TKH Technical Briefing Note 4

Hot Melt Adhesives

Version: March 2015

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

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Introduction

It is no longer possible to imagine modern wood and furniture production nowadays without hot melt adhesives. They are the only adhesive system that permits a modification of processing parameters during application. For instance, the viscosity of a hot melt adhesive can be adapted to the desired conditions by controlling temperatures within wide limits. That makes hot melt adhesives the perfect adhesives when it comes to controlling and automating work processes.

The objective of this technical information leaflet is to explain the wide variety of terms that processors of hot melt adhesives have to deal with.

1. Terms and definitions

According to DIN EN 923[1)], a hot melt adhesive (German: Schmelzklebstoff, French: Colle thermofusible) is defined as an adhesive system which is thermally melted and develops cohesion (internal strength) by means of cooling.

A hot melt adhesive, like all adhesives, generally consists of one or more polymers plus additives such as pigments, stabilizers, etc. More information can be found in Section 2.2. Chemical adhesive properties.

Hot melt adhesives are usually named after the base polymers:

Table 1:
Base polymers used for the production of hot melt adhesives

Base polymer	Comments
Ethylene vinyl acetate (EVA)	Base polymer frequently used for standard applications
Polyolefin (PO)	Permitted for higher thermal stability
Polyamide (PA)	Higher thermal stability
Polyurethane (PUR)	Most reactive system with high thermal stability and moisture resistance
Polyester (PES)	Improved adhesion spectrum and long open time

Many systems are formulated to be **reactive** and **thermoplastic**. **Thermoplastic adhesives** are reversible. At sufficiently high temperatures, they tend to become liquid again and thus lose their cohesion.

To counteract this occurrence (which is sometimes desired, as in precoating), the polymer molecules must be crosslinked after setting (chemically linked). Doing so reduces the loss of cohesion at higher temperatures and thus preserves the bond strength of the hot melt adhesives. Such systems which are subject to chemical crosslinking reactions after the cooling phase are so-called **reactive hot melt adhesives**.

In a melted state, the hot melt adhesive is a **liquid**, the so-called liquefied material. The adhesive wets, only in this state, the elements to be joined, the so-called substrates and develops **adhesive bond** with these elements. A liquid cannot transfer, however, any bonding strength, and thus has little **cohesion**. After cooling, the hot melt adhesive becomes solid ("vitreous" for the most part, rarely "crystalline") with very high cohesion.

Once the bond has been created, the visco-elastic polymers ensure that the adhesion remains preserved even after cooling process with its change in volume and the resulting development of mechanical tensions. The created cohesion imparts bonding strength between the substrates.

2. Properties of adhesives

2.1. Physical adhesive properties

Based on the above description of the bonding process, we must when describing a hot melt adhesive distinguish accurately whether reference is made to the liquefied material, the phase transition or the set solid. Most **application parameters** describe the liquefied material, and most **selection criteria** describe the solid.

The liquefied material is described based on parameters, specifying a liquid, such as viscosity; the solid, however, is specified by mechanical variables such as the G module. The parameters in between describe the phase transition between the two, such as the softening point.

Table 2:
Variables for characterizing the liquefied material

Size	Abbreviation	Unit	Measuring method	Description
Viscosity	η	Pa·s	Rheometer	Describes flow characteristics
Melting Flow Index	MFI	g/10min	MFI meter	Other viscosity characteristic
Melting Vol. Index	MVI	ml/10min	MFI meter	Other viscosity characteristic

Table 3:
Variables for characterizing the phase transition

Size	Abbreviation	Unit	Measuring method	Description
Softening point	EP	°C	Kofler heating bench[2)]; Ring&Ball[3)]	Visual properties of the adhesive during heating

Table 4:
Variables for characterizing the solid

Size	Abbreviation	Unit	Measuring method	Description
Density	ρ	g/cm^3	Volumetric	Specific weight
Elast. G module	G´	Pa	Rheometer	Memory module describes the elasticity
Plast. G module	G´´	Pa	Rheometer	Loss module describes the plasticity
Loss factor	tan δ		Rheometer	Describes the ratio between plastic and elastic properties

2.2. Chemical adhesive properties

Hot melt adhesives are multi-component systems which allow for adjusting certain characteristics by carefully combining different polymers and additives. As a result, hot melt adhesives can exhibit, e.g., thermal or mechanical characteristics that are very different from that of the base polymers. As with the steel alloy, which is far superior to its raw material iron, it is possible to achieve properties by an optimal combination of different raw materials which the single substances do not have.

This allows to customizing hot melt adhesives like polymer alloys. The table below lists the essential raw materials of hot melt adhesives:

Table 5:
Essential raw materials used for the production of hot melt adhesives

Name	Abbreviation	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 materials		e.g. chalk, barite
Pre-polymer		Crosslinking components, e.g. isocyanate
Resin		Tackifier, e.g. natural or petrochemical resins
Additive		e.g. stabilizers, pigments

The ambiguous term **resin** may possibly need some clarification: In line with everyday language use, we call resins the polymers which are primarily responsible in the melt for creating the adhesive bond. These include for the most part low-molecular compounds (compared to base polymers).

The term **filler material** does not represent in this context a synonym for a "cheap" blend. Filler materials have a decisive impact on the rheology and structure of the adhesives and substantially contribute to their profile. For instance, gravel is added to asphalt during road construction in order to ensure the stability of the road surface and not to make the bitumen go further.

3. Substrate properties

The properties of the bond are not only influenced by the adhesive, but also by the substrates. As a result, we expand our analysis to the properties of the bond as a system. After all, we are interested in the system, not the individual components, the adhesives and substrates.

3.1. Physical properties of materials

The following table 6 provides a list as an example of the properties of furniture edges that have particularly high loads for glued compounds.

The last column entitled "Check" should show at least in the form of a comparative test that edge performance allows for assessing the stresses and loads to be expected when exposed continuously to high temperatures over extended periods:

Table 6:
Properties of furniture edges and thus their bonds that may be subject to high loads

Problem	Source	Effect	Check
Internal stress	Extrusion, calendering	Constant load on adhesive. Discharge at increasing temperatures	Behavior of edge in drying cabinets
Flash-frozen internal stress	Production process	Impact visible only after a long time	Behavior of edge in drying cabinets
Degree of condensation	Production process	Internal stress. Water resistance, performance when exposed to moisture	Behavior of edge in drying cabinets

Let's look at the bond of a thermoplastic edge on a particle board. When the temperature rises above room temperature, the hot melt adhesives and the related edges tend to become softer in most cases. The bond will hold if the adhesive is able to transfer the mechanical stress occurring at such temperatures.

The stress on the adhesive is determined by the stress occurring in the substrates – edge and board. As a result, the edge material which tends to shrink at high temperatures (shear stress) or edge material which tends to curl (normal stress) will mechanically overload many adhesives, which is commonly referred to in everyday language use as "low thermal stability".

Another noteworthy example is a water resistant hot melt adhesive. It will not be able to retain an edge on a particle board which swells in water if its top layer or facing becomes detached when exposed to water. These two examples show that "thermal stability" and "water resistance" are typical characteristics of a bond and not of the adhesive by itself. That should be taken into account when considering the requirements and their parameters.

3.2. Chemical properties of materials

The base material serves as a basis for choosing the name of coating materials and edges as well. Table 7 provides a list of some commonly used materials but makes no claim to be complete. Information relating to recycling behavior and mechanical flexural strength can be found in the manufacturers' technical data sheets. The application areas that are relevant for our context are listed in the second column.

Table 7:
Base materials for coating materials and furniture edges

Name	Application
ABS (acrylonitrile butadiene styrene)	Edges, surfaces
PVC (polyvinyl chloride)	Edges, surfaces
PP /PE (polypropylene, polyethylene)	Edges, surfaces
Laminates	Edges, surfaces
PET / polyester	Edges, surfaces
Veneers + solid wood	Edges, surfaces
Aluminium	Edging
Particle board, plywood	Beams
MDF / HDF	Beams
Composite panels	Beams
Solid wood	Beams

Note that many of cited materials cannot be glued or bonded when they are not treated. In some cases, manufacturers will already apply a primer that in turn serves as that actual contact surface for the adhesive.

4. Processing parameters

Table 8 on page 6 provides a list of "practical" parameters. These are variables which can be attributed to the hot melt adhesive's phase transition from liquid to solid.

These parameters directly influence the settings of production machinery. In all actuality, these variables are not adhesive-related parameters, but rather settings, i.e. production parameters, that are defined by the production environment. According to that, these parameters may vary quite significantly for one and the same hot melt adhesive within the framework of the different applications. This explains why every attempt to classify such parameters and variables is destined to fail.

Otherwise, such parameters and variables are the result of practical experience and are thus the only factors that really interest users. We have outlined our considerations based on a simple model which allow for assessing questionable variables which cannot be reliably measured based on measurable adhesive variables and measurable environmental parameters.

The following served as a basis:
A hot melt adhesive wets the substrates only as long as it is still in a liquid state. Wetting depends on viscosity and surface tension in liquid state. Both are measurable functions of the temperature.

An adhesive cools off by releasing heat to substrate and environment. At the same time, its viscosity and surface tension increase, while its wetting capacity is reduced and its cohesion (strength) increases. The speed of these processes is a measurable characteristic defined by the heat flow. (Slow when the environment draws off the heat slowly and the adhesive has a high thermal capacity; and fast when the environment is very cold, because heat flow is substantial).

Table 8:
"Practical" processing parameters for hot melt adhesives

Term	Definition	Controllable variables	Consequences
Open time	Time after application of adhesive during which a wetting of the substrates to be joined is ensured.	Heat flow, ambient temperature, substrate temperature *Can be controlled by user*	Maximum time after application of adhesive until joining of substrates
Setting time	Complete cohesion development. Viscosity unmeasurably high.	Substrate characteristics, ambient conditions *Can be controlled by user*	Minimum time after application of adhesive until the mechanical stability of glued joint is achieved
Surface tension	Temperature-dependent variable for wetting characteristics of liquids.	Adhesive temperature, substrate pretreated *Can be controlled by user*	Important variables for cross-linkability. Impact on amount applied and wetting
Heat adhesiveness Initial tack	Cohesion and adhesion at high temperatures.	Viscosity profile *Can be controlled by adhesive manufacturer*	Impact on mechanical stability during joining process
Time for development of cohesion	% of final strength	Viscosity profile *Can be controlled by adhesive manufacturer*	Impact on mechanical stability right after joining process
Reactivity	Remelting behavior	Reactivation temperature, joining pressure *Can be controlled by user*	Joining behavior (e.g. by precoated materials)
Milling behavior, "smear"		Viscosity profile, processing temperature *Can be controlled by user*	Machining of finished parts, tool, contamination of finished parts
Stringing, "Angel hair"		Adhesive temperature *Can be controlled by user*	Contamination of finished parts and tools
Adhesion	Reciprocal effect of adhesive – substrate "adherence“	Temp. , surface tension, dust and grease-free	Cleaning of parts to be joined

5. Processing methods

Table 9 provides a list of typical applications for hot melt adhesives in the furniture industry and the related processing methods. The processing parameters described above have a different impact on the various application. The most important parameters are listed in the last column.

Depending on application method and type of adhesive, the **form of delivery of the adhesive** may vary. It is important that application method and adhesive type are optimally matched to one another. Some typical forms of delivery include, e.g., granulates, cartridges or blocks. With reactive hot melt adhesives, packaging must protect the adhesives from ambient moisture in order to prevent any premature reactions. The adhesive must also be protected against ambient moisture in the melting units.

Table 9:
Typical applications of hot melt adhesives in the furniture industry

Application	Characteristics	Application method	Important parameters
Straight edge	Application of adhesive to base plate or edge material	Applicator roll, nozzle, adhesive application systems	
Soft forming	Application of adhesive to edge material	Applicator roll, nozzle	Open time, initial strength
Stationary processing	Workpiece is clamped and machined and an edge is added	Applicator roll	Initial strength
Pre-coated edges	Application of adhesive to edge material; subsequent reactivation of adhesive	Applicator roll, nozzle	Reactivity
Post-forming	Shaping of surface coating around the narrow edge	Applicator roll, nozzle application	Initial strength
Coating	Application of adhesive to coating	Applicator roll, nozzle	Open time
Assembly bonding	Assembly aid, "hot nail"	Nozzle, manual gun	Open time

6. Test methods

In Table 10, we list the most important methods for testing a bond made with hot melt adhesives. The majority are implemented for quick quality control at the customer's premises. All of these methods have one thing in common that they are object tests. Although they are reasonable tests for checking bonds, they do not claim to provide information about an adhesive without a substrate. This is not acceptable in terms of the above statements.

The two last columns represent the assessment by TKH - Technical Committee on Wood Adhesives. Resolution is a term used in measurement technology and test engineering and is used to characterize the potential of the relevant process to detect subtle differences in quality.

Table 10:
Most important methods for testing an adhesive bond with hot melt adhesives

Term	Methods / characteristics	Resolution	Informative value
Peel strength	Peeling 90° Flexural strength of edging[4)]	Depends on edge material	Good
Manual adhesion test	In-house methods	Variable	Good
Ascending heat test	Customer-dependent test methods	Moderate	Good
Cold testing	Application-specific object test	Moderate	Limited
Alternating climate test	Application-specific object test DIN 50016/50017	Adequate	Moderate
Endurance test	Common application-specific object test	Adequate	Good
Water resistance	Common application-specific object test	Poor	Very limited

7. Technical requirements

The appropriate adhesive can be selected based on the processing methods (Section 5) and the relevant processing parameters (Section 4). In addition to that, the technical requirements can be determined on the basis of the different areas of application. Different test methods (Section 6) help in comparing test results.

The suitability of an adhesive for a specific area of application depends not only on the raw materials or other individual parameters. A combination of all of these factors must be taken into account in any case. Certain adhesives might be designated in many cases as the standard for certain areas of application. In other words, they have proven themselves over the years and satisfy the main stress classifications listed in table below.

8. Environmental and safety aspects

The safety, processing and disposal guidelines of the adhesive manufacturer must be observed.

The impact that the adhesive has on test results is considerably lower than generally assumed. Instead, the processing method used is especially decisive for the adhesive bond, just like the stability of coating materials and substrates.

The results of such tests only demonstrate how the components behave and perform under certain climatic conditions. These tests are suited for defining the quality achieved. The results can subsequently be used as reference for quality control tests.

Literature:

1. DIN EN 923 "Adhesives – Terms and definitions", Draft standard from March 2015, Beuth Verlag, Berlin
2. Kofler heating bench: Metal plate with defined temperature gradients
3. ASTM E 28: Standard test methods for softening point of resins; Ring and ball method
4. DIN EN 1464 "Adhesives - Determination of peel resistance of adhesive bonds - Floating roller method"