

PUR Applications in Folding-Carton Production

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Baumer hhs GmbH
Adolf - Dembach - Str. 19
47829 Krefeld
Tel. +49 (0) 2151 - 4402 -0
www.baumerhhs.com

Responsible for content: Andreas Brandt / Thomas Walther
Author: Jens Backer

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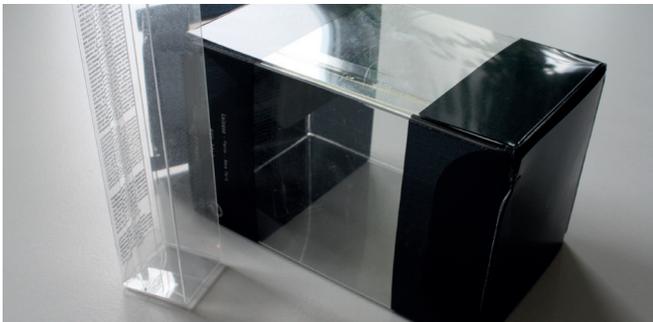
Packaging enhances the product value

The days are long gone when packaging merely served to protect its contents. If a carefully conceived folding carton is printed and produced to high quality standards, it can do much more than that. It adorns and upgrades the packaged product, offers valuable space for information and advertising, and ultimately becomes a selling point in itself thanks to its attractive and exclusive look.

The choice of material plays a major role in this context. Elaborately coated materials are frequently used, their convincing features being an unusual appearance and pleasant tactile properties. As a result, more and more use is today being made of plastics or composite materials, where a folding carton made of simple board would still have been used not long ago. Innovative printing processes make it possible to achieve special gloss or holographic effects on the surfaces of metallised and plastic-coated materials.

Folding cartons made of completely transparent plastic are a special form of this packaging. In this case, the aim is to give the observer an unobstructed view of the product. He can get an immediate, direct impression of its appearance or design, rather than just seeing a printed image of it. The product itself is the focus, more so than in the case of a window carton. And despite the clear view from all sides, the transparent folding carton still offers every possibility for protection, providing space for information and enhancing the product.

Be it for model trains, underwear, toys, cosmetics or foods of all kinds – packaging in transparent cartons is a rapidly growing



Pic. 1: High quality box out of transparent material

market, particularly in the high-end price segment of many products. Special and occasionally novel materials are the means of choice when it comes to attractive and effective packaging. And the end of new developments and ever more effective materials and surfaces is not yet in sight.

Materials for the packaging of the future

While simple PE films were still the predominant material for transparent folding cartons just a few years ago, many more plastics are available today. Their properties and processing options are correspondingly different and diverse. Every substrate has its own, highly individual advantages and disadvantages that always have to be taken into account when using and processing the material in the form of folding cartons. For example, while PE (polyethylene) is one of the cheapest film materials, it also has substantial disadvantages, particularly for folding-carton production. It is always slightly milky-opaque and matt (the higher the density of the material, the

greater the opacity of the film), is easily scratched on the surface, has a low deflection temperature, displays high resilience (memory) and is known for being very hard to print or glue by conventional means and methods. Everyone is familiar with the little plastic tray made of PE, in which the typical 2-pack epoxy resin adhesive for household use is mixed. The fact that a block of cured adhesive can later so easily be detached from it, illustrates the difficulty of gluing PE films on a folder-gluer.

However, the material needs to be as crystal-clear as possible if transparent folding cartons are to be produced. It should be highly scratch-resistant, it must be printable, the resilience must be manageable, it should permit good, stable gluing, and the stability and deflection temperature of the product must later be sufficient for the intended application.

This is where the many different materials and manufacturing options in plastic film production come to bear. The appearance and

Designations of some transparent plastics

- PE: Polyethylene
- PE-HD: Polyethylene of high density
- PE-LD: Polyethylene of low density
- PC: Polycarbonate
- PP: Polypropylene
- MOPP: Monoaxially oriented polypropylene
- BOPP: Biaxially oriented polypropylene
- PVC: Polyvinyl chloride
- PLA: Polylactic acid
- EVA: Ethylen vinyl acetate
- PET: Polyethylen terephthalate
- PET-A (aPET): Amorphous polyethylen terephthalate
- PET-G (gPET): Polyethylen terephthalate with glycol
- PET-M (mPET): Metallised polyethylen terephthalate; also called mylar polyester film or biaxially oriented PET (boPET)

properties of films can be modified and selected on an application-specific basis. Individual plastics can be modified by means of additives, and the advantages of several individual materials can be exploited by producing composite materials. For instance, PET-GAG film combines the advantages of the two PET types: the facing layers of PET-G ensure that the surface is easy to print and glue. In contrast, the solid inner layer of PET-A gives the film its mechanical strength, as well as ensuring low gas permeability and a moderate price of this film type. In this context, recycled material is also used for the PET-A core, this enhancing the sustainability of the film. PET film is generally appreciated for its numerous positive properties in folding-carton production. In contrast to PE or PVC folding cartons,

Resilience („memory“)

The tendency of a material to want to return to its original position after being folded, is particularly pronounced in some plastic folding cartons. The forces generated as a result are referred to as resilience or „memory“. The term refers to the material's „memory“ of its original form. In plastics, this property has its origin in the orientation of the long-chain molecules.

This unpleasant effect becomes most apparent in the folder-gluer when the folded and glued cartons emerge from the pressing belt and have to be packed. They often pop open so much that they are difficult to pack at all. The glued joints can also suffer greatly as a result of the high resilience, both in optical terms (in transparent packagings) and as regards its load-bearing capacity.

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which are usually slightly milky, it displays extremely high transparency, can often be glued better than other films, and has very little resilience. Polycarbonate likewise has excellent transparency, can withstand high temperatures, and is very scratch-resistant. Owing to their safety as regards migrating harmful substances, packagings made of PLA film are eminently suitable for packing foodstuffs and pharmaceuticals. They do not need additional lamination or barrier coatings, and can nonetheless be used as primary packaging at any time.

Deflection temperature

The deflection temperature is a measure of the temperature resistance of plastics. If finished folding cartons made of plastic film are later heated, they become deformed and, in the area of the folds, tend to return to their previous form. If a hot melt adhesive is used for gluing, application of the adhesive can itself already cause deformation, particularly in the case of relatively thin films.

Finally, one of the key factors for the folding-carton manufacturer is the gluing properties of the film material. Plastic films, film-laminated board, aluminium foil lamination and UV coatings can be a real challenge in this respect. Hot melts have no hold on the smooth surface; when gluing with dispersion adhesives, the water cannot soak in and dry. Indeed, as a result of the low surface energy, no glue appears to adhere to plastic or metal surfaces.

Recycling and sustainability

Resources should be handled responsibly. Therefore, efforts are undertaken to keep the cycle surrounding the production of PET films as closed as possible. This includes the sorting and collection of production and die-cutting waste, so that it can be reused for producing industrial films.

However, the repeated heating of plastics during recycling often causes them to lose some of their specific properties and thus reduces their quality. This is then referred to as „downcycling“.

The example of PLA (polylactic acid) film clearly illustrates how high-quality, transparent packaging can be produced from renewable raw materials that are 100% biodegradable.

But these are precisely the packaging materials that the current market demands. And those are just some of the complex properties of the plastics, coatings and materials finished by packaging printing. The types of packaging described are in greater demand than ever. And the requirements will probably continue to increase in the future, as developments progress. The processor therefore has to face up to the tough demands. He needs to engage in constant continuing education and, if necessary, must also adapt his technical equipment in order to remain competitive.

The high art of gluing

The processing of such difficult substrates calls for special expertise and specific measures, which will be extensively illustrated and described in this paper. It is, as it were, the „high art“ in the production of folding cartons.

The first thing is to get the frequently pronounced resilience of the materials under control. This is important for two reasons: so that the products can pass through the transitional areas between the machine segments of the folder-gluer without causing problems, and so that they can also be packed without difficulty after emerging from the machine. High resilience can also have a negative impact on the adhesive strength. This happens when the folding cartons are transported on the delivery belt and the freshly glued side seam is exposed to tensile stress during this time as a result of the resilience.

So, to be able to work efficiently with the aforementioned materials, there is a need to counteract the effects of such forces before they occur in the first place. Particular attention has to be paid to the scoring of the material for this reason. In this context, plastic films

Surface energy

The surface energy is a measure of how easily a surface can be wetted by a liquid (e.g. water or adhesive), or how easily the liquid runs off. The surface energy of a body also determines whether another solid body adheres to it readily or poorly.

The wetting properties of a solid body can be quantified by measuring the contact angle. The contact or wetting angle of a drop of test liquid on the surface of the substrate is measured to this end. As a measure of the wettability and the adhesion properties, the surface energy of the solid body can be determined even more easily with the help of commercially available test inks or test pens.

The unit of measure for surface energy is millinewtons per metre [mN/m] or dyn/m (1 dyn = 10 µN). The surface energy should be at least 36 mN/m to obtain good wettability and gluing.

should be processed on flat-bed die-cutters equipped with specially heated tools for processing plastics. This kind of hot stamping, instead of simple „cold“ scoring, not only supports subsequent edge- and position-accurate folding, but also serves as a means of minimising resilience during the folding process, while at the same time counteracting fracturing of the surfaces during folding. The next thing to think about is the right glued joint. Which type of adhesive should be used to ensure secure and durable gluing of the hard-to-glue material? How can an aesthetic glued joint be achieved on a completely transparent folding carton where you can later see through the glued flaps?

Familiar hot melts, and also dispersion adhesives, do not have sufficient adhesion on films or metallised cartons. This is because the adhesive strength of simple hot melts is based on the liquified adhesive mechanically anchoring itself between the material fibres of the substrate or on its rough surface. Similarly, a dispersion adhesive surrounds fiber structures of the substrate and holds more or less mechanically on the substrate after film formation, i.e. following complete absorption and evaporation of the water. However, smooth, metallised surfaces and films do not offer structures of this kind. In addition to which, when gluing with waterbased dispersion adhesives, this water has no way of escaping. Neither can it soak into the substrate, since the surface does not absorb moisture, nor can it evaporate, since it is trapped between the two substrate layers to be glued.

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One of the alternative options for gluing is the use of pressure-sensitive adhesives. These are usually hot melts, based on natural or synthetic resins, whose surface always retains its stickiness, even after cooling and setting. This property enables them to even adhere to films or metallised surfaces.

Pressuresensitive adhesives of this kind do, however, also have a number of disadvantages that need to be taken into consideration. The temperature stability of a glued joint based on a pressure-sensitive adhesive is very limited. A pressuresensitive adhesive becomes soft at elevated temperatures and can no longer withstand any great stress. Cartons processed in this way can often not permanently stand up to the resilience of the substrate or the later pressure of the contents, and then pop open. At low temperatures, such as occur in freezer packagings, for example, there is also the risk of the stickiness declining and joints simply bursting open. A very cold adhesive layer becomes „glassy“ and can then itself also break. In the course of time, pressuresensitive adhesives also lose some of their adhesiveness due to the volatilisation of plasticisers and similar constituents. In addition to which, the colour of the adhesive is not always exactly what is wanted. Pressuresensitive adhesives are usually not completely colourless, but normally more of a yellowish-brown colour. The glue seam will therefore always be slightly yellowish and is thus often noticeable and unattractive on completely transparent packagings.

Of course, an attempt can be made to conventionally glue cartons made of coated or specially printed materials. Coatings or varnishes can sometimes be cut out, meaning that the actual surface to be glued is the layer of board below. Also, some surfaces can be prepared by plasma pretreatment, in such a way that some conventional adhesives adhere better to them than usual. Without cut-outs, a number of manufacturers avoid gluing on the varnish or coating by gluing the flap (side seam) on the inside.

All these methods are feasible, but they are also ultimately a compromise. Technologies of this kind do not permit production of a folding carton that is not only technically and aesthetically faultless, but also stable and durable. The high art of gluing when processing such high-quality substrates necessitates an adhesive that not only offers mechanical adhesion, such as described above, but also creates a chemical bond with the substrate. A suitable adhesive may not subsequently be altered by temperature or tensile stresses, nor may it lose its durability. It must be completely clear and transparent, so that it remains inconspicuous but still delivers the expected performance. The type of adhesive that best does justice to these high demands is polyurethane (PUR).

PUR: The right mix

The abbreviation PUR stands for polyurethane hot-melt adhesive. It is what is known as a reactive hot melt, i.e. an adhesive that can enter not only into a superficial, mechanical bond with the substrate, but also into a chemical bond. The advantage of this is that the smoothness of the surface to be glued is no longer important. The decisive aspect is the number of bonding partners of relevance for the adhesive that the surface offers. If these bonding partners are present, and once the adhesive has fully reacted, PUR creates an extremely strong, reliable bond.

At the same time, this advantage also entails a particular challenge that is often considered to be a drawback: a reactive adhesive system has to be controlled very exactly. Once cured, an adhesive has completed its chemical reaction and can then no longer be melted.

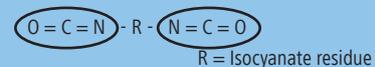
So, there is a time window for processing, and it has to be strictly observed. Otherwise, some of the adhesive could even cure in the adhesive application system, the tank, hoses, etc., making them unserviceable. Nevertheless, it is perfectly possible to work with polyurethane hot-melt adhesive.

Polyurethane chemistry

The main components of a polyurethane hot-melt adhesive responsible for the reaction are a diisocyanate and a polyol. Different diisocyanates, and also different polyols, are used in order to influence the properties of the hot-melt adhesive in the desired manner.

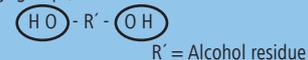
Diisocyanates are characterised by the fact that they display two reactive cyanate groups (N=C=O). The remaining, inactive part of the compound is located between them.

Diisocyanate:



The two reactive cyanate groups of the diisocyanates in the adhesive particularly bond with hydroxyl groups (OH). They are to be found in alcohols, water and cellulose. This is why paper and wood can also be glued so well with polyurethane adhesives.

Diol (alcohol with two hydroxyl groups):



A compound comprising many individual diisocyanate molecules (monomers) with many diol monomers is known as linear polyurethane. The compound-forming reaction is referred to as polyaddition.

If, however, linear molecules of this kind bond with polyols – i.e. alcohols with more than two OH groups – or with water molecules, the result is crosslinked polyurethanes. Once the chemical process has been completed, crosslinked polyurethanes of this kind can no longer be melted.

When three-dimensionally crosslinked structures of this kind enter into chemical bonds with suitable bonding partners on the surface of the substrates to be processed, the result is the desired, extremely durable adhesive bond.

Its outstanding adhesive properties, its extreme temperature resistance and that fact that cured PUR is virtually insoluble, are advantages that by far outweigh all the objections to it. So, what is PUR? What are its typical constituents and how does the gluing of plastic materials or metallised surfaces with a polyurethane hot-melt adhesive work?

A little chemistry is necessary to answer these questions. Polyurethane is generally more familiar in the form of polyurethane foam. This usually comes in cartridges or spray cans, from which two different chemical components are brought together, mixed and foamed together. The foamed compound subsequently cures, then having the familiar foam structure. A PUR hot-melt adhesive likewise consists of two main components that are capable of reacting with each other. In an adhesive container, these two components are already in mixed state, but are kept inactive. Only during the heating necessary for melting the adhesive is one of the two components (a diisocyanate) released, allowing it to initiate the crosslinking process.

Crosslinking takes place after the adhesive has solidified. On the one hand, isocyanate molecules bond with the crosslinking partner, i.e. the second adhesive component (a polyol). On the other hand, PUR also crosslinks with suitable chemical bonding partners on the surface of the substrate to be glued, this giving rise to the extraordinarily good adhesion. Thirdly, the adhesive components also

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crosslink with water originating from atmospheric humidity or the moisture of the substrate.

How durable is a PUR connection? Once the adhesive has cooled, the connection is initially no better than after normal gluing with a conventional hot melt. However, following complete reaction and curing of the polyurethane on a suitable surface offering sufficient bonding partners, polyurethane is connected virtually inseparably to the substrate and can no longer be detached without destroying the adhesive film or the substrate surface. Complete crosslinking of the adhesive can, however, take some time. Depending on the amount of admixed free isocyanates, a polyurethane hot melt adhesive can theoretically already crosslink completely within a few minutes (accelerated adhesives), or it may need several days for the chemical process (decelerated adhesives). Crosslinking usually takes approximately 2 to 3 days for the adhesives most suitable for closed adhesive systems. It may be that the durability of the products is only very limited during this time. If high resilience is present, cartons can even pop open if they were not packed correctly. Nevertheless, the finished, PUR glued product is ultimately glued better than would be possible with any other conventional adhesive.

As already clearly indicated by the aforementioned differences in the crosslinking time, PUR hot melt adhesives can demonstrate very different properties. They are usually specifically set by varying the nature of the principal components and/or the additives used. The essential properties include the „hot tack“. This term denotes the adhesiveness of the adhesive in hot, liquefied state. The highest possible hot tack is often desirable, owing to the resilience encountered. The open time is also of great importance when gluing folding cartons that are difficult to process. The term „open time“ means the time within which a layer of hot adhesive of defined thickness can still be glued effectively.

The colour of the PUR adhesive was already mentioned earlier. It can be white, yellowish-transparent or also completely crystal-clear. Another relevant property, particularly when the adhesive is applied

carton parts can later either not be detached or separated at all, or only by extensively damaging the material.

Special properties call for careful handling

Needless to say, careful thought has to be given to their typical properties and special features when it comes to processing polyurethane hot melt adhesives. They require professional handling to ensure that the glued joints, and ultimately the products to be manufactured with them, actually do justice to the high demands. Attention also has to be paid to health-related aspects. Reactive polyurethane adhesives contain harmful constituents that are particularly released in the form of gases when the adhesive is heated and melted. By definition, the products in question here are always reactive PUR hot-melt adhesives based on so called polyester-urethane prepolymers with isocyanate groups. According to EC Directive 91/155/EEC, the following are indicated as harmful constituents: 1-3% MDI (diphenylmethane-4,4'-diisocyanate) and small quantities of TDI (2,4-toluene diisocyanate).

The aerosol of these substances that is released upon melting can irritate the eyes, the mucous membranes of the airways and the lungs, or cause headache. Other, longterm damage is possible if the adhesive is not handled correctly.

Tamper Evidence

By adopting Directive 2011/62/EU on 8 June 2011, the EU paved the way throughout Europe for improving the identification of falsified medicinal products for human use in order to protect the health of patients. The elements of this amendment in the so called EU Pharma Package include the two new regulations added under letter „o“ in Article 54.

A serialised code on every pack puts the participating partners in the supply chain in a position to verify this pack on the basis of a database entry. Every pack bears an individual code that makes the pack unique.

At the same time, the Tamper Evidence regulation makes it more difficult to manipulate packs. The pack is closed in such a way that premature opening or manipulation of the pack by partners in the supply chain, such as the issuing pharmacist, is detected. One purpose of this regulation is to prevent the re-packing of falsified medicinal products in valid packs.

using a closed application system with non-contact application nozzles, is the right viscosity. It can be between several hundred millipascal-seconds (mPas) and many thousand mPas. The viscosity of the adhesive influences its hot tack, and also the wetting of the substrate and the cut-off of the adhesive from the application nozzle.

Their outstanding adhesive properties, and their resistance to moisture and solvents, also make polyurethane adhesives a favourite for Tamper Evidence solutions. The cured adhesive ensures that glued

Threshold limit value

The tolerated limit for aerosols in inhaled air is referred to as the TLV (threshold limit value). A quantity of 0.05 mg/m³ is defined as the constant upper limit for isocyanates at the workplace. Whenever the processing conditions for the PU adhesive are changed, the operator of a production facility must, in the context of his duties under Section 18 GefStoffV (Hazardous Substances Regulation) in German law, determine whether this limit for isocyanates is complied with.

In the area of an open PU gluing unit, the regulations require operation of an extractor with a capacity of at least 300 m³/h and a vacuum of at least 1,000 pascal [Pa]. At the same time, the gluing unit must be effectively sealed off by a hood. The adhesive temperature should be kept as low as possible, in order to minimise the escape of isocyanates. As the critical temperature range in which isocyanates are released from the melted adhesive is roughly 140 °C, some textbooks recommend a processing temperature of < 130 °C.

In addition, a number of personal protective measures are necessary in order to prevent contact with, and intake of, PU adhesive and isocyanate vapours. These measures include hygiene and the use of personal protective equipment (PPE). If appropriate, special respiratory equipment may even need to be worn.

If a polyurethane hot melt adhesive is processed in an application system with an open adhesive tank, it is thus necessary to take elaborate protective measures in order to minimise the concentration of toxic gases at the workplace. Direct skin contact with melted adhesive is also far more likely, in which case the body can absorb the toxic isocyanates through the skin.

If, in contrast, the polyurethane hot melt adhesive is processed in a closed adhesive system, the workplace is not exposed to these toxic vapours in the first place. Depending on the design of a corresponding adhesive application system, the values achieved can be well below the valid TLV, making it possible to eliminate all health-related concerns regarding the use of polyurethane. Another special feature that has to be borne in mind is the tendency

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of a polyurethane hot melt adhesive to already crosslink in the adhesive system – both as a result of ambient humidity and due to permanent heating. In this case, reactive molecules combine to form long chains and cause the melted adhesive to become increasingly viscous – i.e. ever thicker. The consequence of this is that – following machine stops or in the event of very slow production with little adhesive consumption – the settings for applied quantities, pressures, application heads, etc. have to be constantly adapted to the changing viscosity in order to keep the process as stable as possible. Given a constant temperature, the viscosity of some polyurethane hot melt adhesives can even double within a few hours. Adjustments to such dramatic fluctuations in viscosity can make it more difficult to process polyurethane. A suitable adhesive application system must already give consideration to this tendency, and the system must be as gentle as possible on the adhesive and counteract this effect.

As previously mentioned, the resilience of the product has to be taken into account when selecting a suitable adhesive. The open time and the viscosity of the adhesive must be matched to the probable machine speed and the expected resilience of the material to be processed. If the open time is very long and the machine speed fairly high, or the machine relatively short, there is a risk of the freshly glued products popping open on the delivery belt. On the other hand, the adhesive must remain open until the carton really has been completely glued and entered the pressing belt. This can be a problem if the adhesive is applied very thinly and at slow machine speeds. Then, too, the products will not be durably glued and may possibly later come apart during erection and filling.

If the manufactured products are to be shipped immediately after processing in the folder-gluer, the durability and strength must again be expected to be limited. Since the polyurethane always needs a certain time for the crosslinking process, customers should be warned that the cartons may not be filled until after this time. It is advisable to include a corresponding note that clearly indicates the time of production and the period of time required for complete curing of the adhesive.

In the case of transparent folding cartons, particular attention is paid to the appearance and complete transparency of the adhesive film. However, gas bubbles are often to be seen in the cured adhesive film, because the crosslinking of isocyanates with water molecules takes place by elimination of a carbon dioxide molecule. These inclusions sometimes make the glue seam noticeable and ugly. As the generation of gas inclusions and the formation of bubbles can be due to many factors, this property of polyurethane hot melt adhesives must already be taken into account when selecting the adhesive application system. The following sections go into more detail regarding the special features that a suitable adhesive application system must display, and the settings to which attention has to be paid in order to minimise the probability of bubbles being formed.

„Melt-on-demand“ from Baumer hhs does justice to the demands

Generally speaking, a so-called „melt-on-demand“ system is a suitable application system for a polyurethane hot melt adhesive. This means that the system does not melt a relatively large quantity of adhesive „in stock“, as it were, as is customary with conventional hot melt systems. Rather, the system only ever melts the quantity required at the moment from the respective container, heating only this quantity to processing temperature. In other words, the system heats and delivers the adhesive „on demand“. This method prevents adhesive currently not required from already being heated to processing temperature and then kept permanently hot, thereby receiving too much thermal energy. This avoids the aforementioned crosslinking process in the system, and thus the steady increase in viscosity and the associated, constant adjustment of settings.

The core element of the system envisaged by Baumer hhs for processing a polyurethane hot melt adhesive is therefore a bag melter specifically designed for the purpose. Bag melters are the most common form of „melt-on-demand“ system.

The bag melter contains a melting plate perforated with circular holes, onto which is placed a cylindrical adhesive container, open on one side – a bag made of metallised film containing a block of solid polyurethane. Above the melting plate, a cylindrical container and the lid of the unit ensure that the adhesive container is hermetically sealed off from the atmosphere. Located below the melting plate is a small collecting vessel, in which the adhesive locally melted by the heated melting plate is collected and kept at the right processing temperature. From there, the liquid polyurethane hot melt adhesive is fed to the hoses and application heads by means of a gear pump.

Various sensors in the unit ensure that the melting plate only ever melts as much adhesive as is actually used. If there is sufficient adhesive in the collecting vessel below, the melting plate is no longer heated. As a result, the block of adhesive above also stops melting. In contrast to conventional hot melt units with a tank, where hot melt in the form of granules or in other types of container is



Pic. 2 : Xmelt Bagmelter for PUR adhesives

processed, the polyurethane in a bag melter is not unnecessarily subjected to thermal stress. This makes for consistently high stability of the adhesive and prevents the causes of the release of unnecessarily large quantities of isocyanates. In addition, the carefully designed closure of the bag melter prevents the escape of the harmful aerosols.

Baumer hhs pays great attention to manufacturing safe adhesive application systems. However, since the health risks involved in handling polyurethane nevertheless repeatedly give rise to questions, the entire PUR adhesive application system from Baumer hhs

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presented here, with bag melter and application head equipment, was subjected to a corresponding expert appraisal by the employers' liability insurance association. Following the careful design work, this expert appraisal finally provided additional, certified confirmation of how low the level of exposure to harmful isocyanates really is.

That is not the only reason why the lid has to close tightly. To prevent crosslinking of the unused portion of the adhesive container, it must be reliably ensured that no moisture can penetrate the system. The normal atmospheric humidity of the ambient air would already be sufficient for a thermosetting film that cannot be melted to form around the adhesive remaining in the system within a few hours at most. Incompletely consumed adhesive would slowly crosslink on the surface, making it unserviceable for further processing. Once opened, an adhesive container would therefore always have to be discarded at the end of production.

In contrast, the described system from Baumer hhs guarantees outstanding protection against the ingress of moisture. Therefore, adhesive containers that have already been opened, and even heated, can be left unheated in the system for several days and ignored, without the chemical crosslinking process progressing. Work can continue immediately when the bag melter is switched back on after this kind of stoppage, without cleaning and without replacing the adhesive already in the unit.

The closed design of the bag melter also means that there is no need to blanket the adhesive left in the system with dry nitrogen or dry air. Measures of this kind are only necessary if polyurethane hot melt adhesives are to be processed using the familiar, conventional hot melt systems. Elimination of the blanketing of the bag melter with dry gas equally cuts out the costs associated with the nitrogen or air used, as well as the continuous electrical control of blanketing. Likewise eliminated are the frequently complicated logistics of

gas cylinders. Should the Baumer hhs adhesive system not be needed for a time on some occasion, it can simply be switched off and set aside, cold and without power. When it is switched on again at any time, it is ready to go again in less than half an hour with the „old“ adhesive that was left in it.

Apart from the correct handling of the adhesive owing to its chemical characteristics, the production of transparent folding cartons using polyurethane also involves other special features that require a specially coordinated mode of operation of the various system components.

Coordination of adhesive handling equipment and application technology

In the simplest form, transparent folding cartons are glued along the side seam only. What is needed in this case is either a glue application head that applies the adhesive in the form of a thin bead by a noncontact method, or one that applies a narrow, thin film in direct contact. The advantage of the contact method is that the adhesive film applied can already be set to be very thin. As a result, the adhesive does not spread laterally when the product is pressed, this sometimes looking untidy and uneven. Similarly, there is less likelihood of bubbles forming in the adhesive film, since the CO² gas developing during crosslinking can escape better from a thin adhesive film.

Contact application may, however, not be suitable if difficult plastic products can only be processed on the machine at very low speed. When applied very thinly, the temperature of the adhesive declines extremely quickly, and the open time of the adhesive – i.e. the time window in which correct pressing of the product is still possible – becomes very short. So, if glued cartons take too long to cover the distance between application head and pressing belt, the glued joint will subsequently be deficient and the cartons may even pop open. An adhesive with a sufficiently long open time should be selected in such instances. If this is not possible, the only alternative is non-contact adhesive application. Owing to its initial form, a bead of adhesive applied in this way retains the heat much longer and thus remains open longer.

To obtain uniform gluing of the side seam, the adhesive application system must be set in such a way that the amount of glue remains constant at all times, regardless of the speed of the folder-gluer. The Baumer hhs bag melter system has a suitable control system for this purpose: an adhesive check valve (bypass) in the unit is appropriately controlled in such a way that the pressure in the adhesive system is adjusted proportionally to the speed of the production system. An additional challenge arises when applying glue dots to the bottom flaps of crash-lock bottom boxes. Glue dots can only be applied using suitable dot application heads, where the size of the dots is

Expert appraisal regarding the emission of toxic aerosols

On 19 November 2012, DGUV Test, a testing and certification agency for the printing and finishing industry, confirmed that, with the XBM-02 bag melter and HP 500 application head components, Baumer hhs provides an adhesive application system for use on folder-gluer that displays only very low isocyanate emissions. The values are far below the valid limits for isocyanates.

The test measurements were performed on the basis of European Standards EN 1010-1:2011 and EN 1010-4:2010, based on the Principles for Testing and Certification of Polyurethane Adhesive Emissions, GS-DP-03. To determine the relevant emissions, the adhesive application system was operated to simulate processing on a folder-gluer. A typical, non-low-emission polyurethane hot-melt adhesive was processed, the quantity of adhesive processed corresponding to typical production conditions. Air measurements were performed at a height of roughly 165 cm in the direct vicinity of the bag melter and approx. 30 cm above the adhesive application head. The intermittent mode of operation of the bag melter was taken into consideration for the measurements.

Particular attention was paid to the emissions during a bag change (replacement of the adhesive container), for which purpose the lid of the system has to be opened, and to the special situation when the unit is cleaned, the tank lid again being open at this time. Toxic isocyanate aerosols can in principle escape in these critically rated situations, and particular caution should be exercised in order not to inhale contaminated air directly above the unit.

The expert appraisal by the employers' liability insurance association, and the certificate issued, indicate that the values measured were well below the limits at all times – throughout the entire test and also in the more critical situations described. The valid limits were not exceeded at any of the measuring points. It was documented that reliable compliance with the limits is thus guaranteed in continuous operation and that the system can safely be used for processing polyurethane adhesives.



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determined by the opening time of the head during production. Needless to say, once it has been set and adjusted for the product, the size of the glue dots should not change. Consequently, the application of dots calls for a constant pressure that is independent of the production speed, whereas the pressure for the side seam has to be constantly adapted to the speed.

This special feature makes it indispensable to have an adhesive application system with two, separately adjustable pressure units. The PUR bag melter system from Baumer hhs is equipped with two gear pumps and two pressure control systems for this reason. The adhesive pressure for the glue dots is set just once on a separate pressure regulator, then remaining unaffected by the machine speed. Only in this way do the corresponding dot application heads always apply a constant amount of glue, once it has been set. In contrast, the adhesive pressure for the side seam is adapted to changes in the speed of the production machine by means of an electrical connection between the application controller and the bag melter. The amount of glue emerging for gluing the side seam varies in proportion to this pressure change, such that glue application is again uniform at all times.

Uniform pressing of an adhesive bead applied by the non-contact method is often a problem, particularly with the crash-lock bottom boxes mentioned above. Once the box has been folded, there are almost always areas where several layers of material overlap. While there are usually three overlapping layers in the area of the side seam, the additional flaps on crash-lock bottom boxes result in there often being five overlapping layers. If these flaps are also located in the area of the side seam, the adhesive applied at this point is subjected to far greater pressure, this often resulting in the width of the adhesive bead varying greatly after pressing. The consequence is an adhesive film displaying extreme fluctuations in width, this looking unattractive on a transparent folding carton.

This problem is the main reason for using contact application whenever possible. However, the application heads to be used for this purpose are of a different design and also require a different bracket. Therefore, the types of product and material to be processed, and the adhesive application method to be selected, should already be considered before purchasing a polyurethane application system.

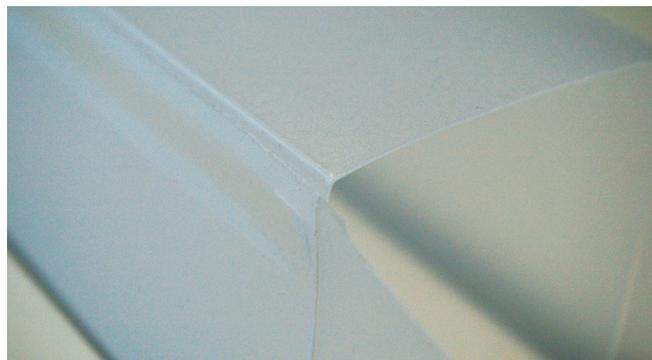
Contact application requires very accurate setting of the height of the application head. The product must gently touch the head at the adhesive discharge point, a coating head. However, the application head must not cause scratches or other marks that could possibly occur as a result of the high temperature. Nor may the product be trapped between any guides and the application head, so as to avoid displacement between the conveyor belts. On the other hand, if the application head is set too high, continuous contact between the adhesive discharge point and the product is not guaranteed. This then results in uneven adhesive application, marks and air bubbles within the polyurethane film. Consequently, faultless production of plastic folding cartons with polyurethane calls for possibilities for fine-tuning both the guides for the product and the height of the adhesive application heads.

For side seam gluing, the Baumer hhs PUR system therefore includes a sophisticated bottom gluing unit, comprising careful product guidance and the bracket for the application head, as well as the possibility for accurately setting its height. On most common folder-gluer, this bottom gluing unit can simply be installed in place of the disk gluing station provided for the side seam.

Non-contact dot application heads must likewise offer a possibility for accurate setting. A well-applied glue dot should look as round as possible after pressing. Of course, very fast application heads with

extremely short switching times are needed for this to be possible. However, if the glued joint is to look neat, the typical tailing tendency of polyurethane additionally has to be controlled. Most of the countermeasures are already integrated in the design of the application head. However, tailing is also influenced by the height of the application head above the product, among other things. So, the head brackets likewise need a possibility for precision adjustment of the height. Again, good product guidance is important in this context, to ensure that the distance from the flaps to be glued really is equal at all times. The Baumer hhs application heads used for dot gluing with polyurethane already come with the necessary controls and guides. The corresponding counterpart guides are also provided. These guides are mounted under the product, and their height can, of course, likewise be adjusted.

High-quality gluing and outstanding product quality can only be ensured by an adhesive application system that guarantees gentle handling of the polyurethane hot melt adhesive and where material transport, application head technology and product guidance are optimally coordinated. But, as already became clear earlier on, it is not only important to have the right adhesive system when processing plastic materials. The entire machine – from the feeder to packing of the glued folding cartons – is affected by measures and ancillary equipment that make the special, high-quality folding carton possible in the first place.



No ordinary equipment for the extraordinary folding carton

If a folder-gluer has so far been used only to glue products made of simple board, lots of dust have probably always been generated. If the same machine is now to be used to process plastic materials as well, there will be a major build-up of static that will make the dust really stick to the surface of the new materials. So, an existing machine always needs to be thoroughly cleaned before switching to plastic. It is best if one machine is reserved exclusively for producing plastic folding cartons. In this way, the special ancillary equipment needed for processing plastic is always available and the machine is kept in a condition that is indispensable for producing high-quality, transparent folding cartons.

If a new system is to be used specifically for the materials described, the special design of the machine and certain prerequisites can be taken into account from the outset. For instance, thought should be given to the frequently poor flatness of the die-cut plastic blanks, and also their tendency to build up static charges. Consequently, the first major problem when producing plastic folding cartons is often that of neatly pulling the individual blanks from the feeder and aligning them straight at the start of the conveyor system.

While a normal folding carton made of board is usually pulled from

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the magazine from below, it should be considered whether plastic cannot be processed using a feeder where the material is taken from the top. This method results in far lower frictional forces, meaning that the blanks build up less static and are also scratched less. In addition, more blanks can be loaded in a stack that moves up from below. If plastic material is loaded into a conventional magazine and pulled out from the bottom, the material often already jams at stack heights of just a few blanks, this leading to skew feeding into the conveyor system. As a result, it is often only possible to load very small number of blanks at once in conventional feeders. Sometimes, plastic blanks are even fed singly, simply to prevent them from getting scratched.

When producing plastic folding cartons, all guides, bars and tools in a folder-gluer have to be covered with adhesive velvet or Teflon tape, or other suitable materials, to prevent scratching of the sensitive, crystal-clear surfaces. Attention also has to be paid to cleanliness, so that no unwanted streaks or impressions are later to be seen.

Soft conveyor belts with good grip are needed for the particularly smooth material. They are often somewhat thicker than the standard conveyor belts found on folder-gluer. So, the conveyor belts need to be replaced, which means additional expenditure and also a certain amount of work. This is, however, worth while, especially if a machine is intended solely for processing plastic materials and adapted accordingly.

A machine of this kind should also always be equipped with a separate pressing unit, located up-stream of the actual pressing belt. Pressing of the products in the shingle stream is not sufficient for good side-seam gluing with polyurethane. Particularly suitable is a special, variable-height pressure roller with narrow setting rings that can be positioned on the glued joints. If necessary, the rings should also be covered with adhesive tape, so that no marks are produced on the products and the pressure can be applied as uniformly as possible. It is sometimes necessary to position additional rollers between the conveyor belts in order to obtain more local pressure.

The chemical and physical nature of the products to be glued was already described above, and the possibility of plasma pretreatment of the hard-to-glue materials was mentioned. Polyurethane needs points of chemical attack, such as the OH groups (hydroxyl groups) mentioned. While they occur naturally in such substrates as wood, paper and board, they are not present in plastic materials. The long, uniformly closed molecule chains of plastics normally have no attraction for the reactive polyurethane adhesive. The surface energy – i.e. the measure of how well the surface can be wetted by the adhesive and how well the latter adheres to the surface – is very low. In contrast, plasma-pretreated material has a higher surface energy that favours the adhesion of an adhesive.

Plasma pretreatment of this kind – sometimes also referred to as corona pretreatment – breaks up some of the molecule chains on the surface of the substrate and incorporates oxygen. The oxygen atoms and other elements from the air are chemically added, and roughly 20 different chemical compounds are formed, with which the adhesive can subsequently crosslink directly. The surface energy of the material changes as a result. While low values between 20 and 30 mN/m (millinewtons per metre) are often measured on untreated plastics, values of up to 70 mN/m can be measured on films treated with plasma immediately beforehand. This holds the promise of excellent glue adhesion.

Films with full-surface plasma pretreatment are also available on the market. This kind of film should always be used if the folding

cartons are printed. After all, the things that apply to good glue adhesion, must also be borne in mind in connection with the previously applied printing inks. However, the initially high surface energy declines again in the course of time, meaning that films that have been stored for a lengthy period are later again more difficult to glue.

For this reason, targeted plasma pretreatment is additionally applied once again, directly in the processing machine. Various mobile plasma units for this purpose are available on the market and can be used directly on the folder-gluer. The plasma nozzles of these systems are positioned directly above the flap surfaces to be glued in the machine, thus locally increasing the surface energy immediately prior to gluing. This guarantees the best possible adhesion of the glue, regardless of how long the material was previously stored. Ancillary equipment is also often necessary at the end of the production line, when the glued products emerge from the folder-gluer. The task then is to pack the products quickly and under slight pressure. Otherwise, they might pop open, or bubbles could form in the fresh glue seam. If the machine stops and individual products are left on the delivery belt that are not sufficient to completely fill a packaging unit, they must nonetheless be subjected to pressure immediately. Used for this purpose in most cases are weights or mobile strapping units, by means of which even small numbers of products can quickly be strapped and thus put under pressure. So, as described, only effectively coordinated technical equipment makes it possible to achieve optimum quality. In addition to which, it takes a good portion of experience in handling plastics and polyurethane. How can the special properties of these high-quality materials be exploited most effectively? How can undesirable effects be counteracted?

Tips and tricks for difficult materials

Time and again, one of the essential tasks when processing completely transparent folding cartons is to counteract the tendency towards the formation of bubbles. It is impossible to avoid the fact that CO₂ gas occurs during the crosslinking process of the adhesive. There are, however, ways of influencing the speed at which the gas is formed and whether or not it later leaves the undesirable bubbles in the adhesive film.

The most reliable way is to apply as little adhesive as possible and to compress the adhesive film to a thickness of less than 0.1 millimetres by applying high, targeted pressure. This thin adhesive film allows the gas molecules to drift out of the material as they are produced, before larger quantities of gas can form bubbles at all. If an adhesive that crosslinks relatively slowly is selected from the outset, the gas is likewise formed at a slower rate and it is highly probable that the gas can escape from the slowly crosslinking adhesive film before bubbles are formed.

It is important to make sure that the sensitive polyurethane adhesive is not already exposed to high shear forces in the application head. Unnecessary forces of this kind occur if the application heads are only opened to a very slight degree and high forces are used at the same time. Polyurethane then rapidly foams, and the gas bubbles formed in the process are applied directly, together with the adhesive. It is better to work with lower pressures and instead open the application heads farther. In the Baumer hhs system, the polyurethane nozzles are already adapted to the special requirements of polyurethane adhesives.

The flaps of a transparent plastic folding carton likewise need to be brought together skilfully. This should not be done until immediately

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upstream of the above mentioned, separate pressing unit. It should be noted in this context that the adhesive may on no account be laterally smeared. This leads to visible shadows and increased bubble formation at the edge of the adhesive film. To avoid this, additional guides have to be used that keep the upper part of the folding carton largely open and away from the glued, lower flap. Only about one centimetre in front of the pressure roller is the upper part of the folding carton brought into contact with the glue flap with the help of a guide rod.

Faultless guidance of the product is also necessary in the case of crash-lock bottom flaps provided with glue dots. Once the flaps have been brought together, they press the applied adhesive into a round dot. After that, however, the flaps may no longer be moved or slip relative to each other. If a glued flap comes apart again in the machine, this will likewise inevitably lead to air inclusions and the formation of bubbles.

In connection with polyurethane and the polyurethane removers offered on the market, the question is repeatedly raised as to the necessary cleaning cycles. The available removers come in the form of granules or closed bag containers, and primarily displace the polyurethane. Beyond this, the ingredients of the special polyurethane removers also deactivate the active isocyanates in any polyurethane left in inaccessible corners of the system. This kind of cleaning should only be done if the polyurethane system is not to be used for more than a week. In this way, any residual adhesive is completely removed that could otherwise partially crosslink in the system. The drawback of this kind of cleaning is that all the remover itself has to be removed before the machine is restarted. Residual remover would impair the crosslinking process of the adhesive. The removers are dyed to ensure that only pure adhesive is conveyed through the system. Only when the polyurethane adhesive delivered is completely colourless again, is it certain that the glued joints subsequently applied will hold. So, every cleaning cycle costs a little time and takes roughly one container of adhesive that has to be discarded. Consequently, it is best to operate a polyurethane system every day. It then makes no work and merely needs to be switched on and off.

Reliably high quality

Polyurethane hot melt adhesive application can be combined with glue monitoring by means of special HLT hot melt sensors. Camera systems can sometimes also be used for monitoring when dealing with particularly difficult substrates. This high-end quality control on the machine, and the electronic link-up to the machine control system, provide centralised assessment of the products, and incorrectly glued products can be ejected directly with the help of a linear ejector or some other suitable unit.

Choosing a polyurethane hot melt adhesive system from Baumer hhs enables you to manufacture top-quality products made of exclusive materials. A team of experienced technicians and an efficiently organised Service Department are available to provide you with training and practical advice to support your specific applications.

When processing polyurethane professionally, high process reliability is crucial, the safety of your staff is important to you and, not least, the products have to be reliably glued and of outstanding quality. All that calls for expert knowledge and experience that not everyone has. But if you decide to take up the challenge, you will be opting for added value and the products of the future.



Pic 5: Glue sensor for PUR detection

Baumer hhs GmbH

With its headquarters in Krefeld, Germany, Baumer hhs GmbH is an internationally operating manufacturer for industrial glue application systems in conjunction with quality assurance systems and camera control systems. They provide their customers with a carefully selected portfolio from the areas of hot melt and cold glue processing with guns, pumps and pressure tanks, as well as control and monitoring systems for quality assurance in glue application and adhesive application for factory automation.

Baumer hhs is part of the Swiss Baumer Group. With over 2,500 employees and production plants, sales offices and representations in 36 branches and 18 countries, the family business is always close to its customers. With high quality standards that remain constant across the world and an enormous innovation potential, the company provides customers from numerous industries with crucial advantages and measurable added value.

More information about Baumer hhs, to all products and other services are available on the Internet
www.baumerhhs.com