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Development of Furniture and Raw Material Efficiency Through the Recycling of Sawdust in the Wood Industry

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Abstract
Wood, the main material for furniture in Indonesia is facing many problems, one of which is its rarity. Methods to improve efficiency must be done, including minimizing waste. The waste products of the wood industry include solid, liquid, and gas. Sawdust is one of the solid waste by-products of the industry, and it can be recycled as a method to improve efficiency. This research explores the use of sawdust through selecting, straining, and mixing sawdust with other materials as a part of improving efficiency. The processed sawdust is then used as a base for product design. The results of this research found that the material made from processed stardust can be used for an arts and craft project as well as furniture, specifically for chairs and tabletops.
Keywords: design, environmentally friendly, waste, industry.

Introduction.

For anyone including politicians, scholars, artists, technocrats, economists, etc. The worrying condition of the environment supports the formation of environmental movements. Natural disasters and environmental destruction in many parts of the world force humans to care more about the environment. The forest, as a part of the environment, has an important ecological function that needs to be protected. One of the strategical functions of the forest to humans is the creation of wood-based industries, which makes the demand of eco-friendly wood products higher and higher. This includes the furniture and wood processing industry.

According to the department of industry and trade, the wood processing industry is divided into upstream timber industry and downstream timber industry. The upstream timber industry include sawmill, plywood mill, particle boards, and the medium density fibreboard industry. The downstream timber industry includes woodworking, furniture, and wood crafts industry (Hidayat, 2011). The ecolabel certificate through the Forest Standard Council (FSC) and Wood legality verification standard (SVLK) are among the certificates used by the furniture and wood processing industry in Indonesia

Ecolabeling is one of the indicators that an industry has implemented environmentally friendly or “green” industry principles. This includes green process and green products. The market’s demand for green products and production methods is both a challenge and a chance for players in the industry. Environmentally friendly products are more appealing to the current demographic of customers. Therefore, the production of raw material into products is more important for the customers. The processes that needs to be more green include material processing, material selection, the industrial tools, workers, as well as how it impacts the environment.

The effort to holistically preserve the forest and the availability of raw material means that the efficiency of materials needs to be maintained in every part of production. Eco-efficiency principles include maximizing products by minimizing the use of natural resources to lessen the destruction of the raw material source. The Efficiency of raw material needs to be maintained to preserve the availability of raw material and the industry itself. The wood processing and furniture industry generates waste which is divided into waste from the wood harvesting efforts and waste from the wood processing efforts (Sumarno, Sri Hestiheriwati, Deny Dwi Hartomo, 2015). The waste by-product of the furniture and wood processing industry include particles, splinters, and wood pieces. Specifically, Haygreen and Bowyer (1996) mention that the waste products of the processing industry include shavings, flakes, wafers, chips, sawdust, strand, slivers, and excelsior.

selanjutnya adalah sebagai dasar dalam desain produk berbasis limbah serbuk kayu.

Large industries with adequate funding and cutting-edge tools have been developing waste by-products into particle boards. On smaller and middle-ranged industry, the processing of production waste products is still under developed, despite the economic potential. Waste by-products are created in large amounts and they are very cheap. This research is an effort to use sawdust as a waste by-product with simple technologies to make it practical for smaller industries. Therefore, this research is regarding how to recycle solid industrial wastes in the form of sawdust into new material as a basis for product development. Furthermore, the raw material as a result of the next research will be used as a base in designing sawdust-based products.

Material.

The material of this research is the wood industry’s solid by-product in the form of sawdust. Sawdust is produced as a waste product from the sawmill. The size of the wood particles made from the waste can be as

large as 1 mm. The most popular wood processing industry in Indonesia uses teak wood as the main material. Therefor, this research will use teak sawdust with a maximum size of 1 mm. The sawdust is treated and mixed with several other materials to create a new material. This new material is then used as a base for furtinure and crafts design.

Methods.

This research aims to utilize sawdust waste to create a new material. This research uses a qualitative method, which means the composition and mixture of sawdust was not analyzed in more detail. This research is an applied research that will be preceded by an experiment. The steps done in the research include:

1. Selection of teak sawdust
2. Straining of sawdust to achieve 1 mm sawdust products.
3. An experiment to create new materials by mixing sawdust with multiple other materials.
   The experiment's research method lies on the recycling principle to refine new materials from solid waste products of wood processing. The experiment method used is the development method to test, check, and prove a hypothesis of a cause-and-effect connection (Hadi, 2015).
   The experiment done to sawdust uses four variables: white cement, white glue, calcium mixed with water, and drying.
4. The new refined material is then used as a basis to design crafts products and furniture. The development of the new material is done through designing two-dimensional and three-dimensional products with the mold, carve, and printing techniques.

Discussion.

The woodcraft and furniture industry in Indonesia are creative industries that contributes to the Indonesian economy. They are a part of Indonesia's main national industries which include agricultural industries (CPO, cocoa, rubber), fish and fish products, textile, footwear, leather and leather products, food items, fertilizer, engineering, metalworks, and furniture[1]. The furniture industry in Indonesia is currently facing several problems, one of which is a material problem.

Wood, as a commodity and main material for the furniture industry, is facing several problems which include the unfulfilled supply and demand of raw materials, lack of raw materials in the market, fluctuating price of wood as a raw material, and the inefficiency of wood production itself (Parlinah, 2010). The causes of those problems are several connected factors.

An effort to improve the efficiency of raw materials need to be done in the production process by minimizing the waste products in each production stages. The stages in the production roughly include the input, process, and output stages, which are linked together and cannot be separated. The problem-solving efforts need to look at the bigger picture, as the stages cannot be separated (Tesoriero, 2008). Therefor, the attention to minimizing the amount of waste on each stage needs to be done.

whole cannot he separated. When detailed, there are sub-input, sub-process, and sub-output steps in those steps. Those steps also include smaller substeps, which continues to make a network of productions that cannot be separated. The output on any level cannot be separated from waste and products.

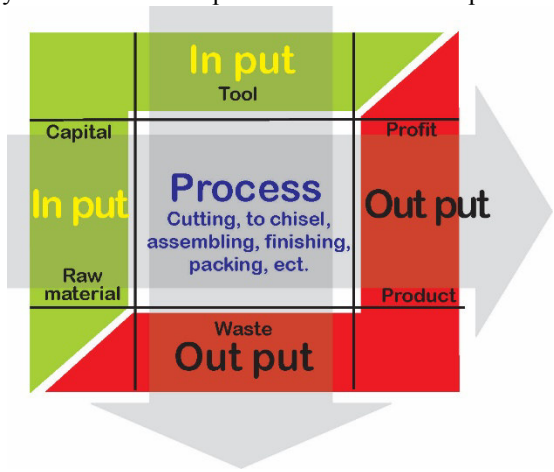

Figure 1: Production flow and waste by-products

In the woodworking industry, wood as a raw is an input, where as in other systems, wood is the output of forestry. In forestry, wood is an output, and prime teak seeds is the input. However, in other systems, the seeds are an output of plant variety research, and it all continues to create a symbiotic relationship in the industry.

as a commodity of the forest needs to be improved to preserve the environment and the industry. Green

process as an effort to maintain the continuity of the material and the industry needs to focus on efficiency, usage of renewable energy, and the ratio of product and waste. The principle of efficiency is the comparison of ecological and economic concepts (eco-efficeincy). The less waste created, the less negatife impact the industry will have to the environment (Soemarwoto, 1997). The most popular techology of eco-efficiency users apply the 3R principles of reuse, recycle, and reduce. Another applied principle consists of refine, refill, repurchase, and remix.

a. Recycle industrial waste to refine raw materials.

The furniture industry in Indonesia is dominated by smaller and middle-ranged micro-industries, which makes up 80% of the market. Wood raw materials dominate over other raw materials, in both the smaller and larger industries. The raw materials used for the furniture that Indonesia exports consist of 59.5% wood, 8.1% metal, 7.8% rattan, 2.3% plastic, 0.5% bamboo, and 21.3% other raw materials (Hidayat, 2011). More than half of exported Indonesian furniture are made of wood, which means that issues in wood material production would affect it heavily.

The efficiency and refineing of new raw raterials is unavoidable, the efficiency of using wood in the crafts and furniture industry is urgent because of the high inefficiency of production. The main theory regarding the material-waste ratio is 60-40. Waste of the wood industry include shaving, flake, wafer, chips, sawdust, strand, sliver, excelsior, as well as bark (Haygreen and Bowyer, 1996).

Basically, a production method is effective and efficient when the comparison between energy, resource, and waste is equal to or larger than the product value. This value can be based on quantity or quality. Quantitative comparisons include measured values such as dimensions, amount, cost, or required time. Qualitative comparisons cannot be directly measured and includes economic value, and the benefit of the product compared to the environmental impacts caused by its production. The usage of natural resources for a human's basic needs can be controlled when one considers the preservation of the environment.

Efforts to improve efficiency by refining particle wastes to particle boards have been done by large industries with adequate funding and production tools. However, considering that the woodworking industry in Indonesia is dominated by smaller industries, most of the by-products, including sawdust, are still unused. A practical refining method needs to be applicable by smaller industries and with more practical technology.

The principle of eco-efficiency in the use of sawdust is recycling and refining new raw materials. The waste from production consiste of different items of shapes and sizes, depending on the activity and tools used. Production activities in the furniture industry include cutting, cleaving, smoothing, drilling, etc. The tools used in this activity include the planner, jointer, ticniser, hand drill, table saw, rip saw, bend saw, jack saw, chisel, belt sander, etc. The waste by-products based on form include solid, liquid, and gas wastes. The solid waste can be reused as a part to increase efficiency and maintain the continuity of raw material.

The types of tools or machines used affect the shape, size, and characteristic of solid waste by-products. The most common solid waste from woodworking include shavings, flakes, wafers, chips, sawdust, strands, slivers, and excelsiors. The solid waste by-products are usually used as kiln fuel, thrown away, or even burned because they are presumed useless. However, these waste by-products can still be used to create products.

Sawdust

The focus of this research is the usage of sawdust to create new raw material. Sawdust is a solid waste by-product from the woodworking industry that's no larger than dust, around 200 µm – 3 mm. The usage of sawdust into particle boards are divided based on their density level:

a. 0,4 g/cm3 Low Density Particleboards.
b. 0,4-0,8 g/cm3 Medium Density Particleboards.
c. 0,8 g/ cm3.High Density Particleboards.

Density levels will affect the quality of the product in the pressure, flexibility, and resilience. These points affect its ability to be processed, with stronger particles being able to be refined to wider products. The quality of particle boards regarding the density and resilience of the board is also affected by the adhesive used. Particle boards from sawdust based on its adhesive are comprised of:

a. U-type boards which uses urea formaldehyde adhesive or its equal.
b. M-type boards which uses urea-melamin formaldehyde adhesive or its equal.
c. P-type boards which uses phenol formaldehyde adhesive or its equal.

U, M, and P type adhesives are chemical-based adhesives are are unknown by low to middle range productions. The research regarding the environmentally-friendly use of sawdust waste was performed by Hermawan and Kusumah (tt). Particle boards without formaldehyde-based synthetic adhesives is done by boiling the sawdust, turning it into sheets, and heat pressed. The heat press is an expensive production tool, and smaller industries usually have a limited amount of funding. There needs to be a method to use sawdust with natural items or readily-available resources so that smaller industries can perform it themselves.

The effort to reuse sawdust in a budget is used by mixing sawdust with readily available materials. These materials include water, white cement, calcium, wood glue, latex, starch, sand, bricks, etc. The best composition of materials is a mixture of sawdust, water, wood glue, using white cement and calcium as catalysts.

The comparison can be seen below:

- 1 liter of water.
- 600 kg of wood glue.
- 1 liter of white cement
- 1 liter of calcium
- 3 liters of dry sawdust.

The first step is to mix sawdust, water, and wood glue into a container. The second step is adding white cement and calcium to hasten the drying process of the mixture. The third step is to dry the mixture by exposing it to the sun. This process is entirely natural, which will take 2-3 days. A good drying process is done on a stable heat. An unstable heat will cause breaking or reduction.

This process does not involve head press, and compression is done by hand. However, using a press will make the compression process a lot more refined. Because of the limitation in funding, the compression is done manually, which results in low-density particle boards as a product.

The density level will affect to the resilience and how wide the particle board can be made. A lower density level will make the resulting particle board narrow, which means that the boards cannot be made thinner and according to the standards of a particle board's width. A recommended solution is to use a thicker, three-dimentional support structure to support the product.

The experiment managed to create a new material using sawdust, water, wood glue, white cement, and calcium. The new material is hard, waterproof, and fire resistant. Its main material is sawdust, but the new material itself resembles clay. The differences between the new material with clay and wood are thus:

Characteristic	Clay	Wood	New Material
Weight	Heavy	Light	Heavy
Print-work	Yes	No	Yes
Carve work	No	Yes	Yes
Drying	Baked	Dry/Oven	Dry
Flexibility	Yes	No	Yes
Color	Brown	Brown	Grey
Can be spread	No	Yes	No
Fire resistant	Yes	No	Yes
Waterproof	Yes	No	Yes

Table 1: comparison between clay, wood, and arbuksium.

The resulting material from mixing sawdust, water, white cement, glue, and calcium needs to be dried for a long time. It can be printed, molded, or carved. The process is done by adjusting the shape of the material directly because of soft properties before it is dried. However, the material is brittle when it's not dried yet. It cannot be modled like clay. The material and techniques to work it can be used as a base to develop crafts and furniture.

b. Developing products from the new material

The pressure of environmental issues requires designers to have the ability to analyze, organize, and innovate: to develop a design to answer recent issues correctly (Papanek, 1995). Environmental issues are a serious problem. The efficiency of raw material through the refining of waste by-products as an effort to develop products through new material from waste by-products can seize market opportunities in a greener product-oriented market.

The conception of product development is a chain of activities that starts with the perception of market opportunities and ends in the production and sale. Steps that are considered the most important are marketing, design, and production (Karl T. Ulrick and Steven D. Eppinger, 2004).

Molding Technique.

The soft characteristic of the material means that the material can be processed with the molding technique. This is done by pouring the mixture into a mold, either a fixed or a non-fixed variant. When the mixture is dried, the mold is then opened. The following are examples of using sawdust using non-fixed and fixed molds.

.Picture 2: The usage of sawdust in making chairs and stools.

One of the more important part of production is its economic value. The calculation of economic value was done on wood-based and sawdust-based mask crafts. The masks were molded, so the work can be done on a larger scale. Overall, the process or time needed is relatively shorter. The price of material used are also cheaper. The comparison between production costs of sawdust and wood masks are 1:2.3, which means that the sawdust masks are a lot cheaper to make.

Figure 3: comparison between production processes of wood-based and sawdust-based mask products

Carving Techniques

Carving techniques are needed to create more detailed products. The carving process is done after the sawdust

mixture has dried and hardened. The hardness of the dried products mean that it can carved on. The hardness of the material is comparable to white stone. The recommended technique is the *lemahan* technique, and the material is incompatible with the *krawangan* technique. The following are the usage of sawdust on a table top using the *lemahan* technique.

.Figure 4: tabletops using the carved material.

The drying process needed 2-3 days, which makes that the molding technique can be done instantly. However, the material has a low elasticity level, which makes that it cannot be as easily molded as ceramic or terracotta. Another weakness of this material is the relatively high reduction level, which will impact the size and the shape of the material.

CONCLUSION.

The design of an environmentally-friendly product based from solid industrial by-products can be seen as an effort to maintain the environment through the material efficiency. The usage of sawdust as a material will increase the economic value of production by-broducts. This can capitalize on a market where being environmentally-friendly is key. Sawdust can create a creative, innovative, and aesthetic product.

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