Hot melts for bookbinding: past, present, and projected

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This review of the bookbinding process highlights the uses and limitations of hot-melt adhesives in such operations as lining up, hinge gluing, tight backing, rounding and backing, and perfect binding.

Adhesives have been helping to hold books together since the early versions of our modern books were devised. The original adhesives were simply starch pastes made of flour and water or animal glues derived from cooking down bones or hides.

Even after the advent of movable type, it was still some years before book production was automated, due in part to the limited availability of paper. As paper became more plentiful, the number of printed books increased. Early books were held together by hand stitching the pages and then gluing on a handmade cover. Starch pastes and animal glues were quite sufficient for hand operations.

By the early 1900s, the demand for publications had increased to the point that a means of rapid production was necessary. Wire was widely used in production of "saddle stitched" books that were held together with stitches or staples placed from the outside to the center fold of each book. The demand for these publications continued to grow, as did the demand for publications of larger size. The market responded by developing innovative methods of rapid assembly.

After the turn of the century, machines were developed to "side stitch" high-volume books and magazines. The side-stitched publications had soft covers held in place with animal glues. These glues, which were applied warm, cooled down and gelled for rapid setting but had a long tack time. The use of these adhesives eliminated much of the hand work associated with book production, thus paving the way for further developments.

Early hot melts

Animal glues were replaced by hot-melt adhesives shortly after World War II. Hot melts were relatively easy to apply, and they set rapidly enough to hold the cover on the spine of the book under relatively high production rates. After the signatures—folded printed sheets—had been side stitched together, the uneven ends on the spine of the book were milled off to give a square finish.

Shortly thereafter, side-stitches were eliminated in favor of "perfect-bound" books. (Your copy of *Tappi Journal* is a perfect-bound book.) Such books obviated the need for stitches or staples, since they were held together with nothing more than adhesive. This innovation marked the beginning of the modern bookbinding era, starting in the late 1950s. It was during this era that emulsion polymers—synthetic plastic-like polymers suspended in water—found increasingly greater application in hard-cover bookbinding. These polymers were used alone or in combination with starches that were enhanced versions of the earlier flour pastes.

During the late 1950s and early 1960s, the use of hot-melt adhesives for binding soft-cover books and magazines increased rapidly. The earliest products were manufactured using whatever thermoplastic materials were available. Polyvinyl acetate (PVAc), a homopolymer with plasticizer, was one of the first major innovations. The development of a redispersible, carboxylated version facilitated the recovery of wastepaper but proved to be less than satisfactory in binding applications. Emulsion adhesives—applied to the spine of the book and then allowed to dry—served as a primer for the hot-melt adhesive. The resultant books were sufficiently flexible, but they had a tendency to come apart under stress because of the cold-flowing nature of the adhesive system.

Following the development of ethylene vinyl acetate (EVA) copolymers in the early 1960s, it became possible to produce a hot-melt adhesive that could be applied to book spines in a single application at high production speeds. The EVAs were combined with waxes and tackifiers, thus paving the way for today's hot-melt technology.

A manufacturing rate of 60-100 books/min was considered to be a high rate of production until the mid 1960s, when it became possible to produce books at what was then a blinding rate of 180 books/min. The race was on to produce perfect-binding hot-melt adhesives that were longer lasting, more heat stable, lighter in color, and economical. Cost and quality were, and still are, major factors controlling the direction of research.

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One of the first applications of hot-melt adhesives to hardcover books was in the operation known as "lining up." The "lining up" of a book involves bonding the reinforcing "scrim"—an open woven fabric also known as the "super" or "crash"—to the spine of the "rounded" book prior to application of the kraft liner. By the early 1970s, hardcover book manufacturers were evaluating hot melts in an effort to replace some of the hinge pastes and, shortly thereafter, to replace certain emulsion resins used to "tight-back" books. "Tight-backing" is the bonding of the case to the back of the book block to further reinforce the backbone of the book. The book's cover or "case" is manufactured and then attached to the book in a separate operation.

Hot melts also were tested as replacements for animal glues in the production of cloth-covered "cases" for hardbound books. Bookbinders believed that the animal glues used to bond the cloth to the end boards contributed to the case's tendency to warp. (Subsequent studies indicated that animal glues were not a major cause of warping.) Unfortunately, the thermoplastic hot melts in use at that time presented problems during hot-stamping or embossing operations. The heat from the hot-stamping or embossing irons drove the hot melts into the end-board stock, thus effectively removing the bond between the board and the cloth cover. When the irons were lifted from the cover, the picking action often was sufficient to lift the cloth cover free of the end boards, thus creating a blister in the portions of the cover that had been stamped or embossed. This was the major reason for discontinuing experimentation with hot melts in case-making operations. A simultaneous reduction in the cost of animal glues further reduced interest in the use of hot melts for this application.

Up until the late 1960s, the industry believed that hot-melt adhesives had too much "memory" to replace the traditional practice of sewing book blocks together before encasing them in a hardbound cover. When it became apparent that paper itself had memory and that the gluing of books with hot melt merely added more material to push when rounding and backing the spine of the book, development took off for hot-melt adhesives that were flexible enough to be stretched out and had enough loss of memory to remain in the new configuration.

During the late 1960s, use of the early plasticized PVAc homopolymers was discontinued because some of the plasticizers were found to be hazardous to the environment. This left a vacuum in the area of flexible adhesives for magazine production. Work done with rubber-based polymers, such as styrene-butadiene rubber (SBR) and styrene acetate copolymers, was revised. These polymers, combined with waxes and tackifiers in a fashion similar to EVA compounds, worked best when used with emulsion primers similar to those used with the plasticized PVAc hot melts. The major difference in the emulsion primers was that they were based on EVA rather than plasticized PVAc. This development, along with gradual improvements in the EVA-based hot melts, prepared the way for the replacement of sewn books, encased in hard covers with hot-melt perfect binding.

During the late 1970s, hot melts were foamed in an attempt to extend their mileage and thus make them more economically attractive. Foaming also increased open time and improved bonding to many surfaces. Tight backing, hinge gluing, and lining up seemed to be compatible applications for the technique. However, attempts to incorporate foamed hot melts in perfect binding met with limited success.

Hot-melts: applications and limitations

Major developments in hot-melt adhesives have continued throughout the 1970s and into the 1980s. These developments include improved adhesion and strength as well as adaptation to changes in paper stock. Refinements in such parameters as color, product stability, and temperature resistance are continually introduced as new raw materials become available. Products are also developed in response to such machine properties as open time, rate of set, and product foaming in the applicator pot due to agitation at high machine speeds.

There appears to be a limit beyond which hot-melt adhesives will no longer increase application speed or rate of set. This is because hot melts, like all adhesives, require a certain amount of time to wet the surfaces that are to be bonded. Proper adhesion is a function of time as well as surface tension, which determines the time needed for wetting.

Equipment developments allowed smaller operations to utilize hot melts for lining up. As a result, hot melts found a market in lining-up operations for hardcover books with small press runs. Further equipment developments enabled the use of hot melts in book-hinge applications. These adhesives had to be flexible over a wide temperature range and hold well to paper, including synthetic papers, under conditions of mechanical stress. The most important requirement was a long open time. This allows hot melts to be applied in thin films while retaining their ability to bond.

Hinge gluing involves the application of heat and compression to the joints or hinges of a book after the cover has been applied. The additional heat applied to the joint or hinge tends to reactivate previously applied adhesives in that area, allowing wetting from the book block to the cover. The challenge is to produce an adhesive that continues to hold when the compression is released and the covering material on the book tries to pull away from the bond in the joint area.

Hot melts used in tight-backing and lining-up operations also must be capable of maintaining their bonds at the elevated temperatures common in many warehouses. If the bond fails to maintain its integrity under these conditions, the cover and liner can be separated from the book.

The viscosity ranges of various bookbinding adhesives are listed in **Table I.** The relatively low viscosity of hinge-gluing and tight-backing adhesives allows application by extrusion through a nozzle. However, this poses an additional problem. The lower viscosity can be attained only by lowering the adhesive's average molecular weight. The lower molecular weight represents a challenge to adhesive formulators, who must provide compounds that can maintain their tack and strength while meeting application requirements.

Lining-up adhesives are frequently applied with a roller-type applicator. This allows the use of higher-viscosity products, which gives bookbinders the option of using adhesives with higher molecular weight and thus greater

I. Adhesive viscosity for various bookbinding applications

	Viscosity, cP or mPa
Hinge gluing	1000–2000
Tight backing	1000–2000
Lining up	3000–5000
Perfect binding	4000–8000

strength. The lining-up adhesives are sometimes bonded to the backs of books that already have been glued with an emulsion resin or another hot melt. These bare surfaces present a bonding challenge for lining-up adhesives, which are also expected to bond to the scrim or crash and the head bands on the kraft liner. The head bands, which today have little more than decorative value, present a bonding problem, since they are frequently starch sized and thus provide a loosely anchored surface for adhesion.

Perfect-binding adhesives

One-shot and two-shot perfect-binding hot melts are expected to have considerable strength, both adhesively and cohesively. The one-shot adhesives are expected to bond to a wide range of paper stocks and have good adhesive aggressiveness to end-coated papers and papers that have been coated with a wide variety of materials to enhance their appearance and print quality. Many of these coatings are designed for cosmetic reasons, and it is the adhesive formulator who must cope with the problems involved in binding these papers into a book or a magazine.

Perfect-binding adhesives are expected to bond to the edges of the paper sheets that form the pages of the book or magazine. If the surface area of the paper edge is the only surface area bonded, the adhesives used for bookbinding are severely challenged. For example, if we are bonding to sheets of paper that are 0.005 cm thick (0.002 in. or two points) and trimmed to a book length of 25 cm (10 in.), and if the adhesive's strength is equal to its internal or cohesive strength, then the cohesive strength of the adhesive would have to be a least 10,340 kPa (1500 lb/in.^{2}) to develop a page pull of 14 kg (30 lb) per page.

Since the cohesive strength of most perfect-binding adhesives is somewhat lower than that value, some adhesive penetration between the pages is needed to provide a small amount of side-to-side bonding along the backbone edge. This slight penetration adds considerable strength to the book. Such penetration can be accomplished mechanically, but the type of paper and coating, its smoothness, and its porosity all affect the adhesive's ability to penetrate into the paper along the backbone. In two-shot systems, the primer is expected to develop this penetrating bond.

In both one-shot and two-shot hot melts, the adhesives are expected to be flexible enough to allow the book to be opened easily while providing sufficient support to prevent disruption of the side-to-side bonding and to prevent breaking of the backbone. This suggests a cohesive or tensile strength of at least 5510 kPa (800 lb/in.^{2}) and adhesive ability at least equal to the cohesive strength of the adhesive. However, the ability of the adhesive to penetrate between the individual pages of the book allows the use of hot melts having lower-than-theoretical cohesive strength.

Adhesives used in rounding and backing operations must provide sufficient memory loss and a yield strength low enough to allow the product to be stretched out and then remain in that stretched condition. Ideal yield strengths range between 2100–2800 kPa (300–400 lb/in.^{2}). Memory loss should allow a product stretched out three times its original length to remain stretched out to approximately two times its original length.

Perfect-binding adhesives can have a much shorter open time than adhesives used in tight-backing or hinge-gluing applications. This is because perfect-bound books require a much shorter time between application of the adhesive to the spine and subsequent application of the cover.

Future developments

The recent past and the present provide clues to the future of bookbinding adhesives. There have been periodic requests for products that allow the wastes trimmed from the books, or even for the entire book, to be repulped. This need fluctuates with the cost of wastepaper. The cyclic nature of these requests has impeded the development of repulpable products. While such products are available, they have not received the attention that has been devoted to the more commonly demanded and readily available EVA- or SBR-based products.

Another future need is for products that will resist the effects of ink solvents. Ink solvents are often trapped in the signatures that constitute a book block. After the books are manufactured, the solvents tend to migrate. If they reach an area that is open to the air, they generally evaporate. If high concentrations of these solvents reach the adhesive that binds the book, they can soften the adhesive significantly, causing the book to weaken and, in some cases, come apart almost spontaneously. Certain types of polyamides and post-curing adhesives containing polyurethane are potential solutions to this problem. Since the solvents in question attack primarily the tackifying resins of the EVA or SBR adhesive types, it is this component that needs to be eliminated from the system. Polyamide hot melts appear to offer the greatest prospect of relief.

There is also a demand for books that will last longer. In this case, it appears that polyurethane post-curing adhesives are likely candidates to provide longevity as well as resistance to temperature extremes and other environmental factors that weaken the adhesives used in perfect-bound books.

Post-curing adhesives, including polyurethane-based types, may also be candidates for the manufacture of book cases or covers. Since they would cure out after application, they may be able to resist melting under the high temperatures imposed during hot stamping or embossing.

Pressure-sensitive hot-melt adhesives, recently introduced to provide open time and better adhesion in areas such as lining up, hinge gluing, and tight backing, may have a good future if they can be compounded to resist the cold flow or creeping often associated with these products.

It is unfortunate that polyurethane-based post-curing adhesives, polyamids, and redispersible adhesives are more expensive than the adhesives commonly used for bookbinding. While the average cost for most hot melts ranges from $0.90 to $1.20 per pound, the more innovative adhesives usually start out in excess of $1.75 per pound, with the cost of most substances at $2.00 per pound and more.

New and innovative bookbinding adhesives are available for the future. With but little research, compounds available today could be modified to meet individual needs. The question, then, becomes one of economics: Is there a willingness to pay for new adhesives and will they really be worth the additional cost?

To project into the future, we need to look into the past. There have always been economic incentives to provide competitively priced new products to satisfy the needs created by new developments in papers, inks, and machining conditions. Economic forces will continue to shape the market. However, it appears that significant future developments will depend upon daring and innovative people who are willing to look at available technology and then expend the necessary time and effort working with their suppliers to bring that technology on stream.□

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