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ABSTRACT

RESEARCH AND DEVELOPMENT ON RADIATION CURING OF SURFACE COATINGS IN INDONESIA. Research and development on curing of surface coatings by using electron-beam (EB) and ultra-violet (UV) radiation have been done on various kind of wood panel substrates, such as plywood, particle-board, parquet flooring, and some commercial timbers. Experiments on other substrates, such as ceramics, asbestos and gypsum are being developed intensively. Moreover, test production has been done on plywood, particle-board and parquet flooring. Coating work services are given to the companies, which in their business need coated wood panels or flooring. These irradiated coated products have been used for laboratory equipment, office building, house and mosque.

ABSTRAK

PENELITIAN DAN PENGEMBANGAN PELAPISAN PERMUKAAN DENGAN CURING SECARA RADIASI DI INDONESIA. Penelitian dan pengembangan pelapisan permukaan dengan curing secara radiasi menggunakan berkas elektron dan sinar ultra violet telah dilakukan pada berbagai jenis kayu, yaitu kayu lapis, papan partikel, lantai parket dan beberapa macam kayu perdagangan. Percobaan pada substrat yang lain, misalnya keramik, asbes, dan gipsum sedang dilakukan secara intensif. Demikian juga produksi percobaan telah dilakukan pada kayu lapis, papan partikel dan lantai parket. Layanan pelapisan juga telah diberikan kepada beberapa perusahaan yang dalam usahanya memerlukan panel-panel kayu atau lantai dari kayu yang sudah dilapisi. Produk-produk yang sudah dilapisi ini telah dipakai untuk peralatan laboratorium, bangunan kantor, rumah, dan lantai masjid.

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INTRODUCTION

Radiation curing systems, especially those involving electron-beam (EB) and ultra-violet (UV), are finding increasing applications in the fields of printing inks, coatings and paints. Radiation curing of coating can be applied on a variety of substrates such as wood, metals, paper and ceramics. In West Europe (Netherland, French, Germany, Belgium), this technology has been used commercially in furniture and wood industries since 1973. Universal Woods Inc., USA, has used this technology for coating and laminating wood panels. In Japan, EB curing has been applied for finishing motor-cycle parts and roof tile. Finishing of paper, flock and foil, using this technology, has also been adopted in Germany and USA [1].

According to Omega Research Associates, Inc., USA, the volume growth based on the Original Equipment Market (OEM), coatings market has been modest, running about 4.3 % per year, between 1983 and 1988. This appears rather high, but it was what several industries reported. Omega's feeling is that growth through 1993 will be lucky to reach a 3 % per year level. Omega also feels that the best method of subdividing this very complex market is in considering what substrate is to be coated (wood, paper, plastic, etc.)

In Indonesia, a pilot-plant for radiation curing

technology, which was particularly designed for wood surface coatings, had been installed at Centre for The Application of Isotopes and Radiation, National Atomic Energy Agency (CAIR - BATAN), Jakarta, in 1984. The pilot-plant was constructed under a cooperation between Government of Indonesia and IAEA/UNDP, and had been used for research and development, regional training course & demonstration, and some radiation services.

This paper describes the activities and achievements involving EB and UV, in terms of radiation curing of surface coatings using the pilot-plant at CAIR-BATAN.

PILOT-PLANT SPECIFICATION

The pilot-plant consists of a building of 720 m^2 equipped with a low energy electron-beam machine (300 keV, 50 mA), and a number of wood coating and wood handling equipments. In 1986, a UV irradiation source having 80 Watts/cm intensity, was also installed in the building. A small modification of some equipments, and plant layout, as well as installation of a liquid nitrogen generator was done in 1989. The equipments in the facility are in commercial size, but it was not designed for commercial production. All equipments were designed for processing of standard size wood panels (2.4 x 1.2 m). Specification of the equipments is shown in Table 1.

Table 1. Specification of equipments

Equipment	Type	Conveyor speed, m/min	Power, kW
EB machine*	Low energy accelerator, scanning type, 300 keV, 50 mA.	2.5 - 25	35
UV source**	One lamp, 80 Watt/cm.	3 - 6	10
Sanding machine.	Belt type	-	38.6
Direct roll coater.	-	10 - 40	1.2
Reverse roll coater.	-	10 - 40	6
Curtain-coater	Flow-type	40 - 120	1.2
Film laminator		5 - 20	9
Liquid nitrogen generator.	-	-	75

Note :

* Manufacturer : Nissin High Voltage, Co., Japan.
** Manufacturer : IST Strahlen Technik, Germany.

To determine the quality of coated products, various testing apparatus are available in the Radiation Processing Laboratory. The testings covered the hardness, adhesion, chemical resistance, weather resistance and gloss, as well as determination of coating materials

properties. Testing and measurement were conducted according to the American Society for Testing and Materials (ASTM) Standards, International Organization for Standardization (ISO), British Standard (BS), Japanese Industrial Standard (JIS) and Indonesian Industrial Standard (SII).

ACTIVITY

Research & Development. Research and development efforts are being carried out covering synthesis and formulation of radiation curable materials, radiation surface coatings of several substrates, and economic evaluation. Formulation and radiation curing of surface coating were done using commercial acrylated oligomer/ prepolymer, such as epoxy-acrylate, polyester-acrylate, and urethane-acrylate after mixing with reactive monomer and some additives. The prepolymers were mostly imported i.e., Laromer (BASF, Germany), Aronix (Toagosei Chem. Ind., Japan), Radicure (Kansai Paint, Japan), Setacure (AKZO, Netherland), Synocure (CVP, England), and Raycron (PPG, USA). One of the radiation curable materials is unsaturated polyester - styrene, available locally and produced by Pardic Jaya Company.

The results of studies carried out at CAIR, can be featured as follows:

1. Synthesis and Formulation.

a. Synthesis of Epoxy-acrylate.

Synthesis was done by heating glycydil methacrylate (GMA), ethylene glycol (EG) and triethyl amine at 80°C for 8 hrs. The best results were obtained by using a 2 to 1 mixture of GMA - EG, which gave a stable viscosity for six months. Films irradiated at the dose of 60 kGy were resistant to 5 % acetic acid, 50 % alcohol, 1 % sodium carbonate and petroleum benzene [2].

b. Effect of Diethylamine and Triethyl Amine on Radiation Curing of Unsaturated Polyester-styrene.

The addition of diethyl amine (DEA) or triethyl amine (TEA) increased the viscosity of the resin and properties of the films, such as gel-fraction, hardness, adhesion, and chemical resistance. The use of 1 % DEA or TEA was able to reduce irradiation dose from 100 kGy to 70 kGy at the gel fraction level of 90 % [3].

c. Radiation Curing of Commercial Acrylate.

Addition of tripropylene glycol diacrylate (TPGDA) monomer in the range of 30 to 40 % by weight to Laromer PE 55 F or Laromer PE 46 gave a good physical and mechanical properties of its films. Films made of Aronix Ar 7100 showed better

film properties than Aronix M 5700, PE 55 F or PE 46. The optimum dose required was 50 kGy by EB curing and 1% Darocur 1173 photoinitiator (produced by Merck, Germany), for UV curing. EB curing produced better film properties than UV curing [4]. This research is partially supported by IAEA under research contract No. 4821/RB.

d. Thermal Stability of Epoxy-acrylate and Urethane-Acrylate Films.

Thermogravimetric analysis (TGA) and activation energy calculation gave the conclusion, that thermal stability of epoxy acrylate film (Laromer EA 81) was higher than that of urethane-acrylate (Laromer LR 8739). The activation energy of EA 81 -TPGDA mixture (3 : 2) at the dose of 40 kGy was -54.9 kcal/mole, compared with only 28.5 -kcal/mole for LR 8739 - TPGDA mixture (4 : 1). Initial decomposition temperature of EA 81 - TPGDA mixture (3 : 2) and LR 8739 -TPGDA (3 : 2) were 310^{o}C and 260^{o}C, respectively at the dose of 40 kGy [5].

2. Radiation Curing of Surface Coating of Various Substrates.

a. Plywood

Pigmented coating of plywood for ceiling was carried out using titanium oxide. The use of 40 %

titanium oxide gave the best result in the film properties such as adhesion, weather and water resistance at the dose of 50 kGy for PE 46, and 100 kGy for polylite KC 288. Weather and water resistance of the films produced by EB curing was better than that produced using commercial emulsion paint.

Experiment on PVC film lamination on plywood has been done using Aronix and Laromer as oligomers. Aronix Ar 8060 gave the best adhesion property at the dose of 50 kGy. The addition of reactive monomers (Ar M 5700, TPGDA, HDDA) decreased the adhesion.

One of the experiment is the use of pigments i.e., aluminum oxide, titanium oxide, and zinc oxide. In this study, Aronix Ar 7100 and Aronix M 210 were used as coating materials to study the effect of pigmentation. Hardness of the film increased and adhesion decreased with increasing pigment concentration. The best result was obtained by using 10 % of titanium oxide at the dose of 30 kGy.

b. Parquet Flooring

Parquet flooring from teak wood waste, was found to be excellent in appearance, and has a

highly potential market, either for domestic or for export. Research on this material was conducted under a cooperation between CAIR-BATAN and Forestry State Company (PERUM PERHUTANI). PERUM PERHUTANI was responsible for supplying the raw materials (parquet flooring), whereas CAIR - BATAN was responsible for the radiation curing technology. The coating materials used were Laromer and Aronix. Results of either laboratory or field tests indicated that technically, surface coating using radiation technique can be used for parquet flooring production [6,7].

Economic evaluation of the process either by using the pilot plant, or a special design plant for curing of coating, have also been done. In the evaluation, important factors such as capital-investment, production cost, sales price, break-even point, pay-out time, and internal rate of return had been calculated [8,9].

c. Commercial Timbers

The Indonesian forest is categorized as low land tropical rain forest. It consists of more than 4,000 hardwood species, of which 120 species are now commonly known as commercial woods [10]. Five commercial timbers, i.e., mahoni (*Swietenia*

macrophylla King), sonokeling (*Dalbergia latifolia* Roxb.), sungkai (*Peronema canescens* Jack), jati (*Tectona grandis* L.f) and linggua (*Pterocarpus indicus* Willd) have been used as a substrates for surface coating experiments. Laromer PE 55 F, PE 46 and Aronix Ar 7100 were used as coating materials. Maximum hardness of 3 H was obtained by EB curing for some substrates and coating materials, and a maximum hardness of 2 H by UV curing, when using Aronix Ar 7100 on sonokeling. A comparison study between EB and UV curing showed that EB curing gave better result than UV curing [11]. This research is partially supported by IAEA under Research Contract No. 4821/R1/RB.

The other timbers used were jeungjing (*Paraserianthes falcataria* (L) Nielsen) and rubber wood (*Hevea brasiliensis* Muell. Arg.). In this case, Laromer EA 81, LR 8739 and Setacure AP 590 were used as coating materials after being added with TPGDA. Hardness and abrasion resistance of films coated by irradiation are better than that coated by conventional method. All the coated products were resistant to chemical, solvent and stain. The best weather resistance was obtained by using LR 8739 (60%) with the dose of 50 kGy coated on rubber wood,

and EA 81 (50 %) with the dose of 30 kGy coated on jeungjing.

d. Particle Board

Particle board is widely used for construction materials, furniture, and as parts of electronic goods. Experiments using this substrate were done mainly for pigmented coating purposes. The use of Laromer and Aronix gave the result that base coat using EB curing was better than commercial emulsion paint. Top coat using epoxy acrylate Laromer EA 81 have better chemical resistance, compared with polyester acrylate Laromer PE 55 F and PE 46 [12].

Another experiment using PVA emulsion paint, coated on particle board as base coat also gave poor adhesion to Setacure AM 541 film. The combination of base coat by conventional method and top coat by radiation, usually gives poor adhesion. One of the advantage in using particle board is that higher hiding power can be achieved for the same pigmented coating materials, compared with using plywood, because the porosity of particle board is lower than plywood.

e. Metal

The EB curing process has some disadvantages, one of which is that the coatings formed have in

general poor adhesion to metal substrates. This is probably due to instantaneous formation of three dimensional structures and apparently bigger volume shrinkage. Adhesion can be improved by slowing the curing process, the use of better adhering composition, and by surface preparation. Research on pigmented coating of mild steel is partially supported by IAEA under Research Contract No. 4821/R2/RB. By increasing the pigment concentration, the hardness, abrasion, chemical and solvent resistance will decrease. Therefore, the use of pigment should be limited in order to minimize the negative effect. Pretreatment of mild steel by using Kephos (trade name of chemical solution which is usually used for surface preparation of iron and steel) could improve adhesion by around 4 or 5 grade higher than without pretreatment.

f. Ceramics

Ceramics are widely used for construction materials, such as for flooring and wall covering. By radiation curing many advantages can be achieved such as creating a solvent free system, less energy consumption, much higher production rate, and processing ability at ambient temperature for coating of ceramics. The experiment using Aronix Ar

7100, Aronix 8060 and EA 81 gave excellent hardness and good chemical, solvent and stain resistances. Urethane acrylate Laromer LR 8739 yielded lower hardness and abrasion resistance, but better weather resistance than EA 81, Aronix Ar 7100, or Aronix 8060.

g. Others

Radiation curing of surface coating of gypsum tile, asbestos and marble are in progress.

Training and Demonstration. Up to now, the pilot-plant had been used four times for training and demonstrations on radiation curing of surface coatings of wood products. The courses were attended by participants from Bangladesh, China, India, Indonesia, Malaysia, Singapore, Sri Lanka, South Korea, Thailand and Vietnam under direction of IAEA. The subjects of the courses and training consisted of basic knowledge regarding the technology and practical experience using the pilot-plant. Duration of the courses was between 3 weeks and 4 months.

Radiation Services. Although the technology is not yet transferred to industry, a significant development has been achieved. A few companies have used the coated plywood and particle board mostly of 18 mm thick, irradiated with EB to get a special properties of the finish product. The coated products were used especially

for laboratory furniture. Some thousands sq. m of irradiated coated parquèt flooring either mosaic or block type had been used for flooring of house, office, and mosque. The pilot-plant had also been used for trial and experiment by the wood company to coat their products in order to get special properties of coating for various end uses.

CONCLUSION

The pilot-plant for radiation curing technology is very useful for studying technical and economic aspect of EB and UV curing, as well as for demonstration. So far, research and development on radiation curing of coatings on various substrates, especially for wood products, has been done at CAIR - BATAN, since 1984. Some of the irradiated coated wood panels such as plywood, particle board, and parquet flooring have been used for laboratory furniture, office building, house and mosque. Although the technology is not yet used by the company, some activities to push transfer of technology to industry will be realized soon or later.

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