Smart bonding.

Versatility on a roll:

Bonding and welding with thermoplastic adhesive films

Introduction

Industrial bonding and welding with hot-melt adhesives in film form, thermoplastic adhesive films, is a rather young technique. It's application possibilities is illustrated in greater detail in the following article.

Composites and Textile Industries are among the most appropriate targets for adhesives films. In non-construction bonding, hot melts have established a strong position in the last 30 years, not least of all because of their low environmental pollution. Thermoplastic adhesive films represent a valuable addition as more creep resistance of structural bondings may be achieved. Thermoplastic or hot-melt adhesive films could be characterised as very processing-friendly forms of hot-melts, since they do not require conditioning lines in the processing plants. However, it is not only in application techniques, but also in raw materials and adhesive properties, that there are distinct differences between hot-melts and thermoplastic adhesive films: Thermoplastic adhesive films permit continuous or batch bonding even on large surface areas with a high degree of automation and high production speeds. Materials, from textiles or non-wovens to aluminium foil, from PVC to PU foam, can be bonded in calenders, presses or other installations by means of heat, pressure and time.

Besides classical heating techniques using steam, oil, IR and hot air, HF and ultrasonic techniques are worthy of special mention – techniques that have been used successfully for bonding in the textile industry for over 40 years.

HF and ultrasonics allow for very rapid heating of the glue line with high process safety. In these cases, the thermoplastic adhesive film is frequently used as a bonding aid to make non-weldable substrates «weldable», e.g. difficult-to-melt textiles, which are then welded and bonded in a kind of mixed technique. The use of process heat in installations for heating the bond is an elegant solution.

Application examples, e.g. from the textile and automobile industries, will help to extend the understanding of films and their associated process techniques.

Furthermore, an overview of the various uses of thermoplastic adhesive film in industry will be presented. Alongside «simple» bonding, thermoplastic adhesive films are used for setting fibres, for coating and sealing, for vibration insulation and non-slip brakes.

Difficult bonding and sealing jobs can be resolved using multilayer films.

Smart bonding.

1. Thermoplastic adhesive film manufacturing processes
Thermoplastic adhesive films are extruded by means of blow or sheet extrusion (= flat die extrusion or cast extrusion), as shown in the picture 1. In both processes, the raw material is heated in an extruder until it flows. It is then formed into a flat film using a flat die (below), or into a tube using a ring die (above). Both manufacturing methods and the subsequent winding and cutting installations allow:

Customer-specific finishing to the required width and thickness (g/m²):

	Cast extrusion	Blow extrusion
Thickness	15 to 500 g/m²	15 to 200 g/m²
Width	10 to 2000 mm	10 to 3000 mm

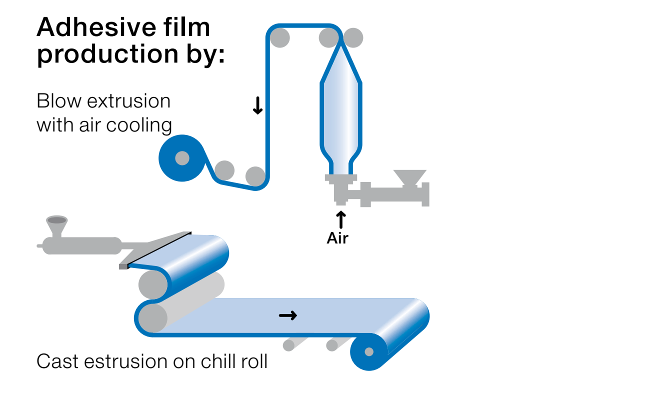
This wide range of thermoplastics includes not only various basic raw materials such as copolyolefins, CoPA, CoPET or TPU, but also raw materials of different viscosities. Extruders accept raw materials, which can be low to highly viscous in the molten state, and consequently the films are also adjustable from low to highly viscous.

By means of co-extrusion, as well as by the extrusion of several film layers one on top of the other in a flat extrusion installation, multi-layer films can be made. And by extruding using a flat die onto textile or other flat substrates, coating or bonding directly on the extrusion installation is possible.

2. Thermoplastic adhesive films – bonding principle
The thermoplastic adhesive film is laid between the parts to be bonded. This «sandwich» is heated under pressure between 10 and 30 °C above the melting point of the film. The molten film will wet the surface of the substrate. The sandwich then cools off and a permanent bond develops.

It is thus a question of a 3-stage process:
1. Heating up (to the melting point + X °C)
2. Applying pressure in the heated state in order to achieve wetting
3. Cooling (to the melting point - X °C), mainly aided by pressure

The speed of the bonding process is primarily dependent on the speed at which the heat penetrates into and out of the glue line. Heat is generated at the glue line particularly rapidly with HF or ultrasonic techniques. The bond strength is mainly of a physical nature: electrostatic interaction between the interfaces. The greatest possible wetting is here an important limiting condition. To improve wettability, pre-treatments, such as corona, plasma or flame techniques, can be used. Difficult-to-



Picture 1: Use of a wide range of thermoplastics.

bond surfaces can also be durably and effectively «activated» by HF (hydrogen fluoride) gas injection. As a rule, polar substrates (PET, TPU) are more easily wetted than non-polar ones, but there is no guarantee for good bonds due to well wetted surfaces. In addition, with fibres or foams, penetration of the adhesive into the fibre interstices leads to anchorage in the substrate. The so called «mechanical interlocking» comes into play.

However, welding effects, i.e. contact surfaces fusing together, can also occur when the temperature at the glue line also causes melting of the substrate to be bonded. The important properties for the end product are the melting point of the film, the elastic modulus as a function of temperature, the crystallinity as well as the viscosity of the film in the molten state. The appropriate choice of these parameters may even lead to the replacement of reactive (cross-linking) systems.

3. Film types: Raw material basis and specific application possibilities
In principle, all extrudable thermoplastics can be used as raw materials for thermoplastic adhesive films. Since the substrates used in the market are extremely varied and bond requirements very different, i.e. hard to soft, porous to plane, chemically stable to soluble, etc., the fully available «raw material range» is required in order to «construct» films that satisfy all possible requirements.

The following raw material classes are predominantly used in thermoplastic adhesive films:
– Polyolefin types (copolyolefins)
– Copolyamides (CoPA)
– Copolyesters (CoPET)
– Thermoplastic polyurethanes (TPUs)

In most cases, as will be shown, none of these groups is exclusively «appropriate» for any particular application. However, as a rule, the following applies: «Like bonds best to like». This means that PE is preferred to bond copolyolefins, PET web for copolyesters, etc.

Polyolefin types are mainly mixtures of copolyolefins containing MAH modified EVA, EEA, PE and PP as adhesion promoters, but they can also be mixed with resins and other components.

Copolyolefins based on **EVA** (ethylene vinyl acetate) are frequently low-cost adhesives with elastic properties and good bonding characteristics on glass, wood and textiles. Other copolyolefins (such as **EAA, PEg and PPg**) can be outstanding textile, composites and metal adhesives, with good chemical and wash resistance.

High temperature resistant «headliner adhesives», with which a variety of substrates can be bonded, from glass fibres to PE or PU rigid foams, also belong in this group.

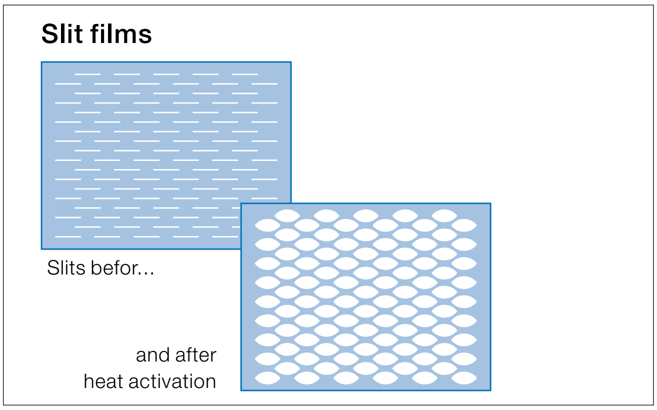
Copolyamides and **copolyesters** are particular «high-performance» adhesives with a wide application range, for the most part tough and rigid, and often being resistant to dry cleaning, sometimes even resistant to plasticizers. They are HF weldable! For **high elastic interlockings**, thermoplastic polyurethanes (TPUs) are the right choice. For the most part, **thermoplastic PU** films do not have a melting point, in contrast to previously mentioned types, but instead a rather wide softening range.

TPUs are all purpose adhesives, soft and elastic, always resistant to plasticizers, for the most part also resistant to a variety of oils and fats and are HF weldable. Applications in the automobile industry include door side panels, seats, sunroofs, and «skin films» (coatings on foam) in the engine compartment. Examples from other industries include shoe adhesives, anti-slip coatings, seal proofing tapes for sown textiles (in particular for Goretex and Sympatex bonded fabrics) and various medical uses. The latter includes sticking plasters and weldable skins for artificial breasts or mattresses (border seams are made by means of HF welding installations) as well as specific applications in aeroplane interiors.

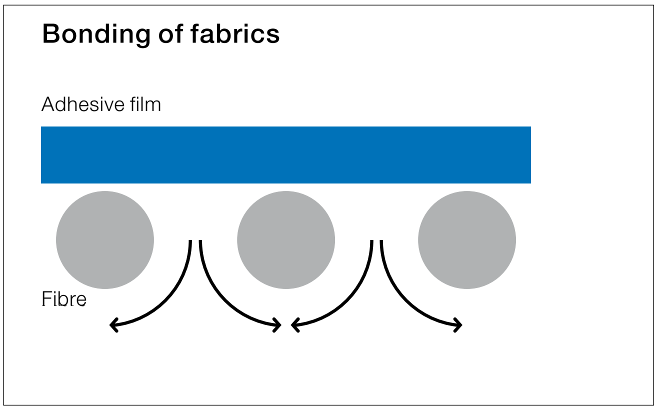
As a rule, low melting point TPU types are manufactured on carriers. However, there is a small range of TPUs from **Collano** that can be delivered without carriers. Multi-layer TPU films find special use in textile sealing. In order to meet application demands, there **are greatly differing melting ranges in all Collano type** groups, starting from around 65 °C up to around 170 °C.

4. Specialities: Slit films, multi-layer films and direct coating

A special feature of film manufacturing is slit film. Slitting not only increases flexibility of the film, but also its permeability to air. The regularly arranged slits (see picture 2) can be opened by means of heat, whereby a lattice structure with a naturally very high air permeability is obtained. Opening of the slits by heat occurs without changing the film width!



Picture 2



Picture 3

Other advantages of slit film are bubble-free lamination, e.g. to imitation leather, a softer hand, improved sound insulation as well as reduced rustling effect are given. **Multi-layer films** with various film combinations solve special coating and sealing jobs (**see «upholstered seat» application example**). The cast extrusion technique can also be used for the direct coating of substrates. Textiles, films, foams and special papers with large surface areas are thus equipped with an adhesive layer.

5. Bonding with thermoplastic adhesive films – specific features, optimisation and constraints

5.1 Bond strengths, pre-treatment, shrinkage

Wetting is the basic condition for optimal adhesion. This is best achieved with low viscous and chemically similar adhesives. A large specific surface, e.g. rough, and a substrate with high surface tension are also helpful. Pre-treatment of the substrate by **corona** or similar can have an adhesion-promoting effect. However, such pre-treatment of the film has little influence, since the pre-treatment effect disappears on the molten film. When bonding textiles, along with the adhesion strength an **interlocking or anchoring effect** also occurs.

In this connection, one effect is worth mentioning: adhesive bleeding. If the adhesive is too fluid, it can seep through open, thin textiles or foams, and possibly come out on the visible face. This effect is generally undesirable since, as a result, the adhesive strength can decrease (para. 5.2) and bleeding is visible in a negative sense. In step three of «our» bonding process, the bond cools down and this is coupled with shrinkage, not only of the substrate, but also of the adhesive coating. This phase leads to **large stresses** on the fresh bond if high modulus adhesives and substrates are combined. Crystallisation of the adhesive accompanies the shrinkage in most cases. Movements due to shrinkage and crystallisation can be substantial, and may destroy the bond in the first minutes or hours.
This is especially applicable to bonds with metals and glass.

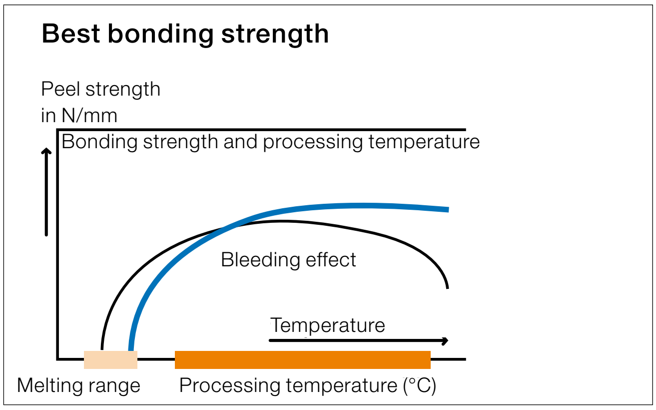
Countermeasures are

– Elastic, low modulus adhesive film
– Low bondline temperatures
– Cooling under pressure
– High film weight

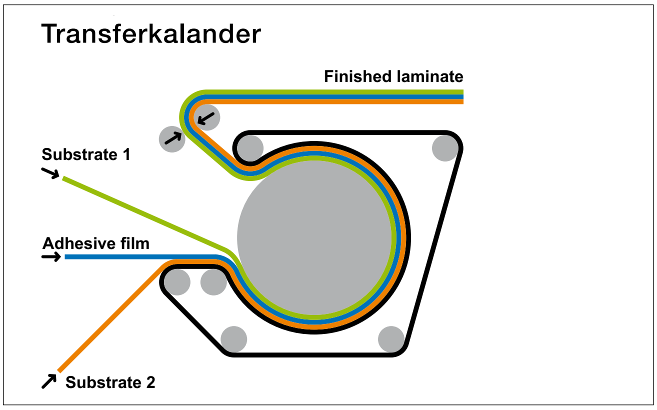
5.2 Optimum adhesion strength by optimisation of bonding temperature and film thickness

As well as the most suitable film type, the optimum processing temperature must be found in order to obtain the optimum adhesion strength of thermoplastic adhesive films. The minimum processing temperature is that temperature above which acceptable adhesion strengths are achieved. This minimum temperature is between 10–30 °C above the melting range. As a rule, above a given temperature, adhesion strength reaches a plateau (picture 4, blue curve). The level of this plateau is dependent on the thickness of the adhesive as well as the adhesive and substrate types.

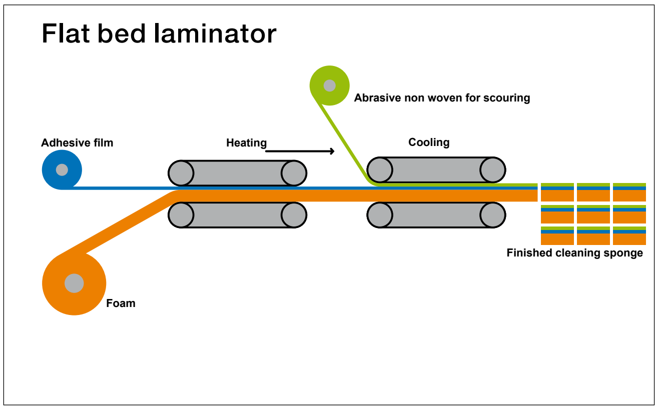
However, in most cases, above a thickness of 75–100 microns no further increase is possible. With textile and foam bonding, low viscous adhesives or high bonding temperature lead to reduced bond strength. For optimising adhesion parameters, advice should be sought from the experienced team of Collano adhesive technologists. In co-operation with them, practical tests can be carried out in order to establish optimum film type, thickness and temperature for the respective application.



Picture 4



Picture 5



Picture 6: Sponge fabrication

6. Processing techniques

6.1 Continuous processes

Calender (see picture 5)
In this method, heat is supplied to the glue line by means of a heated roller. Ideal for thin, flexible substrates. Speed: 2–35 m/min.

Flat laminating installation (see Flat bed laminator, picture 6)
The substrate together with the adhesive film are fed between heating/cooling bands, heated and pressed. Good for thick and also rigid substrates. Speed 2–25 m/min.
The flat laminating installation is used to manufacture small scouring pads.

Flame laminating installation (see picture 7)
A (still) common technique is flame bonding, where foams (PE or PU) are bonded by means of scorching.
Here, by the use of thermoplastic adhesive film, this technique is extended to substrates that cannot normally be activated by scorching. Speed: 15–40 m/min

6.11 Special textile bonding techniques:
HF, ultrasonic, hot air and hot wedge bonding

These techniques are used particularly in the textile industry. In the thermal bonding of textiles, bonding techniques can be basically classified as follows:

1. Crosslinking
2. Form fit joint
3. Adhesive joint
4. Diffusion joint
5. Force-fit joint

Of interest to us in connection with thermoplastic adhesive films are force-fit and adhesive joints. **Force-fit joint** is the technical textile term for adhesion by means of hotmelts and thermoplastic adhesive films.

Adhesive joints or welding, techniques are deployed in greater detail as follows: Thermoplastic adhesive films can be used as welding aids. In principle, when welding, the substrates must be heated to, or above, the melting point, so that they can then fuse with one another. In many cases, this is not possible, either because the melting point of the substrate is too high (PA, PET) or because the softening range is too narrow (the polymer goes directly from the plastic state to the liquid state and loses its shape), or the technique used does not permit sufficient warming (HF with polyolefins). In all these cases, thermoplastic adhesive films can be used as welding aids.

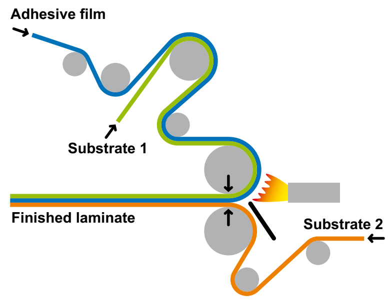
As a result, welding in combination with thermoplastic adhesive films becomes a process somewhere between welding and bonding. In most cases, when using a thermoplastic adhesive film, the temperature necessary at the glue line is reduced.

Welding techniques
Hot air
Hot air is blown in between the parts to be joined. Application: Joining or coating.

Heat contact (between the parts to be joined)
A hot wedge is pushed between the pieces to be joined (see picture 8).
Application: Joining or coating.

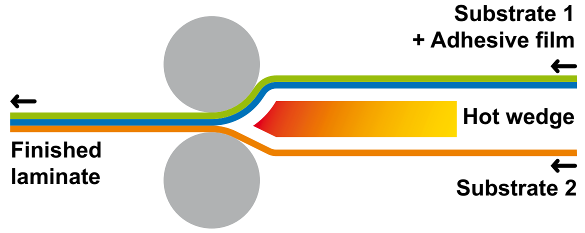
Heat contact (external)
When heat is produced by means of electric impulse and fed from the outside, one speaks of thermal impulse welding. The latter process is extremely elegant and combines a high safety factor at the workplace with perfect welding seams. Disadvantage: Poor heat profile. Well suited for PP, PE and PTFE!

Flame bonding machine



Picture 7

Hot wedge welding



Picture 8

HF welding
When polar, non-conducting materials are placed in a high-frequency field, they heat up. This is due to oscillation of the polar molecules caused by the HF field. This effect is used especially with PVC (the HF welding of PVC was patented in 1941, the first installations were modified sewing machines for manufacturing rainwear).

One speaks here of the dielectric loss factor, a measure for the conversion of HF energy into heat. This factor must be as high as possible (>0.10), and polar thermoplastic adhesive films ensure an increase of this factor while at the same time a decrease in welding temperature.

Examples
PS and PET: polar films help to generate the necessary heat.

Polyolefins basically not weldable, since non-polar

Ultrasonic welding (rotary or batch)
Here, the substrates are made to vibrate by means of ultrasonics. The resulting friction causes them to warm up. A certain stiffness of the substrate is a prerequisite, since otherwise sufficient stimulation to cause vibration of the textile by means of the ultrasonic probes (the «loudspeakers») is not possible.
Ultrasonic welding has been a standard process in joining techniques for 40 years. Here too, thermoplastic adhesive films have the primary task of reducing the welding/bonding temperature. Principle application: By using thermoplastic adhesive films, the joining of textiles to other plastics can be made easier. The installations work continuously and/or batch-wise.

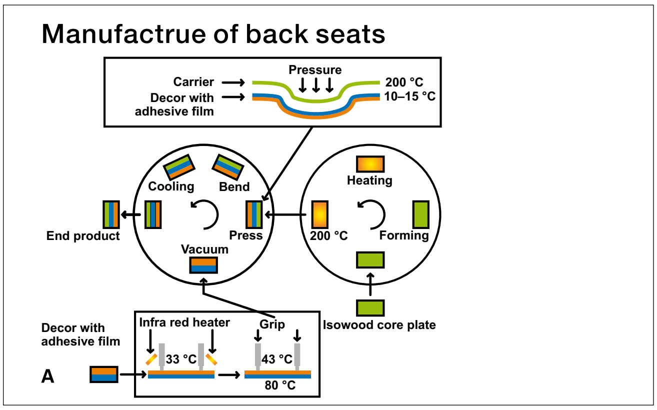
Application areas of welding/bonding techniques:
Weather protection, work and sports clothes, protective helmets, car tarpaulins, marquees, sun blinds, all types of awnings, insulation and filter tubes, cable sheaths, dressing materials, foundation garments and nappies.

The following applications of thermoplastic adhesive films are particularly worthwhile to mention:
- Fixing and welding/bonding together hems and overlapping seams
- Sealing of hems and overlapping seams
- Fixing or bonding finishing tapes
- Anti-fray treatment and sealing of textiles
- Joining thermally resistant textiles (glass fibres, carbon fibres etc.)

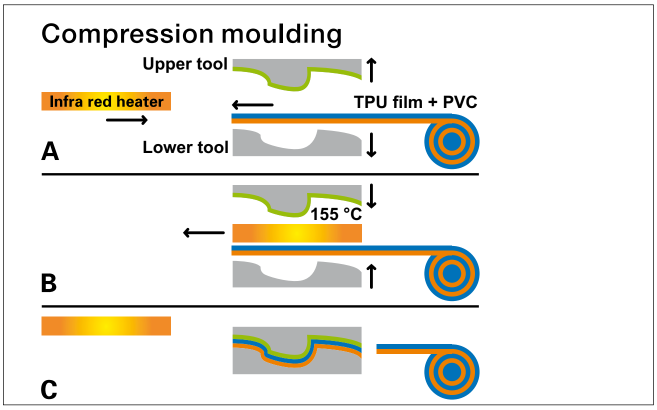
6.2 Batch techniques
Thermal presses with the following heat sources
- Electricity / oil / steam / (induction)
- IR radiation
- HF (high frequency welding)
- Vibration (friction, ultrasonic)
- Hot air, hot gases
- Thermoforming techniques
- Rear injection

The simplest technique is ironing!

7. Processing examples:
Side panels and other decorative parts for car interiors
The bonding of decoration onto supports for side panels by means of **high-frequency presses** can be mentioned as an example of high processing speed. By means of heat presses, which provide energy to the glue line using HF welding, flat and small parts in particular can be produced with cycle times of approximately 10 seconds per bonding step. Such bonds include textiles (PET) and artificial leather to 3-dimensional parts of the most varied raw materials (Lignotoc, Isowood, ABS etc.) (See picture 9).



Picture 9



Picture 10

The frequently used «carrousel» for manufacturing such bonded parts is shown on the right. Thermoplastic adhesive films are set up and at **(A),** decoration already coated with an adhesive film using one of the previously described calender techniques is fed in. Alternatively, the adhesive is laminated to the decoration at this point (in the simplest case by means of a heated roll). The bonding takes place in the «press» area. The mould is heated to 200 °C, transported to the press by the circuit on the right and there it is pressed against the decoration. The temperature at the glue line is about 125 °C.
An alternative is the **input of heat by means of IR radiation in the press.** According to experience, a surface temperature of 150–160 °C is necessary in order to still have about 120–130 °C available at the glue line after allowing 9–12 seconds for transport and the press closing time.

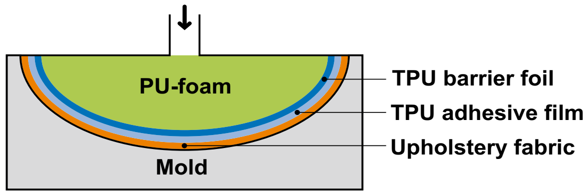
This temperature is sufficient to activate films that melt at 110 °C and have a heat resistance of 90 °C. In heated stamping presses, heat can be generated by HF energy, or stamping presses equipped with swivelling IR heaters can be used. The picture on the right shows the important phases of pressing an ABS moulding with a synthetic leather decoration that has been bonded using a **Collano** TPU film.

To start with, the ABS moulding and decorative film are positioned together with a **Collano** TPU film in the press (see picture 10, **A**). The IR radiation unit is then moved into the press. The radiation quickly heats the surface of the ABS moulding to 150 °C and the PVC decoration, together with the thermoplastic adhesive film, to about 90 °C.

After a few seconds heating-up time **(B)**, the radiation unit is swung out of the press, while the latter already starts to close. Thus, a temperature of about 130 °C is achieved at the glue line during pressing **(C)**. After about 30 seconds cooling (the lower press platen is cooled), the press opens, the bonded parts removed and the cycle repeats from the beginning. An example of an application where film is used to **seal and bond is upholstered seats**, where the upholstery material must be sealed from the foam backing (injection moulding) so that the initially liquid foam does not penetrate through the upholstery material. This happens perfectly with two TPU-based films:

A high melting point TPU cover and sealing film and a low melting point TPU film, which bonds the seal film to the upholstery material (see picture 11). The 2 TPU films are laminated to the upholstery material on a flat laminating installation or in a calender. The same process can also be used for leather seats.

Injection moulding too for upholstery



Picture 11

8. Application areas

Bonding In the car industry is popular with respect to «decorative parts», such as the already-mentioned door, pillar and also dashboard panelling, and also in the head-liner, sliding roof, fitted carpet (in particular heel pads), airbag and various seat parts or the seats, as well as the boot.

In addition, it is also to be found in the prop-shaft tunnel, for the bonding of ventilator flaps or in the field of noise insulation in the flooring and under the bonnet. Besides the above-mentioned combinations in the car industry, thermoplastic adhesive films are used in a variety of other markets.

Below are the main ones:
– Clothing
– Electronics
– Shipping
– Living and household requirements
– Building industry
– Agriculture
– Railways
– Medical industry
– Sport & Leisure
– Aeronautics

As can be seen, the areas of application are widespread, and it would be going too far to break these down into detail. A few products in which thermoplastic adhesive films are used, in addition to those already presented, should however be mentioned as exemplary:
– Blinds
– Carpets
– Shoes
– Jeans
– Suitcases
– Sandwich panels
– Fire-resistant suits
– Textile labels

With thermoplastic adhesive films, one can not only bond, but also proof, stiffen, seal (fabric edges) or coat, even coloured if so required, or by means of slits or holes achieve high air permeability and flexibility of the bond – here, imagination knows practically no limits:

Bonding and sealing against liquids and gases

Examples:
– Textile seam sealing
– Sealing of textiles from foam backing

Bonding and surface finishing

Examples:
– Coating of photos
– Skin films for silicone rubber filled pillows

Stiffening

Example:
– Anti-fraying

9. Summary of user advantages of thermoplastic adhesive films

As has been shown, thermoplastic adhesive films allow in particular the continuous or batch bonding of (large) flat substrates with a high degree of automation. Materials, from textiles to aluminium foil, from PVC to PU foam, can be bonded in calenders or presses by heat and pressure. The typical handicap of hotmelts – limited heat resistance due to the low creep resistance – applies also in principle to thermoplastic adhesive films, but is minimised by high melting points and melt viscosity. The use in headliners shows that heat resistance up to 120 °C can be achieved without any problem. The highest melting point Collano film provides heat resistance to 155 °C, but requires a minimum processing temperature of 185 °C.

Tabular list of the strengths of thermoplastic adhesive films

- Higher automation with shorter cycle times
- Width and thickness can be adapted to customer requirements
- High reproducibility of quality
- Simple and cheap handling, no cleaning, minimum waste
- Processing of large sqm quantities with simple logistics
- Toxicologically harmless in finished product
- Little or no odour

10. Conclusion

We hope to have clearly shown in this presentation that thermoplastic adhesive films are not just hot-melts in film form, but a special type of adhesive, which release technical imagination and can help to save costs by improving processing techniques. And furthermore: adhesive films may be used for structural elements due to their excellent creep resistance in comparison to standard hot melt adhesives!

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