APARATURA

BADAWCZA I DYDAKTYCZNA

Evaluation of water-borne polyurethane pressure-sensitive adhesives used for protective foils

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ABSTRACT

The goal of this article is to synthesize of water-borne polyurethane pressure-sensitive adhesives (PSAs), evaluation of their properties, such as tack, adhesion and cohesion according to their special application for removable products such as removable (protective films) and repositionable self-adhesive materials. Polyurethane PSA coatings, in general, provide excellent chemical, solvent, as well as toughness combined with good low-temperature flexibility. The extraordinarily diverse chemistry of polyurethanes has also contributed to the development of efficient pressure-sensitive adhesives. Water-borne polyurethane pressure-sensitive adhesives ready for coating are seldom commercially available on the market.

Ocena wodnych dyspersji poliuretanowych klejów samoprzylepnych zastosowanych do folii ochronnych

STRESZCZENIE

Celem tego artykułu jest synteza wodnych dyspersyjnych poliuretanowych klejów samoprzylepnych, ocena ich właściwości, takich jak lepność, adhezja oraz kohezja w zależności od ich specjalnego zastosowania do wytwarzania produktów odrywalnych (folie ochronne) oraz produktów samoprzylepnych wielokrotnego zastosowania. Samoprzylepne powłoki poliuretanowe charakteryzują się, generalnie, wysoką odpornością chemiczną, odpornością na działanie rozpuszczalników, połączoną z dobrą elastycznością w niskich temperaturach. Różnorodność budowy chemicznej poliuretanów znajduje odzwierciedlenie w istotnych właściwościach poliuretanowych klejów samoprzylepnych. Poliuretanowe wodne dyspersje samoprzylepne, przeznaczone do konkretnych aplikacji, są niezwykle rzadko dostępne komercyjnie.

1. INTRODUCTION

An adhesive is a compound that adheres or bonds two items together. Adhesives may come from either natural or synthetic sources. Some modern adhesives are extremely strong, and are becoming increasingly important in modern construction and industry [1]. Since Otto Bayer developed the polyurethanes in 1937 [2-3], in modern times this product turned out to be a fantastic success story as well as a business of many billions of dollars. They are produced by the polyaddition reaction of an isocyanate with a polyol and other low molecular weight reagents as chain extenders or crosslinking agents, containing two or more reactive groups. The commercial development of polyurethanes began initially in Germany in the end of the thirties, with the production of rigid foams, adhesive and coatings. Polyurethane dispersions have become commercially available since the 1960s. Owing to their significance in industry as well as their academic interest, more than 1,000 patents have been filed over the last 5 decades and these have been reviewed and documented. Recent patents have mainly focused on the modification of aqueous polyurethane dispersions for specific end uses [4-6]. Among the water-borne polymer family, the polyurethane dispersions benefit over the last few years from a continuously growing attention by the market that recognizes their high performance and strong potential from soft and rubber properties to rigid thermoplastic or after curing to thermoset materials [7]. This article presents research on polyurethane pressure-sensitive adhesives, which were made by using selected water-borne polyurethane pressure sensitive adhesives, based on hydroxylated soft polybutadiene, diisocyanates, polypropylene glycols and dimethylolpropionic acid.

Low tack, peel adhesion (adhesion) and moderate shear strength (cohesion) have been achieved using synthesized water-dispersible polyurethane PSAs crosslinked with multifunctional isocyanates as crosslinking agents. PSAs are endowed with adhesion and cohesion. Adhesive properties are required for bonding and rebounding processes and cohesion is necessary against debonding. Adhesion is described by tack and peel, whereas cohesion is characterized by shear resistance and partially by peel. Tack, peel adhesion and shear strength are the three general adhesive properties that determine PSA performance. Generally, PSA has to possess a good balance between these three major interrelated properties. The balance is usually adjusted according to the end use of PSA.

2. RAW MATERIALS AND TEST METHODS

All starting materials for synthesis of water-borne polyurethane PSAs, such as hydroxylated polybutadiene (HTPB), polypropylene glycol (PPG), dimethylolpropionic acid (DMPA) and isophorone diisocyanate (IPDI) catalyzed by dibutyltin dilaurate (DBTL) were technically pure and were used in the technological processes without further purification.

Typical performance of water-borne polyurethane PSA such as: tack, adhesion and cohesion, were tested by the use of following polyisocyanate crosslinkers: Desmodur I (monomeric cycloaliphatic diisocyanate copolymer based on IPDI) and Lupranate A 270 (4,4'-diisocyanatediphenyl methane).

The influence of the crosslinking agent is determined in relation to the reaction time and concentration versus the adhesion property under consideration of the parameters: tack, adhesion, cohesion. The polyurethane adhesive containing a crosslinker was coated onto a polyester film. The base weight of the adhesive layer covering the film amounted to 60 g/m^2.

Polyisocyanate crosslinkers will improve the performance of polyurethane dispersions through crosslinking reactions that occur at room temperature in the adhesive film as the adhesives cures to full strength. Polyisocyanate crosslinkers are recommended to be used at a level of 0.1-0.5 or 0.1-0.7 wt. % based on the polymer content in dispersion. The level used for typical laboratory testing with polyurethane dispersions is 0.3 wt. % based on the wet weight of the dispersion containing 50 wt. % solids.

The main properties of the investigated PUR-PSA namely tack, peel adhesion, and shear strength are determined by standard AFERA (Association des Fabricants Europeans de Rubans Auto-Adhesifs). Exact details are found in AFERA 4001 (adhesion), AFERA 4012 (cohesion), and AFERA 4015 (tack).

3. RESULTS AND DISCUSSION

Typical performance of water-borne polyurethane PSA, such as tack, adhesion and cohesion, were also tested after addition of the polyisocyanate crosslinkers: isophorone diisocyanate (IPDI) and Lupranate A 270 (4,4'-diisocyanatediphenyl methane) (Fig. 1-4).

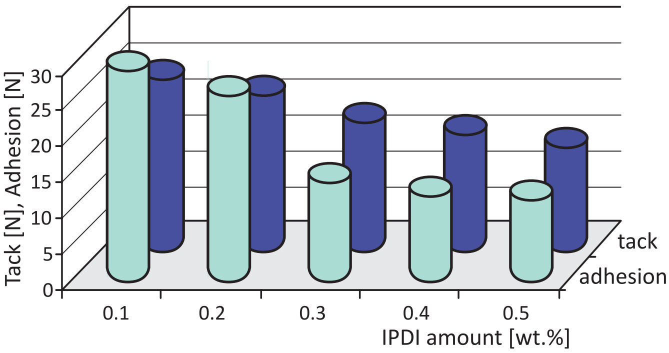

Figure 1. Effect of isocyanate concentration on tack and adhesion of crosslinked (by the use of IPDI) water-borne polyurethane dispersions

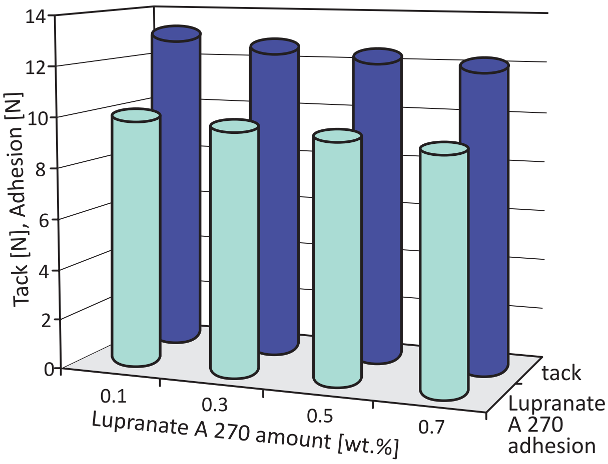

Figure 2. Effect of isocyanate concentration on tack and adhesion of crosslinked (by the use of Lupranate A 270) water-borne polyurethane dispersions

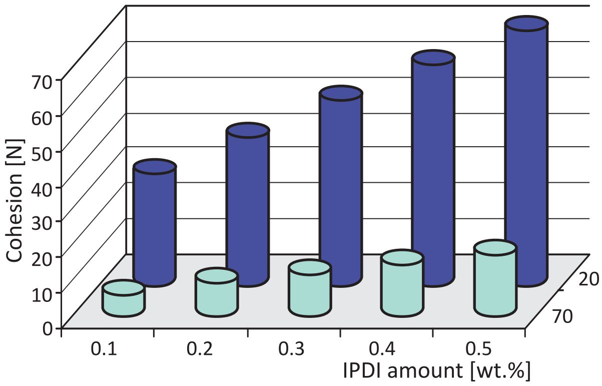

Figure 3. Effect of isocyanate concentration on cohesion of crosslinked (by the use of IPDI) polyurethane water-borne dispersions

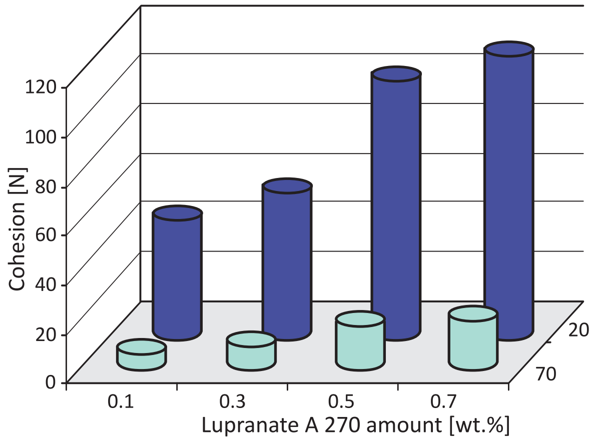

Figure 4. Effect of isocyanate concentration on cohesion of crosslinked (by the use of Lupranate A 270) water-borne polyurethane dispersions

The following conclusions can be inferred from the experimental results:

It can be conducted from these experimental results that the both tested isocyanate crosslinkers have a negative influence on tack and adhesion (Fig. 1-2). By the use of cycloaliphatic isocyanate IPDI in comparison to aromatic isocyanate Lupranate A 270 a more positive influence on the tack and adhesion of investigated polyurethane dispersions was noticed. Cycloaliphatic isocyanate IPDI is inferior to the aromatic isocyanate Lupranate A 270 by testing of adhesiveness properties. By measurement of cohesiveness properties the using of Lupranate A 270 for crosslinking of water-borne dispersions shows excellent cohesion results at 20°C and 70°C of the investigated polyurethane PSAs. The best balance between tack, adhesion and cohesion of applied water-borne polyurethane PSAs for 0.3 wt. % used isocyanate crosslinker were observed.

The uncrosslinked water-borne polyurethane PSA show low value of tack and peel adhesion along with cohesive failure typically for inefficient shear strength. After addition of a small amount of the multifunctional isocyanate as crosslinking agent, the polyurethane PSA begins to crosslink. The PSA structure is now compact, tack, and peel adhesion increases and in the course of the evaluation a maximum of tack and peel adhesion was registered. Finally, at higher concentrations of isocyanate the tack and peel adhesion levels were reduced.

4. CONCLUSIONS

The development of waterborne polyurethane dispersions has been motivated by environmental considerations. Aqueous polyurethane dispersions can be tailor-made and show many of the features of conventional solvent-borne coatings and many technological advantages, such as low viscosity and good applicability. Generally, relatively low tack, low adhesion and moderate cohesion have been achieved using multifunctional isocyanates as crosslinkers in water-borne polyurethane pressure-sensitive adhesives. This justifies the use of multifunctional isocyanates as crosslinkers in water-borne polyurethane pressure-sensitive adhesives in the case of protective films mainly. In fact, the most popular crosslinker for water-borne polyurethane PSAs for protective films is isophorone diisocyanate.

Last years, PSA technology, especially technology of polyurethane PSA systems has made tremendous strides from what virtually was a black art to what is a sophisticated science now. The favorable prognosis for design and development of tailor-made water-borne polyurethane PSAs compositions, which can cope with both the technical and ecological demands, is therefore a continuing challenge for industrial research and development. Progress in the PSA coating technology will open up for new applications and an extended market penetration of polyurethane PSA adhesive raw materials. The next decade will show how the recently developed water-borne polyurethane pressure-sensitive adhesives will position themselves on the market.

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