrier material
Composite panels	Carrier material
Solid wood	Carrier material

4. Application parameters

Table 8 provides a list of parameters that are essential for bonding processes. These parameters are associated with the phase transition of the hotmelt from the flowable to the solid state. They have a direct impact on the achievable bonding quality and require due consideration when setting up a hotmelt application system.

It is important to understand that these parameters, especially in the case of hotmelt adhesives, are not fixed but rather variable settings that depend on the prevailing conditions in the production environment. Accordingly, the values may vary for one and the same hotmelt for different applications. From this context, it becomes clear that any attempt to quantify these variables as fixed values must fail.

On the next page, we will present some practical considerations that allow us to estimate the combination of measurable adhesive parameters and measurable environmental parameters, which is difficult to quantify in the actual production process.

Our aim is to support the hotmelt user in the best possible adjustment of the adhesive processing system.

Typical processes involved in hotmelt application:

A hotmelt adhesive wets suitable substrates as long as it is sufficiently flowable. Wetting depends on the viscosity and surface tension of the adhesive in the flowable state. Both are measurable properties that depend on the temperature.

After application, the hotmelt cools down by releasing heat to substrate and environment.

During the cooling process, the viscosity and surface tension of the adhesive increase while its wetting ability decreases and its cohesive strength increases. The speed of these processes is a measurable property defined by the heat flows: slow progress if the environment absorbs the heat poorly and the adhesive has a high heat capacity, fast progress if, for example, the environment is cold, which results in higher heat flows.

Table 8:
Important parameters for the processing of hotmelt adhesives

Parameter	Definition	Controllable variables	Significance
Open time (wetting time)	Time after adhesive application during which wetting of the substrates to be joined is ensured	Heat flows, ambient temperature, substrate temperature, layer thickness of the adhesive *Can be Influen-ced by the user*	Maximum time after adhesive application until the substrates must be joined
Setting time	Complete development of cohesion. Viscosity not measurably high.	Heat flows, ambient temperature, substrate temperature, layer thickness of the adhesive *Can be influen-ced by the user*	Minimum time after adhesive application until a bonded joint can be exposed to mechanical stress
Surface tension	Temperature-dependent measure of the wetting ability of the hotmelt adhesive	Adhesive temperature, pretreatment of the substrate surfaces *Can be influen-ced by the user*	Important parameter for the wettability
Adhesion	Interaction between adhesive and substrate (adhesive force)	Temperature, surface tension, dust-free, fat-free	Cleaning of the parts to be joined
Initial strength	Interaction of cohesion and adhesion after the joining process	Viscosity profile *Can be influen-ced by adhesive manufacturer*	Resistance to mechanical stress during the joining process
Cohesion build-up time	Measure for the solidification behavior	Viscosity profile *Can be influen-ced by adhesive manufacturer*	Resistance to mechanical stress shortly after the joining process
Ability for reactivation	Remelting ability / remelting behavior	Reactivation temperature, joining pressure *Can be influen-ced by the user*	Configuration of the production process
"Smearing"	Behavior of the hotmelt adhesive during milling processes (so-called flush milling)	Viscosity profile, adhesive temperature, type of adhesive *Can be influen-ced by the user*	Contamination of tools and finished parts

5. Application techniques

Table 9 provides a list of typical hotmelt applications in the furniture industry and the associated application techniques. The parameters described above are of varying importance for the different applications. The most important ones for the respective application are listed in the last column.

Depending on application method and type of adhesive, the delivery form (consistency) of the adhesives can vary. The important thing is that both are (optimally) matched to each other. Some common delivery forms of hotmelts include, for instance, granules, cartridges or blocks. In the case of chemically reactive hotmelts, the packaging must protect the adhesive from ambient moisture in order to prevent any premature reactions. The adhesive also needs to be protected from ambient moisture in the melting units.

Table 9:
Typical applications of hotmelt adhesives in the furniture industry

Application	Procedure	Application device	Important parameters
Straight-edge bonding	Application of the adhesive to the carrier board or edgeband	Applicator roll, nozzle	Open time (or wetting time), initial strength
Soft-forming	Application of the adhesive to the edgeband	Applicator roll, nozzle	Open time (or wetting time), initial strength
Stationary processing	Workpiece is fixed in a clamping device, machined and provided with an edgeband	Applicator roll	Initial strength
Precoated edgebands	Application of the adhesive to the edgeband, later reactivation of the adhesive	Applicator roll, nozzle	Ability for reactivation
Post-forming	Molding of the surface coating around the narrow edge	Applicator roll, nozzle	Initial strength
Sheathing	Application of the adhesive to the coating	Applicator roll, nozzle	Open time (or wetting time)
Assembly bonding	Assembly aid, hotmelt works like a "hot nail"	Nozzle, hand gun for manual application	Open time (or wetting time)

6. Test methods

Table 10 shows the most important methods for testing adhesive bonds that have been produced with a hotmelt. Most of them are employed by users as a means of quick quality control. What all of these methods have in common is that they are "object tests". Although they are useful tests to be carried out on bonded joints, they do not claim to provide information about an adhesive without a substrate. This is also inconceivable in view of the previous explanations.

Table 10:
Methods for testing adhesive bonds produced with hotmelts

Term	Test method / Characterization
Peel strength	90-degree roller peel test (make sure to take the bending stiffness of the edge[4)] into account)
Manual adhesion test	Application-specific object test
Ascending heat test	Application-specific object test
Descending cold test	Application-specific object test
Climate change test	Application-specific object test
Long-term test (endurance test)	Application-specific object test
Water resistance test	Application-specific object test

7. Selection of a suitable hotmelt

The choice of a suitable adhesive for a specific application is not simply determined by the raw material base. Rather, the decisive factor is the interaction between the adhesive and the substrate. When also duly considering the different application methods (section 5), the relevant application parameters (section 4) and the requirements the bonded component has to fulfil, it is possible to choose a suitable adhesive. To support the choice, various test methods (section 6) are available to carry out comparative tests.

Please note: An adhesive is not a cure-all remedy, i.e. not a solution to any and all problem.

It is therefore essential to seek professional advice in advance!

8. Environmental and safety aspects

The adhesive manufacturers' safety, application and disposal instructions must be observed.

Literature

1. DIN EN 923: Adhesives – Terms and definitions. March 2015, Beuth Verlag, Berlin
2. Kofler hot bench: metal strip with a defined temperature gradient
3. ASTM E 28: Standard Test Methods for Softening Point of Resins Derived from Pine Chemicals and Hydrocarbons, by Ring-and-Ball Apparatus
4. DIN EN 1464: Adhesives – Determination of peel resistance of adhesive bonds – Floating roller method

All Technical Briefing Notes
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