CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions[1]

In Dupont impact test, NBDI is much higher than IPDI. The most important factor on the dupont impact of NBDI is OHV while that of IPDI are OHV and catalyst.

Increasing in OHV and catalyst results in decreasing Dupont impact in both of the hardeners. In contrast, Dupont impact test increases with the increase of AV in both of the hardeners.

In chemical resistance, IPDI has more resistance than NBDI and both of them have more resistance to acid than base corrosion.

The most important factor on the chemical resistance of NBDI is OHV while that of IPDI is OHV and catalyst interaction effect.

The chemical, acid and base resistance of NBDI increases when OHV is increased.

The relationship between Dupont impact and chemical resistance of NBDI is presented in Table 6.1 and 6.2. The samples, which have the high Dupont impact, appear to show low chemical resistance. For instance, the sample 3N has the highest Dupont impact but has the lowest chemical resistance. It might

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[1] NBDI is NBDI isocyanurate and IPDI is IPDI isocyanurate.

be concluded that the change in one of these properties will affect the other in the opposite way.

Table 6.1 Dupont impact rank of NBDI sample

Rank	Sample	Dupont impact (mm)
1	3N	500.0
2	6N	487.5
3	5N	287.5
4	4N,8N	262.5
5	10N	150.0
6	9N	137.5
7	7N	112.5

Table 6.2 Chemical resistance rank of NBDI sample

Rank	Sample	Δ acid (mm)	Sample	Δ base (mm)
1	7N,9N	12.5	7N	12.5
2	8N,4N	50.0	9N	50.0
3	10N	62.5	8N	62.5
4	5N	150.0	10N, 4N	87.5
5	6N	300.0	5N	125.0
6	3N	337.5	6N	312.5
7	-	-	3N	325.0

Dry hard times of NBDI are less than that of IPDI. By the similar tendency, the increasing rate of viscosity in gel time tests of NBDI is much faster than that of IPDI. It can be deduced that NBDI has more reactivity than IPDI.

In exposure test, NBDI has better weatherability than IPDI because the reduction of gloss retention of NBDI is less than that of IPDI throughout the testing period of 24 weeks. However, the differences of gloss retention between two hardeners are small (approximately 2%) and can not be apparently distinguished. Consequently, it can be summarized that the weatherability of both is similar. In addition, the gloss retention of both in QUV test is practically the same value and their values are not less than 100% throughout 700 hours of the experiment. However, it is noted that the yellowness of NBDI is higher than that of IPDI

The tensile strength at yield of NBDI is less than that of IPDI while the elongation at break of NBDI is much more than that of IPDI (roughly 8 times)

The most important factor in both hardeners is OHV. The other factor is less significant. So it might be assumed that only hydroxyl group reacts with isocyanate group while carboxyl group does not take part in the reaction as one of reactants because the tensile strength generally varies with crosslink density film (XLD) which depends directly on number of functionality corresponding to OHV.

In NBDI, when OHV is increased, the strength and elongation are increased. This is a good relation, which does not occur in IPDI, in developing a new formula of coating. In IPDI, the strength increases but the elongation at break also decreased, when OHV is increased.

In the dynamic mechanical analysis test (DMA), Tg of coating film is presented. The most significant factor is OHV. Increase of OHV will increase Tg of the film. The other factors also influence on Tg but the extent of Tg change is not so high. In effect of catalyst, increase the amount of catalyst, lowering MW, will reduce Tg of samples. For the AV factor, the more quantity of AV, the higher Tg. Moreover, NBDI's films give lower Tg than IPDI's.

In summary, it can be obviously found that most film properties are chiefly controlled by OHV while the other factors have less effects on film properties. Like most polymeric materials, the film properties of coating can be related to the basic physical properties such as tensile property and viscoelasticity which were employed in this work. The two principal parameters used in coating field to relate film properties with fundamental properties are glass transition temperature (Tg) and crosslinking density (XLD). Both of parameters can be found out from DMA. Thus, film properties can be explained more clearly by using these two fundamental properties. In addition, the relationships between Tg and XLD are also interesting to study. The dependence of Tg and XLD were studied in many models and different ideas. [Ikeda, 1972] However, every publication explained similarly that increase of Tg will increase XLD as well.

It is commonly known that OHV influences directly on XLD due to number of functionality in their molecules. So the network can crosslink more closely. Unlike OHV, the quantity of catalyst affects on the molecular weight (MW) of polyol. The more used catalyst, the lower molecular weight of polyol. The molecular weight also affects on Tg of polymer which impacts to the film properties. The last factor, AV, affects on the extent of reaction and the number of remaining isocyanate group after curing in a certain period of time. [Ludwig and Urban, 1996: Van der Ven et. al., 1992]

The relationship between dupont impact resistance and chemical resistance can explained by this concept too. The film that has high impact resistance is more likely to have low Tg of polymer because it has more softness. The higher Tg of polymer, the more brittleness. This comment can be confirmed by the DMA result that shows the lower Tg of NBDI and the higher in dupont impact resistance. Furthermore, the impact resistance is the ability of material to

dissipate energy which is similar to toughness. [Zosel, 1980] It is found that NBDI has much more toughness than IPDI. In contrast, chemical resistance results from crosslinking density (XLD). It can be concluded that if impact resistance is required, Tg of polymer must be reduced and if chemical resistance is needed, XLD has to be increased. However, many publications state that the change of both Tg and XLD is the same inclination. Thus, it is very diffiicult to increase the impact resistance and chemical resistance at the same time, as the experimental results shown in table 6.1 and 6.2.

2. Recommendations for further studies.

The relationships between film properties and basic physical properties such as tensile and dynamic mechanical property are very interesting to study because the basic physical property is easily related to the chemical structure and characteristic of material which are very necessary to develop the performance of coating to serve the requirement of various application.

Apart from improving chemical structure of material, the progression of reaction during curing is also very important to the film properties. The mechanism of crosslinking reaction is very attractive to study. The factors that affect on this reaction are numerous such as the composition of thinner, curing temperature, curing time, moisture content in atmosphere, catalyst usage and the molar ratio between hardener and resin.

In addition, most of coatings must be manufactured in paint and the pigment also affects apparently on the film properties. So the pigment effects on film properties are also engrossing to find out because there are only film properties of clear lacquer, free of pigment, in this work.

The glass transition temperature (Tg) is one of the most significant factors for controlling film properties. The Tg adjustment can be made by various methods such as monomer composition in copolymerization step of polyol, structural arrangement of polyol by efficient polymerization technique [Gray, 1985: Simms and Spinelli, 1987: Vasanth and James, 1987] and blending different Tg polymer. Moreover, the dependence of Tg and XLD is very absorbing because the interaction between impact resistance and chemical resistance result from Tg and XLD. It is a very challenging work to design the coating to have high XLD and low Tg. [Zosel, 1980] suggested that reduction of Tg and increase of XLD

may be possible due to plasticizing effect from certain monomer. Additionally, Tg adjustment by using a proper plasticizer may be practicable. Thus, it may be necessary to know the mechanism of the plasticizer effects on the film properties.

The last effect that influences on film properties is the type of hardener. The difference of film properties between NBDI and IPDI is clear from the experimental results although both hardeners have similar chemical structure, six carbon atom ring. The reason to explain this is still equivocal. However, it can be assumed that the differences might derive from the different side chain of isocyanate group and the different side chain of isocyanate group and the different reactivity of them. Moreover, the effect of the isocyanurate isomer are needed to be further verified. So it is very striking to study profoundly.