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Waterborne Coatings : An Alternative of Conventional Coatings

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ABSTRACT

A major objective of research and development in the area of surface coatings, is either reduce or eliminate the presence of organic solvents present in conventional coating systems or to replace them with certain environmental favorable solvent such as water in the case of waterborne coatings. The increasing cost specially of petroleum products, environment, energy etc. have increased pressure on paint manufacturers to produce the ideal system which does not contain toxic substances and does not contribute to environmental pollution; has a low raw material cost; provides the necessary protection to the substrate high performance and can easily be repainted. The solvents play a variety of important role in resin manufacture, coating production, application, and film formation. Substantial research efforts are being exerted to reduce and, in at least some cases, eliminate the need for solvents.
Keywords : Waterborne Coatings, Environment, Pollution

I. INTRODUCTION

Waterborne resin technologies are changing the world of coatings. Coatings contain one or more solvents as a primary ingredient. Solvents dissolve the paint materials to form a liquid mixture that can be sprayed. Once applied to a part, the solvent evaporates, leaving behind the paint film. Water is frequently used as a solvent in waterborne coatings. This type of coating contains water-soluble resin; hence it completely dissolves in water and other solvents. A waterborne coating contains organic co-solvents since it undergoes poly-condensation or polymerization reactions. Contrary to its name, waterborne coatings typically contain other solvents which can make up as much as 30 percent of the product. Waterborne coatings have been around in one form or another for decades but have demonstrated greatly improved performance characteristics in recent years. Some common waterborne resins include acrylics, epoxies, alkyds, and polyurethanes. This is better for the user and better for the environment. And because they're waterborne, it also means spray equipment needs just a brief rinse and it is ready to use again. That's less fuss and less waste. China is the leader in driving waterborne resin technologies to impact legislation and promote sustainable coatings. These coatings are also known to be environment-friendly as US and European regulations require waterborne coatings to have a VOC content of less than 3.5 pounds per gallon of water.

Need and driving forces to use water borne coatings

The need and driving forces for the use of water borne coatings can be summarized as follows:

- Higher solvent prices
- Increased energy cost
- Restrictive emission regulations
- Protection of environment
- Ecology
- Ease of cleanup in most cases
- Decreased fire hazard
- Lower insurance cost

Water, as a substance, is unique: it is the only inorganic liquid to occur naturally on earth, and it is the only compound which can be found in nature on earth in all three physical states,solids, liquid and vapour. Water has very unusual physical properties when compared to other liquids as follows:

Table-1. Comparison of water with other conventional coating solvents

Property	Water	Mineral Spirit	Xylene
Molar mass	18	170	106
Boiling point (^0C)	100	214.5	144
Surface tension (dynes cm^{-1})	73	18	30
Latent heat of evaporation ($Calg^{-1}$ at bp)	540	115	94

Types of Waterborne Coatings

The various types of waterborne coatings available in the coating industries are as follows:

- **Water-soluble paints** – contain water-soluble resins whose individual molecules dissolve completely in water. The resins are usually produced via polycondensation or polymerization reactions in an organic medium, hence they mostly contain organic co-solvents like alcohols, glycol ethers or other oxygen-containing solvents that are soluble or miscible with water. The resins used include polyesters, polyacrylates, alkyds, epoxies and epoxy esters. These paints provide high gloss, a high level of corrosion protection, good pigment, wetting and stabilization.
- **Water-dispersible paints or colloidal coatings** – contain small clusters of insoluble resin particles that are suspended in water using mechanical agitation. Small quantities of organic solvents are used as coalescing agents, which evaporate on drying. The resins used in these types of dispersion paints include vinyl propionate copolymers, vinyl acetate copolymers, acrylate-methacrylate copolymers, and styrene-butadiene copolymers and polymers. Colloidal dispersions are used mainly to coat porous materials.
- **Emulsions/latex paints** - are quite similar to water-dispersible paints. The main difference is that the resin clusters in emulsions tend to be larger, and an emulsifier is required to keep the clusters in suspension. The resins used include styrene-butadiene copolymers, acrylics, alkyds, polyvinyl acetate, and polystyrene. These paints posses increased permeability which allows them to "breathe," thus reducing blistering or peeling.
- **Water-based alkyds** – These coatings tend to take longer to dry than solvent-borne coatings; however the end result has similar gloss, flow and levelling properties. They are very versatile as they can be thinned with water to almost any viscosity. Water-based alkyds can be applied with spray or dip applications, and are one of the cheaper VOC-compliant coatings.

The characteristics of various water based resins can be tabulated as follows

Table-II. Characteristics of Various Water Based Resins

Resin Type	Major Characteristic(s)
Latex	Particle size of 5 nm - 10 microns, opaque liquid
Water Reducible	Reduction with water results in irregular viscosity vs. solids relationship
Polyurethane Dispersion (PUD)	- Particle size of 1- 20 microns - Lower Minimum Film Forming temperature in relation to dry film Tg - Lower cosolvent demand
Miniemulsion	- 50 – 500 nm particle size
Microemulsion	- Particle size 10 – 100 nm - Clear liquid
Core-Shell (Low Tg shell with high Tg inner core)	- Reduced blocking - Lower coalescent demand

Formution Aspects

The main routes reported in the literature to render the polymers water-soluble are :

(a) By salt formation through acid-base reaction
(b) By Bunte salts formation
(c) By Ionomer formation
(d) By introducing nonionic groups in polymers
(e) By converting the polymers zwitterion intermediates

(a) By salt formation

The most important methods which have been used on a commercial scale are by salt formation through acid-base reactions, where the polymer backbone is converted into anions or cations. According to this method polymers containing carboxylic or amino groups were converted to their respective salts by neutralizing with a suitable base or an acid. Water-soluble polymers containing cationic groups have recently found extensive applications, especially in cathodic electrodeposition coating compositions. The main cationic groups which have been used are amino groups, quatenary ammonium groups, tertiary sulphonium and phosphonium groups.

The application of these water-soluble polymers are limited mainly by the low molecular weight of the resins. Water- soluble resins have successfully been used for maintenance and industrial coatings on the interior and exterior metal substrates.

(b) By Bunte salt formation

Thames (1990) described a new method to obtain water solubility through Bunte salt polymers. Organic thiosulphate are usually termed as Bunte salts after the name of Hans Bunte who first discovered, that when aqueous solution of sodium thiosulphate is heated with ethyl bromide, organic thiosulphate are formed. Bunte salts are initially soluble in water which can be converted into insoluble films by crosslinking under the influence of heat or photolysis. Water solubility can also be achieved by copolymerizing with Bunte salt monomers. These monomers are prepared by reacting aminoethane thiosulphuric either with halogenated vinyl monomers or acid chlorides or with glycidyl methacrylate.Addition of melamine resin also resulted into films having mechanical and physical properties similar to conventional thermosetting acrylics.

(c) By Ionomers formation

Water-borne systems can be obtained through ionomer formation which contain a minor proportion of an acid functionality which are then neutralized to varying degrees by a metal or quaternary ammonium ion. Water insolubility in this case is achieved by curing the film at about 250ºC.

Although the formation of ionomers is an interesting route to obtain water-soluble systems, the high curing temperature seems to be a strong limitation against the commercial implication of such systems.

(d) By Introducing Nonionic Groups

To eliminate the use of an amine or a cosolvent to achieve water solubility, this new class of low molecular weight polymers has been devised. These polymers have been shown to be compatible with the existing water-borne resins as well as with most of the solvent-borne resins and can therefore be used as reactive diluent to replace cosolvents and some amine in the system. These resins show similar performance to that of alkyd resins. Water solubility of this new class of polymers is obtained by introducing nonionic groups such as polyols or polyether groups.The main drawbacks with this class of resin are the water sensitivity of the dried films and poor adhesion to steel substrates.

(e) By Converting the Polymer Zwitterion Intermediates

Water-soluble or water-reducible systems free from amine or formaldehyde emission have recently been obtained by the formation of zwitterion-type copolymers in which both the amineand the carboxylic acid are attached to the resins by covalent bonds.

Qualities and Advantages of Waterborne Coatings

The prime concerns behind the development of water borne coating have been:

- High gloss
- High corrosion protection
- Wetting and stabilization
- Good pigmentation
- Good flow and leveling properties
- Good resistance to heat and abrasion
- Low toxicity and flammability
- Cleans easily with water or water-based solutions
- They are ideal primers as they posses good resistance to heat and abrasion
- Provide excellent adhesion
- Low toxicity and flammability due to low VOC levels
- Help reducing air emissions

Waterborne versus solvent-borne coatings:

- In most cases, these coatings cost less than solvent-borne coatings and require no additives, thinners, or hardeners
- compared to solvent-borne coatings, less coating is required to cover the same surface area
- The pot life of waterborne products is relatively long and unused coatings can be preserved in a sealed container for future use
- Waterborne primer is ideal for use where solvent primer would react with existing substrate materials or coatings
- The paint guns can be cleaned easily with water or water-based solutions and do not require paint thinner, acetone, or methyl acetate
- Waterborne coatings are more corrosive than solvent born coatings and thus require lined containers, plastic or stainless steel to avoid rust
- Can use conventional application techniques

Drying of a water based system

The drying of a water based system involve various stages. The first stage involves the evaporation of water. The second stage includes the continued evaporation of water and cosolvent to the point where the latex particles touch and begin to coalescence to form a film that is partially dried. The final stage involves the continued coalescence and cure (in a crosslinked system) to form a cured, dry adherent paint film (Fig-1).

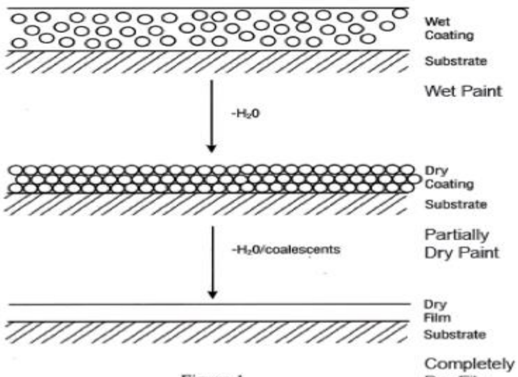

Figure 1

Various stages in drying of a Water based paint system

Concerns while using waterborne coatings include:

On the contrary the presence of water as a solvent possesses some problems as well. The main problem are as follows:

- High surface tension of water (poorer wetting) makes it poor solvent for flow characteristics
- High dependence of evaporation rate on relative humidity
- High heat of evaporation for water requires 2260 J/g for water and for example only 373 J/g for 2-butoxyethanol, a commonly used cosolvent

- Nonlinear viscosity reduction curve for coatings using water reducible resins
- High dependence of flow and appearance on relative humidity
- Waterborne coatings are more prone to popping in baked applications as film formation begins to occur before water evaporates from the film
- Poor detergent resistance

II. Conclusion

The use of water-soluble resins has increased significantly in recent years in the surface coating industry. Motivation for the growth of such resins has arisen from their ease and cleanness of application and their low odour levels and toxicity. The air pollution caused by solvents and their bad effects on human health led to the advent of Rule 66 in the mid 1960s and increasing regulations on pollution control. Consequently, the surface coating industry is being forced to adopt low-solvent and water-borne coating technology. In addition, the ever-increasing prices of coating solvents is another reason to accelerate the changeover to water borne coatings. However the continued advancement in material science to include innovations in resin chemistry, surfactants, wetting agents and flow agents will help enable the continued growth of waterborne coatings.

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