Laminating Window Profiles

Investigation of Cross-linking in Reactive Hot Melts

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When laminating PVC window sections the quality of the adhesive binding depends among other things on the curing reaction of the reactive hot melts. Isocyanate cross-links with water to form polyurethane. IR spectroscopic methods were used to determine humidity requirements during processing and the lamination process was optimized.

Development of the use of windows as colourgiving, supportive, style enhancing building elements continues (Fig. 1). This applies particularly to plastic windows. A combination of the general advantages of plastic windows, such as maintenance ease and price, with the desire for colour can be realised technically using three different techniques. They are coextrusion, coating and lamination.

Coextrusion primarily with PMMA provides excellent colours. However, it is difficult to process the window sections at lower temperatures because of the brittleness of the PMMA. The great colour variety obtainable by painting stand in contrast to the economic disadvantages of the high initial investment costs of the painting equipment with explosion protection and afterburning or solvent recovery. The solvents in the lacquer likewise pose difficulties with respect to environmental protection.

Lamination offers several advantages, outstanding among which are the very good UV stability of the films used and the availability of many different colours.

Reactive Hot Melts

The adhesives used for lamination can be roughly classified into systems containing solvent and solvent-free systems. The solvent-free hot melts become quite strong immediately after solidifying. The reactive adhesives containing solvent need a substantially longer time to develop comparable strength (Fig. 2) [1]. However, the absolute strengths of the reactive adhesives are usually greater than those of the hot melts.

Reactive hot melts combine the advantages of both types of adhesive (Fig. 2):

- High initial strength through solidification on cooling and
- high final strength after termination of the curing reaction.

In particular the ecological disadvantages of using adhesives containing solvent are avoided by use of solvent-free reactive hot melts [2].

In single component reactive hot melts based on PUR already cross-linked high molecular weight polyurethanes (prepolymers) with terminal free isocyanate groups are available. During the curing reaction with water they form polyurea. In the hardened polymer both urethane linkages from the prepolymer and urea linkages from networking with water are therefore present. For complete curing by precipitation the molar quantities of the isocyanate in the adhesive and of the externally supplied water must be equal. Thus 2.14 g of water are needed to cross-link 10 g of isocyanate (NCO content). The water must be made available during the lamination process [1].

The Lamination Method

First the surfaces of the PVC window sections are cleaned and pre-treated with primer. The liquid melt adhesive is applied to the multilayer film. The film covered with adhesive is pressed onto the profile by a pressure roll. Fig. 3 shows a lamination system with the profile in place.

Since for process engineering reasons both profiles and films are preheated with hot air blowers, condensation of air humidity on the profile or the film is impossible. Therefore during the lamination water uptake occurs exclusively on the adhesive surface. Thus at any time exactly sufficient air moisture must be available to this adhesive surface. Too little humidity terminates the curing reaction while too much humidity affects the strength of the profile/adhesive boundary surface negatively.

For the water uptake the most important process parameters are

- the water requirement of the adhesive,
- the lamination rate,
- the temperature and
- the moisture content of the surrounding air.

In enclosed systems if the temperature is kept constant then a certain air humidity should be chosen for a certain lamination rate. This air humidity depends on the water requirement, that is, the isocyanate content of the adhesive. Therefore the curing reaction is tested in incoming inspections. This serves to check the adhesive quality on the one hand and on the other hand to regulate the process parameter "air humidity".

> **Infrared spectroscopy**
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> In IR spectroscopy absorption spectra are measured in the wavelength region shorter than that of visible light. The absorption bands occurring in the IR spectra can be assigned to the vibrations of certain bonds in the polymer molecules. Extensive reference books exist for identification of the bonds. IR spectroscopy gives information on the existence of certain types of bonds, crystallinity, tacticity and the orientation of polymers.

IR Spectroscopy

Infrared spectroscopy makes it possible to follow the curing reaction of the adhesive [3]. Therefore in the laboratory the adhesive is applied to the preheated film under process conditions and depending on the lamination rate exposed for a certain time to an air atmosphere with a defined controlled humidity. Afterwards instead of the profile another film is applied to the film and many samples are made from the sheet. These samples are stored under realistic conditions. Samples are examined at fixed time intervals. From the beginning the films are prepared in such a way that it is no problem to open windows on both sides.

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The IR spectroscopic measurement in Fig. 4 shows the isocyanate peak of the thermoplastic reactive hot melt. The blue surface corresponds to the isocyanate content and it is to be expected that this changes with time. The spectra of the samples were measured at two-hour intervals. The coloured curves in Fig. 4 show example IR results after 24, 48, 72 and 96 hours (50% relative humidity). The reduction of isocyanate content is clearly seen [4].

The course of the reaction is shown in Fig. 5. The measured values are shown for foil with reactive hot melt exposed to air of two selected humidities. The blue curve shows results from Fig. 4. The red curve is for the reaction process for 5% relative humidity. These two curves exemplify results for too little (red) and exactly the correct amount (blue) of air humidity or water. A curing reaction of about 90% after 100 hours is regarded as optimal.

The curves can now be compared with earlier measurements. The current quality of the applied adhesive, the content of isocyanate, can be judged. For acceptable adhesive qualities the humidity during the lamination process can be suitably chosen. Unacceptable qualities should be refused and the adhesive returned to the supplier.

Summary

To make the complex lamination process easier to understand the dependence of the water requirement and the supply of humidity on the adhesive were analysed with the other parameters held constant. IR spectroscopic techniques are used for acceptance inspections of adhesives and when the quality is acceptable to adjust process parameters in production. Fluctuations in adhesive composition can thus be compensated for adequately. Optimization of the air humidity as a function of the lamination rate during the lamination led to a substantially lower rejection rate.

Fig. 1. Building front with covered window sections

Fig. 2. Temporal increase of the strength of hot melts, reactive adhesives and reactive hot melts
Festigkeit = Strength, Zeit = Time, Hotmelt = Hot melt, Reaktiv-Klebstoff = Reactive adhesive, Reaktiv-Hotmelt = Reactive hot melt

Fig. 3. Lamination system in operation

Fig. 4. IR spectrum of the thermoplastic reactive hot melts with isocyanate peak (blue) and progress of the isocyanate reaction (hot melt cross-linking after 24, 48, 72 and 96 hours)
Durchlässigkeit = Transparence, Wellenzahlen = Wave number, nach = after

Fig. 5. Effect of moisture on PUR cross-linking
Flächenanteile = Surface fractions, Zeit = Time, rel. Luftfeuchtigkeit = relative humidity