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Colloidal stability and rheology of jatropha oil-based waterborne polyurethane (JPU) dispersion

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ABSTRACT

Jatropha oil-based waterborne polyurethane (JPU) dispersions were produced by polymerising the jatropha oil-based polyols (JOLs) with isophrene diisocyanate (IPDI) and dimethylol propionic acid (DMPA). The colloidal stability of the resulting JPU dispersions were studied by particle size analysis and rheology measurements. Inclusion of up to 5.4 wt.% of DMPA as an internal emulsifier produced a wide range of particle sizes from 84 nm to 825 nm. The dispersions have a solid content of 24.2–26.9 wt.% with a relatively low viscosity in the range 6.2–60.2 mPa s. The JPU dispersions exhibited the typical flow behaviour of the commercial polyurethane dispersions, ranging from almost Newtonian to a shear thinning fluid, and the experimental data correlated well with the Cross model. The samples were stable after 18 months of storage under room conditions.

1. Introduction

Polyurethane(PU) is a versatile polymer which has been employed in a wide range of applications, such as coatings, adhesives, sealants, foams, elastomers, and others. With a proper selection of reactant, PU ranges from high performance elastomers to tough and rigid plastics can be easily fabricated [1]. PU based coatings have an established place in the coatings industry due to the high level of quality such as outstanding chemical and corrosion resistance, excellent abrasion resistance, low temperature flexibility, high toughness, and a wide range of mechanical strength [2,3].

Traditional PU coatings have been diluted with an organic solvent that helps to carry the coatings from the applicator to the substrate. Organic solvents often contain volatile organic compounds (VOCs). The emission of VOCs during the formulation of coatings, inks, and paints has caused a wide variety of air quality problems [4]. With enforcement of stringent regulations aimed at preventing pollution, such as the Clean Air Act, the application of solvent-borne coatings has been phased out and replaced with coatings free of VOCs such as waterborne coatings and ultraviolet (UV) curable coatings (100% solid) [5–7]. In Europe, waterborne technology has been accepted as it has become the largest volume of coatings particularly in terms of decorative coatings [8]. These products fulfil many of the requirements related to conventional solvent-borne coatings, e.g., low viscosity at a high molecular weight and good applicability [9]. The transition from solvent-borne to waterborne PU may lower the manufacturing costs associated with solvent cost, and reduce the health and fire risks [10]. It has been forecast that the global PU dispersion market will grow at a CAGR of 7.5% in the years 2012–2018, with the market value estimated to be worth US $ 1.18 billion by 2018 [11].

Waterborne polyurethane (PU) dispersion is a typical colloid system consisting of PU particles stabilised in a continuous water phase. In preparing a waterborne PU dispersion, ionomers which contain hydrophilic groups are incorporated into the side chain or the backbone of the polymer to enable dispersibility of the water-insoluble polyurethane. Anionic ionomers such as dimethylol propionic acid (DMPA)

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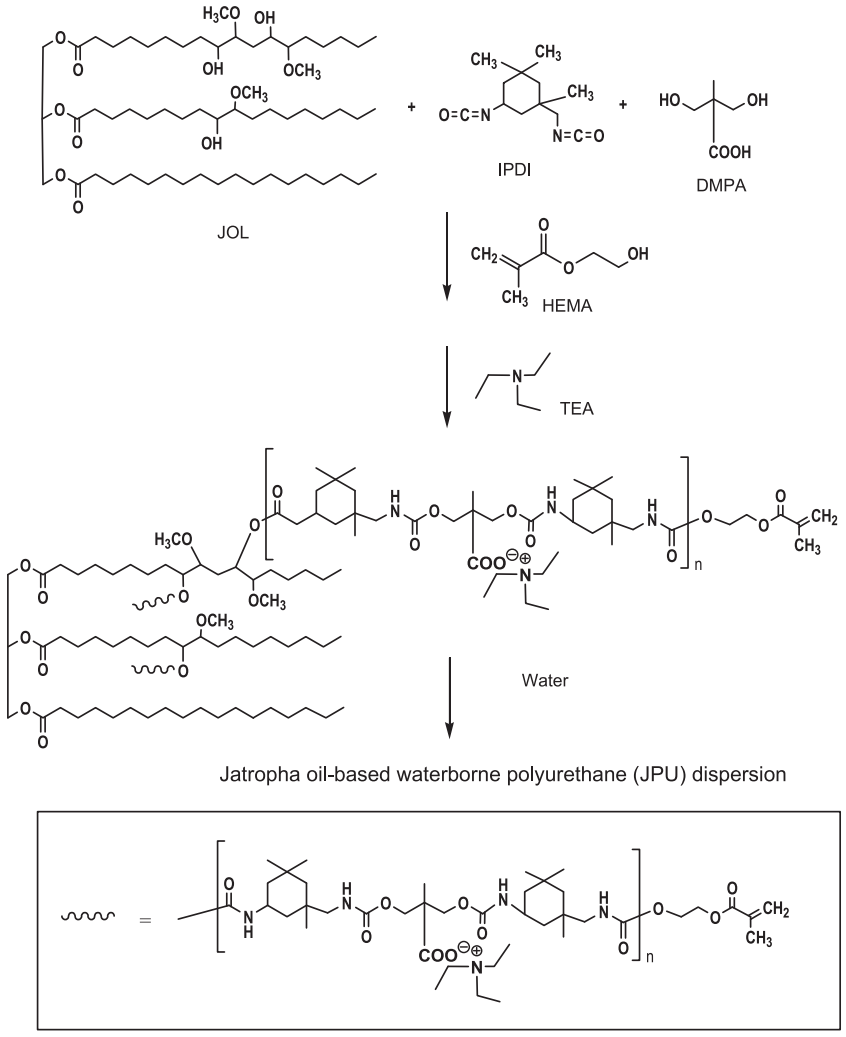

Fig. 1. Schematic for the synthesis of waterborne polyurethane dispersions.

act as an emulsifier to provide dispersion stability for longer storage of the waterborne PU dispersion. Currently, most waterborne PU dispersions are derived from a petroleum based polyol which is non-renewable. As fossil resources become depleted, coupled with awareness of environmental issues related to non-biodegradable products, utilisation of more sustainable and environmentally friendly raw materials for fabrication of bio-based polymers is gaining increasing attention. Recently, the successful synthesis of waterborne PU dispersions from vegetable oil based polyol derived from soybean oil, castor oil, rapeseed oil, linseed oil and jatropha oil has been reported [1,12–18]. However, to the best of the knowledge of the authors, limited research has been reported on the stability and rheology of waterborne polyurethane dispersion.

In general, the characteristics of the colloidal dispersions do not directly affect the mechanical properties of the resulting dry films. However, information on the colloidal stability and rheology of the dispersion is important with respect to storage and application. For example a low viscosity and molecular weight independent of the dispersed polymer is necessary for spray applications, but low zero shear rate viscosity is subject to sedimentation of the PU particles upon storage [19,20]. A few factors have been reported to affect the stability of colloidal PU dispersions such as the degree of neutralisation and the stirring procedure. However, these are less important when compared to the ionic emulsifier content [21]. The ionic groups in the DMPA are reported to improve the mechanical properties, but tend to make the dispersion film more sensitive to water and chemicals [22]. Therefore, the amount of DMPA should be controlled to be as low as possible yet sufficient to stabilise the PU particles upon storage. In addition, a balanced composition between soft segment (polyol) and the hard segment in the PU formulation is an important criterion to determine the mechanical properties of the polymers [16].

In this study, jatropha oil based waterborne PU dispersions were prepared and characterised. The aim is to investigate the effect of hard segment, hydroxyl number, and ionic emulsifier content on the colloidal stability and rheological properties of jatropha oil-based waterborne polyurethane dispersions.

2. Materials and method

2.1. Materials

Isophrene diisocyanate (IPDI), dimethylol propionic acid (DMPA), n-methyl pyrollidone (NMP), hydroxyethyl metachrylate (HEMA), phtalic anhydride and dibutyltin dilaurate (DBTDL) were supplied by Sigma Aldrich. Ethyl Methyl Ketone (MEK), triethylamine (TEA), formic acid, magnesium sulphate anhydrous, pyridine, and sodium hydroxide were reagent grades, supplied by Systerm. Besides that, All chemicals were used without purification. Jatropha oil-based polyol were synthesized by epoxidation and ring opening method. The details procedures has been described in our previous work [18].