Ahkar Kaung Myint

Film-forming substances based on blocked isocyanates for materials applied by cathodic electrodeposition

Abstract

Cathodic electrodeposition (CED) is a highly efficient and environmentally friendly method for forming uniform primer coatings on complex-shaped components. The increasing demands of the automotive and machinery industries require coatings with enhanced corrosion resistance, mechanical strength, and durable decorative properties. This drives the need for optimizing film-forming compositions for CED.

A critical factor in achieving superior coating performance is the chemical nature and reactivity of the film-forming substances. Isocyanates play a pivotal role in this regard, offering high reactivity, the ability to form robust crosslinked structures, and excellent adhesion. The practical potential of this work lies in developing advanced anticorrosive coatings by combining isocyanates with acrylic and epoxy resins. This hybridization allows for targeted property tuning: acrylics impart weather resistance and flexibility, while epoxy components enhance adhesion, chemical resistance, and barrier properties. Such synergy enables the creation of materials with outstanding resistance to corrosion, wear, and other forms of degradation.

The application of isocyanate-based film formers in CED significantly improves the performance and service life of coated metal products, which is crucial for industries ranging from automotive to household appliances and agricultural machinery. Industrial adoption of these materials could lead to substantial cost savings by reducing repair and replacement of corrosion-damaged parts. Furthermore, this research contributes to a fundamental understanding of isocyanate systems in CED, providing a theoretical basis for the rational design of next-generation film-forming materials and advancing the field of protective-decorative coatings.

The aim of this study is to investigate emulsions based on blocked isocyanate film-forming systems for the formation of polyurethane coatings by cathodic

electrodeposition and to determine the feasibility of obtaining clearcoat (varnish) coatings with predetermined properties.

Objectives:

1. To synthesize polyisocyanates blocked with an amine-containing agent and to analyze the resulting products;
2. To examine the parameters and evaluate the stability of emulsions of the synthesized isocyanates and epoxy amine adducts at various degrees of neutralization;
3. To examine the parameters and evaluate the stability of combined emulsions of the synthesized isocyanates and epoxy amine adducts at various degrees of neutralization;
4. To investigate the features of the electrodeposition process of the obtained system components and to select the optimal application parameters;
5. To carry out performance testing of coatings based on the obtained film-forming emulsions;
6. To investigate the influence of functional additives on emulsion stability and coating properties.

Scientific Novelty

The scientific novelty of the dissertation lies in establishing the influence patterns of the chemical structure of film-forming agents based on blocked polyisocyanates and amine adducts on the stability of emulsions for obtaining coatings with predetermined properties (strength, adhesion, protective performance).

It has been shown that introducing a nitrogen-containing blocking agent into the isocyanate structure enables the formation of aqueous emulsions with low particle size; stability is achieved at a degree of neutralization close to 100%.

It has been established that the stability of emulsions combining amine adducts and blocked isocyanates significantly depends on the stability of each individual component. The particle size in the combined emulsions is determined by the molecular weight of the resin.

It has been demonstrated that emulsions neutralized with lactic acid exhibit the highest stability. Furthermore, at equal degrees of neutralization, the lowest electrical

conductivity is also observed for emulsions with lactic acid as the neutralizing agent. This was hypothesized to be related to the dissociation constant of the neutralizing agent.

In the study of emulsions based on adducts of acrylic copolymers with varying tertiary nitrogen content, it was shown that a high nitrogen content leads to the formation of a gel-like structure even at incomplete neutralization (not exceeding 50%).

Theoretical and practical Significance

The theoretical and practical significance of the dissertation results lies in the development of scientifically grounded approaches to obtaining film-forming substances based on blocked isocyanates for cathodic electrodeposition systems. This enables the formation of coatings with uniform thickness on complex-shaped articles, exhibiting excellent anticorrosive properties.

In the course of the work, formulations of cathodically depositable clearcoats (varnishes) based on hybrid epoxy-acrylate film-formers, cured with blocked isocyanates, were developed. The proposed compositions ensure the formation of coatings with a high level of performance properties.

The study revealed the influence patterns of functional additives of various natures and their concentrations on the stability of emulsion systems and the properties of the resulting coatings. This provides a foundation for optimizing formulations with regard to specific production requirements.

Furthermore, practical recommendations have been developed for conducting the process, including electrodeposition parameters (voltage, current density, time, temperature), rinsing and thermal curing operations, as well as quality control methods for finished coatings.

The main provisions for the defense

1. The process of obtaining water-dilutable blocked isocyanates and the investigation of their stability;
2. The influence of the electrokinetic potential and hydrodynamic diameter of individual emulsion components on the corresponding parameters of combined emulsions;

3. Characterization of oligomers and copolymers for the preparation of water-dilutable film-forming substances;

4. The influence patterns of the nature and concentration of acid neutralizers (acetic, lactic, sulfamic acids) on the formation of quaternary ammonium salts, which determine the water solubility of the polyelectrolyte, as well as on the hydrodynamic diameter of droplets and the long-term stability of emulsions;

5. The parameters for applying coatings by cathodic electrodeposition, including the specific technological regimes (voltage, time) that enable the formation of coatings with a high level of performance properties;

6. The influence of functional additives on the appearance and stability of emulsions for coatings obtained by cathodic electrodeposition.