4.3 The Use and Potential Application of Electron Accelerator in Indonesia

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INTRODUCTION

Electron accelerators have been used in radiation processing such as processing of polymer product, sterilization, food preservation, production of wire and cables, heat shrinkable tube and sheets, pre-vulcanization of tire rubber components and radiation curing. In environment issues, electron accelerator is useful for decomposition pollutants in waste water, disinfection of solid waste as sewage sludge, and purification of flue gas.

In 1984, a pilot plant of radiation curing technology particularly for wood surface coating using low energy electron accelerator has been installed in the Center for Application of Isotopes and Radiation (now : Center for Research and Development of Isotopes and Radiation Technology), Jakarta. The accelerator has energy of 300 keV and beam current of 50 mA. The pilot plant was designed, for training and demonstration, studying both technical and economical aspects of the technology and also for radiation services [1]. Another electron accelerator (EBM GJ 2: 2 MeV, 10 mA) was installed at the Center in 1993. The accelerator was used mainly for R & D of crosslinking process such as crosslinking of wire and cable, and heat shrinkable tube and sheets, instead of radiation processing subjects. Another low energy electron accelerator has also been installed by a private company, namely PT. Gajah Tunggal at Tangerang (near Jakarta) for crosslinking of rubber tire in 1998.

This paper describes the use of electron accelerator in Indonesia for research and development, radiation services, commercial purposes and potential application in the future.

ELECTRON ACCELERATOR FOR RESEARCH AND DEVELOPMENT

Wood Surface Coating

Research and development using electron radiation has been started since the pilot plant of wood surface coating erected in 1984. The pilot plant was constructed under the cooperation of International Atomic Energy Agency (IAEA), United Nation Development Program (UNDP), and the Government of Indonesia. The pilot plant is equipped with a low energy electron beam machine (300 keV, 50 mA), a number of wood coating and wood handling equipment such as wood sanding machine, roll coater and laminator. A small modification of equipment, plant layout and installation of liquid nitrogen generator was done in 1989. Table 1 shows the specification of equipment that was used for research & development mainly in the field of radiation curing of surface coating of wood products. This is based on the fact that sixty percent of the tropical rain forests in South East Asia that is equal to 10 % of the world's total area found in Indonesia. The main products of the forest are mahogany, teak, ramin (*Gonystylus bancanus* Kurz), rubber wood, meranti (*Shorea* sp.) and other kinds of timber species [2]. Forest based product such as plywood, furniture & component, building materials, rattan, papers and pulp play an important role in economic development of Indonesia. Surface coating process is needed by almost all of those products for improvement of their physical and chemical properties as well as their performances. Due to the availability of the wood as raw materials of wood based products, the R & D were focused in radiation curing of surface coating of wood products. Several leading wood products have been used in the R & D such as plywood, parquet flooring, commercial timbers, particle board etc. [3]. The production test of several wood panels i.e. plywood, particle board, parquet flooring, and sengon wood (*Parasemianthes Falcataria* Roxb.) have been carried out for calculation of production cost [4, 5]. Some experiments of EB curing of surface coating of several substrates such as metal, ceramics, gypsum tile, asbestos, and marble to improve their surface properties have been done. Good results were obtained in a scientific and technical point of view.

The pilot plant had been used four times for training courses & demonstration on radiation curing of surface coatings of wood products. The training course were attended usually by participants from Malaysia, Bangladesh, China, India, Singapore, Sri Lanka, Korea, Thailand, Vietnam and Indonesia under direction of IAEA. The subjects of the courses and training consist of basic knowledge regarding the technology and practical experience on the pilot plant .

Although the equipment of the facility are in commercial size, but it was not designed for commercial production. The technology is not yet transferred to Industry, but a significant development has been achieved. Several companies have used the EB irradiation for coating of plywood and particle board to get special properties of the finished products. These products were used particularly for laboratory furniture, some thousands sq. m irradiated coated parquet flooring have been used for flooring of house, office and mosque.

Wire and Cable

The experiment on determination of the best result of cross linked LDPE and PVC have been conducted using various energy of electron beam. The results showed that the highest value of the gel fractions of XLDPE was 73 %, tensile strength of 277 kg/cm^2 and elongation at break of 368 %. This result was achieved at energy of 2 MeV, current of 1.0 mA and the dose of 300 kGy [6]. Heat- and oxidative- resistance of LDPE for cable insulation increase significantly by addition of anti oxidant after crosslinked using 300 keV electron beam. Addition of 0.2 % of antioxidant gave the optimum result at the dose of 300kGy. Anti oxidant of Irganox 1076 resulted better film properties as compared to the use of Irganox 1010 and Santowhite powder [7]. The influence of flame retardant to the rate of flammability of polyethylene has been observed. The flame retardant (halogen compounds) used i.e. chloroparafin (CP), tetrachloro-bisphenol-A (TCBA), polyvinyl chloride (PVC) and antimon trioxide (Sb_2O_3). Linear burning rate of sample without irradiation is lower than that of irradiated one. It can be concluded that the flame retardant can not retard the burning rate of the irradiated compound [8].

Vulcanization of Natural Rubber Latex

National Nuclear Energy Agency (BATAN) has been working on radiation vulcanization of natural rubber latex (RVNRL) since early 1970. A pilot plant for radiation of natural rubber latex using γ-ray of Co-60 has been installed at P3TIR – BATAN in 1983 under UNDP / IAEA / RCA Project. This facility can be used for irradiation of 1.6 ton/batch. Instead for R & D, the facility has been used for training & demonstration, studying technical & economical aspects and for radiation services. A lot of papers have been published concerning with RVNRL. using γ-ray of Co-60. A few research on RVNRL have been done using electron beam. One of the experiments is the use of sensitizer for radiation of natural rubber latex using 300 keV electron beam. Data obtained showed that without addition of sensitizer CCl_4, optimum irradiation dose is about 250 kGy, whereas by using sensitizer of 4 phr , the optimum dose can be reduced to about 120 kGy. A comparison study with γ-ray showed that without sensitizer, the optimum dose was almost the same. Sensitizing effect of CCl_4 or a combination of CCl_4 / n-BA were not as good as gamma irradiation [9].

There are three importance factors for producing free-protein pre-vulcanized natural rubber latex using low energy electron beam (250 keV, 10 mA) in a pilot scale i.e. the quality of natural rubber latex, standard irradiation method and treatment of irradiated natural rubber latex. The optimum condition was achieved at the irradiation time between 20 – 30 minutes, 5 phr of 1,9-nonediol diacrylate (ND-A) as sensitizing agent, and rotation speed of mixer was 210 rpm. By using this condition tensile strength of film was 26 mPA (Table 2). The water solublé protein with 1 % of ammonia for 15 – 30 minutes was 34 μg/g, and after adding with PVA (polyvinyl alcohol) or CMC become less than 4 μg/g [10].

Type I allergy is a serious problem in the use of medical rubber products such as surgical gloves, condom, and rubber tube for Spygmomanometer. This allergy is causes by problem of the natural rubber product, which contact with human body. Another serious problem is that various N-nitrosamine have been shown to be carcinogen. The new procedure for solving this problem is to produce free nitrosamine and protein of pre-vulcanize natural rubber latex by using γ -ray or electron beam. It was noted that centrifuged pre-vulcanized latex was free from nitrosamine and protein, which can be used directly for producing condom, surgical gloves, rubber tube for Spygmomanometer etc. The protein and nitrosamine content were 10 μg/g and 2 μg/g respectively. The objective of proposal of this work is to develop the production of pre-vulcanization natural rubber latex and its rubber products free from nitrosamine and protein content in the factory scale [11].

Grafting of Fabrics

The grafting of polyethylene terepthalate (PET) in the form of textured fabrics with normal methylol acrylamide (NMA) or acrylamide (AM) monomers was conducted using 300 keV electron accelerator at total dose of 5 Mrad. Grafting yields obtained by radiation was higher as compared with thermal curing at 135^{o} C for 5 minutes. The grafted PET has maintained its good thermal stability, crease resistance, as well as its stress-strain properties, with some improvements for the hydrophylic properties, such as increasing in moisture regain, dyeability to anionic and cationic dyes, along with its normal dyeability to non ionic-dispersed dyes. The functional group analysis by means of FTIR spectrophotometer has shown some additional peaks of amide group, which indicated for the improvement of hydrophylic properties of the PET [12].

Radiation Sterilization

High energy radiation give the incredible power effects to achieve the rapid effective sterilization of medical products. The target is usually the ubiquitous micro – organisms found in various medical disposables, instruments, implants, etc. Electron beam can attack the metabolic and reproductive systems of such organisms by literally tearing them to pieces. The technique is having the dosage properly distributed to all surfaces and cracks of the product. The packaging material also must maintain the right degree of sterilization up to the point of their use. Generally, radiation sterilization has been successful application where steam sterilization, usually the lower – cost method, can not be used. The radiation technique is successful in replacing ethylene oxide(ETO) which is having difficulty in meeting toxic safety requirements. Ethylene oxide is very toxic and flammable material and has displayed carcinogenic activity. Some disadvantage factors of the use of ETO are patient health concerns, product residues, worker safety, environmental emissions of gas, legislation for the use of hazardous chemicals, increasing capital and operating costs [13].

Degradation of Cellulose

Exposure of pulp to high energy electrons or γ-rays can be used to lower the degree of polymerization of cellulose. Electron –treated pulp has been found to possess higher reactivity, resulting in decreased amounts of chemicals required, such as CS_2. The decreased usage of CS_2 does not have adverse effect to the properties of fibers produced from viscose made by irradiated pulp. The benefits of this method are enhancement of reactivity and lowering the chemicals used such as CS_2, NaOH and H_2SO_4 which can reduce the environmental releases (CS_2 and H_2S). The experiment of this field has been started since two years ago.

HANDICAPS ON THE APPLICATION OF ELECTRON ACCELERATOR

Almost all of the technology have advantage and disadvantage factors such as technology, economic, social and environment point of view. For instance, the advantage and disadvantage of radiation curing of surface coating can be stated as below.

Advantages

- Avoidance of pollution
- No catalyst and heat
- High speed curing
- Space saving
- Instantaneous start-up and shut down

Disadvantages

- High cost of equipment
- Inert atmosphere
- High price of radiation curable materials

Economic analysis based on the present situation concluded that radiation curing of surface coating cost was relatively high. The high price of radiation curable materials, machinery and radiation sources are the main constraint to expand their activity. This condition was pushed by the monetary crisis that hit Indonesia since mid-1997. Effect of monetary crisis on declining of foreign exchange can be seen on Table 3. The constraint of the use of electron accelerator for all application such for cross linking of wire and cable, cross linking of natural rubber latex, sterilization, food preservation, flue gas control almost similar, that is economical aspect.

POTENTIAL APPLICATION

Instead in the field of radiation processing and environment as described above, another potential application look like have a promising application in the future particularly in Indonesia. Those are radiation curing for production of composite and solving the problem of environmental problem.

A major break through for the composite industry by successfully developing Electron – Beam (EB) curable epoxies and EB curing cycles that reduce processing time and cost while meeting the demanding requirements of high- performance composite structures. These developments make it possible to use a large class of common epoxies to build composite parts without the need for slow, high temperature, high pressure curing cycles, the associated expensive fabrication tools, or the toxic chemical hardeners. This method is suitable used for production of automotive, marine and sporting good industries [14].

Electron beam curing can be used to manufacture composite material component at higher speeds and greater production flexibility than conventional techniques. As long as curing process is not initiated until radiation, timing limitation associate with lay up and resin infusion can be relaxed, leading to reduced scrap and rework. In general, E B curing systems are " solvent less " with fewer volatile organic compound(VOC) and therefore more environmentally friendly. One of the practical applications of this system is in the boat building industry. Electron beam can successfully penetrate complex boat structures fabricated with off – the – shelf marine resins. The practical use of low – cost tooling with EB curing system is reinforced. The EB technology successfully in the use of off – the shelf vinyl ester for the production marine craft cured with EB radiation [15]. As the maritime country, Indonesia has a potential application for production of boat by this method.

In environmental issues, emissions of toxic gases, such as sulfur oxides (SO_2) and nitric oxides (NO_x) from industrial plants have become serious problem in many countries. The coal-fired flue gas from thermal power plants is one of the main sources of environmental pollution, due to its large amount of S and N component.

The environmental problems caused by air pollution in Indonesia focus on Java island. Industrial development is concentrated on Java which accounts for only 8 % of the Indonesian land area. Due to further economic growth, the energy consumption of industry, traffic and households will increase significantly, and finally increasing the amount of pollutants released into the environment. In particular pollution due to coal utilization. Environmental pollution in many industrialized area of Java. The air pollution affects the tropical ecosystems (soil, crops, plantations, forest and water) and human health. More serious pollution will occur in the future if corrective actions are not taken in the future. The study on environmental impacts of energy strategies for Indonesia has been done by Agency for the Assessment and Application of Technology (BPPT) from Indonesia, and Forschungszentrum Julich GmbH (KFA) from Germany. One of the study covers assessment and evaluation of the potential risks of the energy related air pollutants (SO_2, NO_x, CH and dust) on the ecosystems of Java until the year 2021 and recommendation regarding the schedule for preventive measures (Table 4). Data on air concentration and deposition rates for SO_2, NO_x and dust predicted for the years 1991, 2001, 2011 and 2021 by the MARKAL Computer Model. Two environmental scenarios (cases) are investigated namely, Doing Nothing Case (DNC) and Emission Reduction Case (ERC). In the DNC, it is assumed that hardly any significant measures will be taken to reduce emissions in the future. In the ERC, it is assumed that significant steps are taken within the next 10 years to reduce air pollution. Even for the total amount of SO_2 and NO_2 will at least triple by the year 2021 and reach 43% of the level of DNC (Table 5). The volatile hydrocarbon (VHC) emissions will double and reach 66% of the DNC. Particulate matter (PM) increasing only by 30% and reach 43% of the DNC level in the year 2021. The critical areas for all ecosystem of Java in the year 2021 at least 38,3% and 75% of West Java. The harmful environmental pollution in the vicinity of large plants should be avoided at present by several ways, namely employing high chimneys by appropriate site selection and abatement technology [16]. Electron accelerator can be used for treatment of flue gas as a promising pollution control method by reducing of SO_x and NO_x with dry process simultaneously.

Almost all technical and environmental aspect the use of electron accelerator have a lot of advantages compared with another method for the same purpose. High population, man power, natural resources as several important factor to develop the market and industry which can use electron accelerator. For example, the data of wood resources balance of Indonesia as shown on Table 6 [17]. So many fields can reached by the technology for production and solving the problem in a current issues such as environment. It is predicted that the market of product treated by electron accelerator will increase in Indonesia due to the following reasons:

- Development of more feasible and economical of electron accelerator for a given process.
- Development of more efficient process to reduce the production cost.
- Awareness of an efficient and friendly environmental process.
- The employment of both ISO 14000 and ISO 9000 as the certification of production method and management systems.
- The hope that monetary crisis will be over as soon as possible.

CONCLUSION

Based on the number of population, man power, natural resources and current problem such as environment issues the application of electron accelerator will increase if several condition can be met, such more efficient process, lower cost of equipment and financial crisis will be over. The promising future for industrial application is in the production of composite, cross linking natural rubber latex, pollution and all process which using abandon of cheap raw materials. To realize this purpose the research and development of the use of electron beam play an important role.

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Table 1. Specification of low energy electron beam machine (Nissin High Voltage) and wood handling systems installed at P3TIR-BATAN.

Equipment	Type
EB machine	Scanning Type, 300 kV, 50 mA
UV source	One lamp, 80 Watts / cm
Belt sanding machine	-
Direct roll coater	-
Reverse roll coater	-
Curtain coater	Flow
Sprayer	High Pressure
Film Laminator	-
Liquid nitrogen generation	-

Table 2. The properties of pre-vulcanized natural rubber latex prepared by low energy electron beam and gamma rays of Co-60 in pilot scale trial production.

Process & Properties	γ-ray of Co-60	Electron beam
Place	P3TIR-BATAN	TRCRE-JAERI
Date of irradiation	Feb. 20, 2000	Nov. 28, 2000
Source	210 kCi (2.96 kW)	250 kV,10 mA (7.5kW)
Sensitizing agent	2 phr nBA	5 phr ND-A
Vulcanization dose	35 kGy	30 minutes (±20kGy)
Capacity of vessel (liter)	1500	18
Speed of stirrer, rpm	25	210
Properties of latex & its film **Source of latex**	Jalupang plantation, Indonesia	Centrifuged NRL, Malaysia
PH	10.3	9.75
Viscosity	94.0	80
Total solid content (TSC),%	64.77	61.7
Dry rubber content (DRC),%	64.47	-
TS-DRC	0.30	-
VFA number	0.003	-
Mg content, % TS	0.00051	-
Extractable protein cont, μg/g	8	4
Modulus-600 %, MPa	2.1	2.2
Tensile strength, MPa	28.0	26
Elongation at break, %	1000	950

Table 3. Foreign exchange earnings of some forestry products from 1994 to 1998

Products	1994	1995	1996	1997	1998	% trend
Plywood & Veneer	3720.25	3465.97	3568.99	3413.32	2079.95	-11.11
Furniture & Component	956.87	943.99	1070.61	972.27	484.06	-12.48
Paper & Pulp	735.97	1452.04	1387.35	1427.78	2115.44	23.30
Printing Mat'l	79.12	118.58	132.96	93.05	65.28	-6.08

Table 4. Comparison of emission for the DNC and ERC in Java.

Pollutant	Case	Emission in Mill t/a			
		1991	2001	2011	2021
SO_2	DNC	0.35	0.56	1.36	2.78
	ERC	0.35	0.45	0.65	1.20
NO_2	DNC	0.56	1.08	2.10	3.95
	ERC	0.56	0.81	1.03	1.73
SPM	DNC	0.85	1.31	1.83	2.56
	ERC	0.85	1.05	1.09	1.09
VHC	DNC	0.28	0.41	0.63	1.02
	ERC	0.28	0.32	0.43	0.67

SPM = suspended particulate matter
VHC = volatile hydrocarbon

Table 5: Sectoral Emission Shares, Java (High Scenario, Doing Nothing Case)

	NO_2		SO_2		PM		VHC	
	1991 %	2021 %	1991 %	2021 %	1991 %	2021 %	1991 %	2021 %
Power Plants	23.4	46.3	62.2	67.9	1.6	11.9	1.6	1.6
Industry	6.7	5.9	30.5	25.2	63.1	70.9	26.3	20.5
Household	4.5	0.8	3.1	0.8	34.3	15.2	18.7	6.3
Traffic	65.4	47.0	4.2	6.1	1.0	3.0	53.5	71.5

Table 6. Wood resources balance in Asia.

Country	Wood resource balance
Japan	Deficit
Philippines	Deficit
Thailand	Deficit
Indonesia	Surplus
Malaysia	Surplus
China	Deficit
India	Deficit
Fiji	Surplus
Myanmar	Surplus