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Understanding and troubleshooting hot melt adhesives

Scope

This Technical Information Paper is presented to serve as a guide in understanding the characteristics of hot melt adhesives used in packaging applications, the terms that are used to express these characteristics, and the factors that influence the adhesives performance. This TIP also serves as a guide in understanding the components of hot melt application systems and their function in the dispensing cycle.

Safety precautions

Safety protocols should be observed when working near molten hot melt adhesives and all parts of hot melt application systems that generate heat or transport molten adhesive. Danger also exists from solid hot melt, especially hard pellets and beads, which if spilled on the floor near a machine can contribute to a fall.

Content

Hot melt adhesives were first developed for commercial use in the 1950's. In the early 1960's they were first used on low speed case sealing equipment to seal the flaps of corrugated boxes. Since then many advancements have been made in hot melt adhesive technology and in the systems that apply them. Customers have demanded higher production speeds and systems capable of providing the desired application pattern, consistent with every dispensing cycle.

As acceptance and dependence has grown, the customers of the box maker have often experienced problems sealing their boxes. All too often a customer has cried that, "something is wrong with these boxes!" when the real problem is a poor understanding of the variables in hot melt adhesives, in the application system, variables in the materials to be bonded, poor house-keeping practices, or inadequate maintenance. It is very hard for the box maker to find a diplomatic way of telling a highly agitated customer that his troubles sealing the boxes may be of his own making. It helps to know the basics about hot melt adhesives and their application systems. When you ask him questions that define the problem, the possible causes are often suggested. These causes may lead the customer to think about first-aid options he can investigate until experts from the adhesive company and/or equipment manufacturer can arrive on the scene. These analytical questions help define what the problem is from what it is not. This is an important first step in solving the quality issue. You have helped the customer help himself. The first part of this TIP will focus on the adhesives themselves, their characteristics and the meaning of the terms used to express these characteristics and factors that influence their performance. The second part of this TIP will focus on the application equipment and the function of each component in the dispensing cycle.

Compliance to safety protocols should always be observed when working near molten adhesive and those parts of the application system that generate heat or transport molten adhesive. Hot melt burns can be very serious. If molten adhesive does get on someone's skin, submerging the area immediately into cold water will pull the heat from the hot melt and reduce the amount of damage to the skin. Another less recognized safety issue has to do with

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using the bead or pellet form of many hot melt formulas. Hard beads or pellets if spilled on the floor can cause an operator to fall.

Hot melt adhesives are **thermoplastic** polymer-based compounds. Hot melt adhesives are sold in a variety of shapes including: pillows, slats, pellets, beads and sticks. When heated these forms liquefy and flow. They return to a solid form when their temperature cools below a certain point. In other words, hot melt adhesives depend on heat for flow and upon heat dissipation for setting.

A variety of synthetic materials are used to achieve the flow characteristics and specific properties desired in a particular hot melt adhesive. The base compounds provide the backbone or core of the adhesive by imparting such properties as mechanical strength, flexibility and end use properties such as: heat, cold and chemical resistance. Two common base compounds are ethylene-vinyl acetate (EVA) copolymers and polyethylene (PE) homopolymers. The base used, its chemical nature and its molecular weight governs how the base works and determines what other compounds are needed to complete the formulation. In most cases the base adhesive will not be used alone. The goal is to match the hot melt adhesive's properties to the performance requirements.

The other chemical additives function to modify the base compound. These compounds fall into three general categories: **Tackifiers**, **Diluents**, and **Stabilizers**, which are also known as **Antioxidants**. **Tackifiers** impart **hot tack**, which is the relative stickiness of the adhesive. This property means that it has a certain degree of holding power even while in the liquid state. The tackifier used depends on the specific adhesion properties required for a particular substrate. The tackifier used will also typically determine the color and characteristic odor of a particular hot melt adhesive. **Diluents**, such as waxes or oils, modify the adhesive's viscosity and **set speed**, which is also known as **set time**. **Stabilizers** help protect the other compounds from **charring** which changes the physical and chemical nature of the adhesive. Stabilizers also provide viscosity stability to the hot melt adhesive. The base compounds plus these additives has resulted in thousands of different formulations. These variations are necessary due to the many ways hot melt adhesives are used in the field.

When matching an adhesive to an application situation and field performance requirements, the first consideration is the specific properties of the substrates to be bonded. Papers high in recycled content are different from high ring crush papers. Coated board is a different substrate than laminated stock etc. The second consideration is the stress performance requirements. These stresses might include: heat, such as a trailer in the summer; cold, such as freezer conditions; mechanical forces, such as case weight; chemical or oil resistance; and cost.

Hot melt adhesives are formulated to perform best when applied in a specified temperature range. This **operating temperature range** will be listed in the guidelines from the adhesive supplier and will vary from product to product. It is very important to follow these guidelines. The temperature range controls the adhesive's viscosity and viscosity controls the adhesive's ability to wet a surface. If heated and applied below the optimum range, the adhesive will be unable to wet out the surface causing a superficial bond that will break when stressed. If the adhesive is heated beyond its optimum range, too much wet out will occur on one side causing the other substrate to be neglected. The viscosity of hot melt adhesives is expressed in units of **centipoise (cps)** at a specified temperature. The term **melt-rate** refers to how fast a particular adhesive will liquefy when heated to its operating range specifications and is strongly influenced by the type of melt unit used and other characteristics of the equipment.

Other properties impacted by temperature are open time and set speed. Open time refers to the length of time the adhesive can be exposed and remain hot enough to create a bonding state. Set speed refers to the length of time it takes for a bond to form between the two substrates. Most hot melt adhesives have very short open and set times and outside factors can easily alter these properties. For example, cold boxes (50-60°F) will cause the adhesive to set-up faster and hot boxes (100-120°F) will cause an adhesive to set up slower. Air fans around the line can also cool a hot melt adhesive prematurely, resulting in inadequate bonding. External environmental factors can play a significant role in influencing the performance of the final bond.

When dealing with hot melt products, the operator should record and save the open time and set time total for each individual line. The reading should be taken with a stopwatch when the line is running smoothly. The temperature of the adhesive at the heat tank and at the application nozzle should also be checked with a good quality, probe-type pyrometer and recorded. The line air pressure should also be recorded since it impacts the quantity of adhesive applied. If possible, the line speed should be slowed until the maximum open time for the adhesive is found, then increased until the minimum set speed is determined. These measurements help define the operating window for that particular adhesive, at a particular application rate and temperature, on a particular application system. If these values are unsatisfactory to production's goals, the adhesive vendor should be consulted for another product that will perform under the desired application conditions and field requirements.

The third property impacted by temperature is the formation of **char**, the biggest villain in any hot melt application system. Char occurs when the properties of the adhesive are altered through **thermal and oxidative degradation**. In its final stages, char results in hard clumps that have lost their thermoplastic nature and will not flow. Slowing the rate of change stabilizes consumption rates and reduces both adhesive waste and waste in the form of boxes that need to be repacked or resealed because of an inadequate seal. Downtime on the equipment caused by clogged filters and application nozzles is also reduced and the life of heating elements extended.

The following illustration depicts the changes to the adhesive during char formation. 1) An adhesive is made up of many polymer chains that combine to form the fluid product. Dissolved oxygen attacks the polymer chains causing them to combine or break apart. In the second picture they combine causing the adhesive to increase in viscosity. As the linkages increase, they form gelled materials. These gels can be seen in the form of skins and clumps of adhesive. Ultimately the gels settle to different areas in the tank or hoses and harden to the point that they lose their thermoplastic nature.

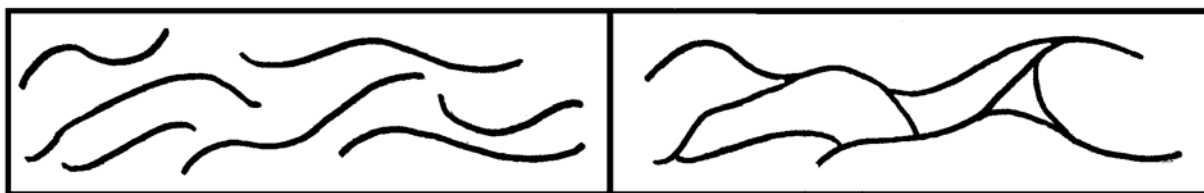


Fig. 1. Changes to the adhesive during char formation.

Many operating procedures and housekeeping practices can slow the formation of char. These practices include: maintaining a consistent level of adhesive in the pot; keeping the pot lid closed; running the system within the recommended temperature range; cleaning the tanks on a regular basis; and turning down the heat when no demand exists for the molten adhesive, such as extended line downtime.

Turning down the heat can be done manually on systems that lack an automatic **set back control**. Failure to turn down the heat when no demand exists for the molten adhesive can easily occur in those operations that run their case sealing machines two shifts a day.

Char is not the only thing that can clog the application system. Foreign contaminants such as paper, dust and other airborne particles can also cause clogs. These contaminants are often introduced into the system because a box or drum of solid hot melt was opened and left uncovered on the factory floor. Contaminants fall into the box and are later fed into the system along with the solid hot melt.

The volume of adhesive applied is another critical operating variable. The amount of adhesive applied is important because the greater the amount, the longer the bonding range the adhesive will have. This does not mean that more is always better, it means that determining the correct amount is necessary. If too little is applied, the adhesive may cool too quickly, resulting in an inadequate bond between the substrates. If too much is applied, the heat may not dissipate fast enough for a bond to form before the case exits the compression section. Too much or too little adhesive can both provide the same result: a poor or inadequate bond.

Once the amount is determined it is important that the **application pattern** be held constant by the application system in order to achieve consistent bond results. This means not allowing size variation in the beads of adhesive applied, or width and length variations when the adhesive is applied in lines. A recommended practice is for the operator to retain a sample of the application pattern of the hot melt, before bonding, when the case sealer is operating properly. This permanent record will give a quick visual reference of how much adhesive is needed for good bond. In the future it could be compared against another bead pattern and reveal, for example, that a partial obstruction has reduced the bead size, which has caused the hot melt to cool faster and resulted in a poor bond.

While invaluable as a quick visual reference during a production run, the measurement of bead and lines should not be used by the customer as a method of determining consumption rates and cost. This is because very small variations cannot be easily observed and measured. For accounting purposes, only accurate weight measure should be used. Weight measurements are far more accurate and are often looked at in the form of some type of mileage indicator, often a cost/unit sealed. This may be something as simple as cost/pound of hot melt purchased vs. thousand boxes sealed. Consumption rates are an excellent means of monitoring application amounts, troubleshooting waste issues caused by char or other contaminants and budget forecasting.