

# TKH-Technical Information Sheet

## Hot melt adhesives

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## Contents

	Introduction .....
1.	Definitions and terms .....
2.	Characteristics of adhesives .....
2.1.	Physical characteristics of adhesives .....
2.2.	Chemical characteristics of adhesives .....
3.	Properties of substrates .....
3.1.	Physical properties of materials .....
3.2.	Chemical properties of materials .....
4.	Processing parameters .....
5.	Processing methods .....
6.	Test methods .....
7.	Technical requirements/Specifications .....

## Introduction

Today's wood and furniture manufacturing is not imaginable without hot melt adhesives. They constitute the only adhesive system which allows modifications of processing parameters during processing. For example: viscosity of a hot melt adhesive can be widely adapted to the desired conditions by controlling temperatures. This makes hot melt adhesives the perfect adhesives when work processes must be controlled and automated.

It is the purpose of this data sheet to clarify the multitude of terms and definitions processors of hot melt adhesives are faced with.

### 1. Definitions and terms

According to DIN EN 923<sup>1)</sup> a hot melt adhesive (German: Schmelzklebstoff; French: Colle thermofusible) is defined as an adhesive system which is hot melted and develops cohesion (internal strength) after cooling.

Principally, a hot melt adhesive, like all adhesives, consists of one or more polymers plus additives such as pigments, stabilizers etc. More information in chapter 2.2. Chemical characteristics of adhesives.

Usually, hot melt adhesives are named after the base polymers:

Many systems can be formulated to be reactive and **thermoplastic**. **Thermoplastic bonds with hot melt adhesives** are reversible. Under sufficiently high thermal stress, they once again liquefy and consequently lose their cohesion.

To counteract this fact (which is sometimes desired – just think of recycling), the polymer molecules must be cross-linked after setting (chemical linkage). Loss of cohesion at higher temperatures is consequently reduced and adhesive forces of the hot melt adhesives are maintained. These systems submitted to chemical cross-linkage after the cooling phase are so-called **reactive hot melt adhesives**.

In melted state, the hot melt adhesive is a **liquid**, the so-called melt. Only in this state, the adhesive wets the elements to be joined, the so-called substrates and develops **adhesion** with these elements. However, a liquid cannot transfer bonding strength, consequently has little **cohesion**. After cooling, the hot melt adhesive becomes a solid (mostly Amorphous, with more or less crystalline fraction) with very high cohesion.

Once the bond is prepared, the visco-elastic polymers ensure that adhesion will be preserved even after cooling process which results in changes of volume and affiliated development of mechanical stress. The built-up cohesion provides the adhesive strength between the substrates.

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

Base polymer	Notes
Ethylene-Vinylacetate (EVA)	frequently used base polymer
Polyolefine (APAO)	For higher thermal resistance
Polyamide (PA)	High thermal resistance and easy processibility
Polyurethane (PUR)	Frequently reactive system with high thermal and moisture resistance

## 2. Characteristics of adhesives

### 2.1 Physical characteristics of adhesives

It results from above description of the bonding process that when describing a hot melt adhesive, we must accurately distinguish if referring to the melt, the phase transition or the set solid. Most **application parameters** describe the melt, in contrast, most **selection criteria** describe the solid.

The melt is described based on variables specifying a liquid, such as viscosity; the solid however is specified by mechanical variables such as the G-module. In-between are the parameters describing the phase transition between the two such as for example the softening temperature.

Variable	Abbreviation	Unit	Measuring method	Description
Viscosity	$\eta$	Pa·s	rheometer	describes flow characteristics
Melting Flow Index	MFI	g/10min	MFI measuring device	Additional viscosity feature
Melting Vol. Index	MVI	ml/10min	MFI measuring device	Additional viscosity feature

Variable	Abbreviation	Unit	Measuring method	Description
Flow point	FP	°C	Kofler-heating bench <sup>2)</sup>	Visual properties of melt during cooling
Softening temperature	EP	°C	Kofler-heating bench Ring & Ball method <sup>3)</sup>	Visual properties of solid during heating

Variable	Abbreviation	Unit	Measuring method	Description
Density	$\rho$	g/ml	volumetric	Specific weight
elast. G- module	$G'$	Pa	rheometer	Memory module describes elasticity
plast. G-module	$G''$	Pa	rheometer	Loss modulus describes plasticity
Relaxation time	$\tau$	sec	rheometer	Describes ratio of plastic and elastic properties

## 2.2. Chemical characteristics of adhesives

Hot melt adhesives are multi-component systems which allow to adjust certain characteristics by expert combining of different polymers and additives so that, for example, hot melt adhesives can show thermal or mechanical behavior which is very different from that of the base polymers. Like with the alloy steel, which is far superior to its raw material iron, properties can be achieved by an optimal combination of different raw materials which the single substances do not have.

This allows to custom-tailor hot melt adhesives as polymer alloys. The table below lists the essential raw materials used for hot melt adhesives:

The somewhat vague term **Resin** requires clarification: following everyday usage we call those polymers resins which during melt are mainly responsible for the generation of adhesion. Those are mostly low-molecular compounds (compared to base polymers).

The term **Filler material** in this context does not constitute a synonym for "cheap blends". Filler materials decisively influence rheology and structure of the adhesives and substantially contribute to their profile. Likewise, gravel added to asphalt in road construction is not used to stretch the bitumen, but rather to ensure stability of the road surface.

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

Name	Abbreviation	Function, examples
Ethylene Vinyl-Acetate	EVA	Base polymer
Polyolefin	APAO	Base polymer
Polyamide	PA	Base polymer
Polyurethane	PUR	Base polymer
Filler materials		e.g. chalk, barite
Pre-Polymer		Cross-linking component, e.g. Isocyanate
Resin		Tackifier, e.g. natural or petrochemical resins

## 3. Characteristics of the substrates

The properties of the bond are not only influenced by the adhesive used, but also by those of the substrates. We will therefore expand our analysis to the properties of the bond as a system. It is the system we are interested in, not the individual components, the adhesives and substrates.

### 3.1. Physical properties of materials

The following table 6 lists as an example the properties of highly demanding furniture edges.

The last column "Examination" wants to infer that, at least as a comparison test, the behavior of edges at permanently high temperatures, permit an estimate regarding stress to be expected:

**Table 6: Properties of furniture edges, making high demands on bonds**

Problem	Source	Effect	Examination
Internal stress	Extrusion, calandring	Constant load on adhesive. Discharge at excess temperature	Behavior of edge in drying cabinet
Frozen-in internal stress	Production process	Effects only shown much later	Behavior of edge in drying cabinet
Degree of condensation	Production	Internal stress, resistance to water when exposed to moisture	Behavior of edge in drying cabinet

Let us look at the bond of a thermoplastic edge on chipboard. When temperatures increase above room temperature, in most cases the hot melt adhesives as well as the edges soften. The bond will hold as long as the adhesive can transmit the mechanical stress even under these temperature conditions.

The stress on the adhesive is determined by the stress occurring in the substrates – edge and board. As a result, edge material which tends to shrink in high temperatures (shearing stress) or edge material which curls (normal stress) will mechanically overstress many adhesives. In everyday usage, this is defined as "low thermal stability".

Another example is a water resistant hot melt adhesive – it will not be able to keep an edge on a chipboard which will swell in water, once the chipboard cover layer detaches when exposed to water.

These two examples clearly show that "thermal stability" and "water resistance" are typical properties of a bond, not of the adhesive alone. This fact must be considered with regard to requirement parameters.

### 3.2. Chemical characteristics of materials

For coating materials and edges as well, the base material is also used for naming. Table 7 lists some current materials with no claim to be complete. Information regarding recycling behavior and mechanical flexural strength are contained in the technical data sheets issued by the respective manufacturer. Application areas pertinent to our context are listed in the second column.

<b>Name</b>	<b>Application</b>
ABS (Acrylonitrile–butadiene– styrene)	edge
PVC (Polyvinyl chloride)	edge, surface
PP –PE (Polypropylene – polyethylene)	edge, surface
Laminates	edge, surface
PET / polyester	edge
Veneers + solid wood	edge, surface
Aluminum	edge
Chipboard	support
MDF / HDF	support
Material mix	bond edge, support

Please note that many of above materials cannot be bonded when left untreated. In some cases, manufacturer will already apply a primer which then serves as actual contact surface for the adhesive.

## 4. Processing parameters

Table 8 on page 7 is a list of "practical" parameters which are often questioned and misunderstood. These are variables to be attributed to the phase transition of hot melt adhesives from liquid to solid.

These parameters, which in most cases refer explicitly or implicitly to time, directly influence settings of the production machine.

Strictly speaking, these variables are not parameters relating to the adhesive, but rather settings, i.e. production parameters, defined by the production environment. Consequently, for different applications, these parameters may widely vary for one and the same hot melt adhesive.

This explains why any attempt to standardize these values must fail.

On the other hand, these variables have emerged from practical experience and are strictly speaking the only information which really interest a user. Based on a simple model, we will try to submit a tool to assess the problematic variables (which cannot be measured) with the help of measurable adhesive parameters and measurable environmental parameters.

### We consider the following model:

A hot melt adhesive wets the substrates while still liquid. Wetting depends on viscosity and surface tension in liquid state. Both are measurable functions of the temperature.

By releasing heat to substrate and environment, the adhesive cools off. At the same time, its viscosity and surface tension increase, wetting power is reduced and cohesion (strength) increases. Speed of these processes is a measurable characteristic defined by the heat flow. (Slow, if the environment poorly abducts heat and the adhesive has a high thermal capacity, fast when the environment is very cold, because in this instance the heat flow is great).

Table 8: "Practical" processing parameters for hot melt adhesives			
Term	Definition	Controllable variables	Implications
Open time	Time after application of adhesives during which proper wetting of substrates is ensured.	Heat flow Ambient temperature Substrate temperature  <i>Can be controlled by user</i>	Maximum time after application of adhesive until joining of the substrates
Setting time	Complete cohesion development Viscosity unmeasurably high. Cross-linking – physical and chemical – has noticeably set in.	Substrate properties Ambient conditions  <i>Can be controlled by user</i>	Minimum time after application of adhesive until mechanical load rating of glue joint
Surface tension	Temperature-dependant variable for wetting behavior of liquids	Adhesive temperature  <i>Can be controlled by user</i>	Important for adhesive discharge on rolls
Heat adhesiveness Initial tack	Cohesion and adhesion with elevated temperatures	Viscosity profile  <i>Can be controlled by user</i>	Effect on mechanical load rating during joining process
Time for development of cohesion	% of final strength	Viscosity profile  <i>Can be controlled by user</i>	Effect on mechanical load rating right after joining process
Ability for reactivation	Remelting behavior	Reactivation temperature <i>Can be controlled by user</i>	Joining behavior
Milling behavior "Spreading"		Viscosity profile  <i>Can be controlled by adhesive manufacturer</i>	Machining of finished parts, tool
Stringing "Angel hair"		Adhesive temperature  <i>Can be controlled by user</i>	Contamination of finished parts and tools

## 5. Processing methods

Table 9 lists typical applications for hot melt adhesives in the furniture industry and the related processing methods. The processing parameters described carry different weight depending on application. In each case, 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** varies. It is important that application method and adhesive type are well coordinated. Some typical forms of delivery are granulates, cartridges or blocks. With reactive hot melt adhesives, packaging must protect the adhesive from

ambient moisture in order to prevent premature reactions. The same applies for melting devices.

## 6. Test methods

In table 10, we are listing the primary methods for testing a bond with hot melt adhesives. Most of them are used at the customer site for quick quality control. All methods have in common that they are object tests. They make sense to test bonds, however do not claim to provide information on an adhesive without substrate. In terms of above statements this would in any case be futile.

The two last columns constitute the TKH assessment. Discrimination/resolution is a term from measurement and test engineering and we

use it to characterize the potential of the relevant process to detect subtle differences in quality.

Application	Characteristics	Mode of application	Important parameters
Straight edge	Application of adhesive to base plate or edge material	Applicator roll, nozzle, HolzHer adhesive application systems	
Soffforming	Application of adhesive to edge material	Applicator roll, nozzle	Open time, initial strength
Stationary treatment	Workpiece is clamped and machined and an edge is added	Applicator roll	Initial strength
Pre-coated edges	Application of adhesive to edge material; adhesive is reactivated	Applicator roll	Reactivation
Postforming	Shaping of surface coating around edge	Applicator roll Application with nozzle	Initial strength
Coating	Application of adhesive to coat	Applicator roll, nozzle	Open time
Assembly bonding	Assembly tool "hot nail"	Nozzle, hand operated gun	Open time

Term	Method / feature	Discrimination	Validity
WPS 68 <sup>4)</sup>	Creep behavior	poor	very limited
Peel strength	Peeling 90 degrees Flexural strength of edge/foil	Contingent on edge/foil material	good
Manual adhesion test	In-house methods	varying	good
Ascending heat test	Proof stress defined by edgefoil material	moderate	moderate
Cold testing	In-house methods	very limited	limited
Alternating climate test	Proof stress defined by edge/foil material	contingent on edge/foil material	moderate
Long-term testing	Proof stress defined by edge/foil material	adequate	good
Water resistance	In-house methods	poor	very limited

## 7. Technical requirements/Specifications

Based on the processing methods (chapter 5) and the relevant processing parameters (chapter 4), the appropriate adhesive can now be selected. In addition, technical requirements for the different areas of application can be defined. Different test

methods (chapter 6) help in comparing test results.

Suitability of an adhesive for a specific area of application not only depends on the raw material base or other individual parameters. In each

individual case, the interaction of all features must be considered. Frequently, certain adhesives might be designated as the standard for certain areas of application. This means that they have been proven and tested over the years and comply with the main stress classifications listed in table below.

The effect of the adhesive on test results is considerably lower than generally presumed. In fact, it is rather processing during bonding, as well as resistance of coating and substrate materials which play the crucial role.

Consequently, the result of these tests only show the behavior of the component under certain climatic conditions. These tests help to define the quality achieved. The results may later be used as reference for quality control testing.

**Table 11: Primary methods for testing of hot melt adhesive bonds**

Area of application	Main stress class	Technical requirements/parameters
Standard furniture sector	Variety of substrates, adhesion requirements	Processing parameters
Bath and kitchen furniture	Heat resistance Vapor resistance	Different test methods (chapter 6)
Extreme climatic conditions	Heat resistance vapor resistance Low temperature resistance	Different test methods (chapter 6)

**Literature:**

- 1) DIN EN 923 "Adhesives – Terms and definitions", German version EN 923:2005, Publisher: Beuth Verlag, Berlin
- 2) Kofler Heat Bank: Metal plate with defined temperature gradients
- 3) ASTM E 28: Test method for softening point; Ring-and-Ball method
- 4) WPS 68: Testing of heat resistance with ascending temperature under defined load