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Reda Rizal [1*], Lomo Mula Tua [2*], Sargi Br. Ginting [3*]

Faculty of Engineering, Universitas Pembangunan Nasional Veteran Jakarta, Indonesia [1]*
reda.rizal@upnvj.ac.id
Faculty of Computer Science, Universitas Pembangunan Nasional Veteran Jakarta, Indonesia [2]*
lomomt@gmail.com
Faculty of Engineering, Universitas Pembangunan Nasional Veteran Jakarta, Indonesia [3]*
sargibarus@gmail.com

Abstract

The problem discussed in this article is related to manufacturing activities that use styrofoam plastic materials as packaging for electronic goods that have the potential to damage the environment. Material innovation from National natural resources is needed to overcome it. The replacement of synthetic materials with rice husk material as manufacturing raw materials is used as a keyword in an effort to minimize the impact of environmental pollution. The study used a trial method of making new material substitutions for the development of green manufacturing. Modeling and testing of chaff material for styrofoam substitutes as packaging for manufactured goods has been successfully carried out with a research performance level of 95%. The resulting husk model has physical characteristics that are close to those of Styrofoam, namely $A_4 + T + P_3 + W + t_6$. model. Micro-biologically, the husk material is easily broken down in the soil so that this material does not disturb the living environment when it becomes trash. While styrofoam material is not decomposed by micro-organisms in the soil, so that the husk material can be used as a substitute for styrofoam plastic materials.

Keywords: husk, styrofoam, environmentally friendly, manufacturing, renewable material, substitution.

1. Introduction

Often found in electronic packaging materials in the packaging box using Styrofoam synthetic material or other designation is styrene. The physical-chemical properties of biology of Styrofoam synthetic materials are not easily degraded by micro-organisms, so that when the material is disposed of into waste, it will have implications for the damage to the soil, water, air and environmental health **[1, 2]**. The global community refuses to buy all products that still contain styrofoam material, even though the presence of this synthetic material only functions as an electronic tool clamp in its packaging. Polystyrene is styrofoam which functions as an ingredient to increase storage time and temperature, so this material is widely used as food packaging **[3, 4]**. This study aims at long-term to realize an operational system of sustainable manufacturing that utilizes renewable natural resources and produces goods products that can be accepted by global consumers and post-use products that do not pollute the environment. The medium term goal is to direct business people to take responsibility for the products they produce, and to be responsible for the natural resources that they use as inputs for their activities. The short-term goal of this research is to design a model of renewable material substitution within the framework of sustainable manufacturing development. The research target is to utilize renewable natural resources in every manufacturing activity to produce goods that are environmentally friendly and do not damage the order of availability of raw materials from natural resources. The introduction of sustainability into products and process development, regarding the environment, economy and society, has forced manufacturing companies to move directly towards the production of sustainable, durable products **[5, 7].** Sustainable manufacturing has received great attention in recent years as an effective solution to support sustainable manufacturing growth and expansion **[6, 7].** Polystyrene plastic products contain a variety of compounds with low molecular mass, including monomer and oligomer polymerization residues, solvent-related chemical residues, and various additives. which is currently widely used as a food container **[8, 10].** There are many toxic compounds in Polystyrene based products, and the most commonly found are benzaldehyde, styrene, benzene, ethylbenzene and tetradecane **[9, 10].** The advantages of Styrofoam as a manufacturing product packaging include parameters of physical strength, modulus of elasticity, density, defense, and heat temperature that can be adjusted in the production process. This material can be adapted to the physical properties needed by the industrial world, and can be purchased in bulk and at low prices. However, the use of Styrofoam plastic plastics is a negative effect on the environment where waste can damage the environment, and uses non-renewable natural resources that are accessible to drain natural resources **[11, 12].** Soluble polystyrene in several solvents such as benzene, toluene, xylene, tetrahydrofuran, chloroform, 1,3-butanadiol, 2-butanol, linalool, geraniol, d-limonene, p-cymene, terpinene, phellandrene, terpineol, menthol, eucalyptol, cinnamaldheyde, nitrobenzene, N, N-dimethylformamide and water. This solvent action does not cause degradation of the polymer chain. Solubility of the polymer in this case solvents at different temperatures has been investigated. Solvents can be easily recycled by distillation **[13, 8].** Research has shown that to develop green process constituents of essential oils, dlimonene, p-cymene, terpinene, phellandrene, is the most appropriate solvent **[8, 14].**

2. Literature Review

2.1 Husk as Agricultural Industrial Waste

Rice husk is a hard protective cover of rice grains, and is a by-product of rice production. The skin is made of hard ingredients, including opaline silica and lignin to protect seeds during the growing season. This economically valuable agricultural waste product is a great source of silica and has many comprehensive applications **[15, 16].** About 20% of the total weight of rice is husk which consists of components of silica and lignin. Rice husks can be recycled to produce high-value environmentally friendly materials, such as silicon (Si), silica (SiO_2), silicon carbide (SiC), silicon nitride (Si_3N_4) and graphene (G) **[6, 17, 18].** The main inorganic components are SiO_2 (80%), and minor inorganic constituents include alumina (3.93%), sulfur trioxide (0.78%), iron oxide (0.41%), calcium oxide (3.84%), magnesium oxide (0.25%), sodium oxide (0.67%), and potassium oxide (1.45%) **[17, 18].** Carbonized rice husks are formed by incomplete combustion results and can be used as plant media and fertilizers, and can be used as activated carbon absorbing water pollutants, but can cause serious problems related to environmental health and human health, due to high air pollutants. in a landfill **[19, 20].** Rice husk and rice husk ash as potential adsorbents, the advantage of using rice husk derivatives as biosorbents / adsorbents / sorbents is their biodegradability and good adsorption properties, which are caused by morphological factors and surface functional groups **[17, 21, 22].** Activated carbon rice husks can be used to absorb various types of heavy metals in wastewater such as lead, cadmium, zeng, so that it can clear up industrial wastewater **[16, 23].** The form of raw rice husks and modifications has been very effective in removing heavy metals after being tested in experiments by changing parameters such as Initial pH, dose, temperature and concentration **[15, 18].** Rice husk which is considered a waste has a high content of silicon and has a large potential to be activated carbon. Carbonization is carried out using carbonizers with the production of carbon-rich precursors through pyrolysis of rice husks in an inert atmosphere. The results show an important contribution to the use of carbon materials, providing direct evidence of the permanence of activated carbon Na + sodium ions. Research shows that the use of carbonized rice husks in water purification is fast, efficient and economically feasible **[17, 18, 24].** Rice husks can be used as value-added materials for domestic and industrial processing such as preparing valuable silicon-based materials, cement, as a source of pet food fiber and as source of dietary fiber, preparation of activated carbon, refractory industry, polymers, rubber, sorbent sorbents for waste water treatment, in bioethanol production, to control insect pests in stored food items, ceramics industry, and biosynthesis of nano silica particles **[18, 20, 21, 25].** Rice husk is widely used and found in rice-producing countries such as China and India which contribute 33% and 22% of their respective global rice production, such as by-products from rice mills. The content of husks ranges from 16-25% of all rice. The composition of the husk material was hemicellulose 24.3%, cellulose 34.4%, lignin 19.2%, ash 18.85%, and other trace elements 3.25%. Hemicellulose is used as a source of activated carbon, xylose and silicon dioxide. Husk ash is the main element component as Carbon 37.05%, Hydrogen 8.80%, Nitrogen 11.06%, Silicon 9.01% and Oxygen 35.03%. Rice husk has a mass density of 96-100 kg / m3, hardness (Mohr scale) 5-6, ash 22.29%, Oxygen 31-37%, Nitrogen 0.23-0.32%, Sulfur 0.04-0, 08%, hydrogen 4-5%. RH composition depends on many factors such as rice varieties, types of fertilizer used, soil chemistry, and even geographical localization of production **[6, 18, 21, 26].** Around 108 tons of rice husk are produced every year in the world, it is observed that agricultural waste can be converted into viable products, economically profitable and also for future use in nanotechnology **[27].** The husks produced during grinding are mostly used as fuel in boilers to process rice, produce energy through direct combustion and / or by gasification. This husk ash is a major environmental threat that causes damage to the soil and surrounding areas where it is removed. Many ways are considered to dispose of it by using it as a filler for concrete and board production, silica roofing material, absorbing oil spilled on the sea, accelerating or slowing down soil drainage, breaking up soil, improving soil structure and soil mineral enrichment **[19, 21, 25, 28].** Rice husk is used as a fuel for the power generation industry that has special characteristics that make it easy to use as an energy source; the average calorific value of 3410 K Cal / kg, 1 ton of rice can produce 220 kg of rice husk, and rice husk is easily collected at very low costs **[17, 23].** Some uses of chaff material in several industries are: i) as reinforcement of elastomeric products such as shoe soles, ii) reinforcement of silicone rubber, iii) reinforcing material in tires, iv) in compound sheaths for cables, v) adhesive constituents for binding unvulcanized rubber with textiles or steel tire straps, vi) in thermoplastics which are used to act as anti-blocking agents and to prevent the effect of plates on production films and films, vii) to improve the mechanical properties of PVC floors, viii) as silica carriers for ingredients and as free flow substances for powder formulations, especially of hygroscopic and adhesive substances, ix) as adsorbents, x) in toothpastes to control rheological properties and as cleaning agents, xi) silica end what is hydrophobic is used in the antifoaming effect of silicon mineral oil and oil, xii) beer purification and stabilization, xiii) blood analysis, xiv) cosmetics, xv) food industry as an anti-caking agent, xvi) silica gel specially prepared from silica is used to make thermal insulation material, xvii) as a moisture-lowering agent for air and other gases **[22, 23, 25].**

2.2 Styrofoam, Benefits and Mudhorat

Styrofoam refers to expanded polystyrene commonly used for food and beverage containers such as disposable cups and boxes, or packaging materials in containers. Due to the low recycling rate, polystyrene has polluted the environment, causing serious problems that pose a threat to wildlife and human health **[8, 10].** There are 30 different compounds in Polystyrene-based products examined; the most commonly found are benzaldehyde, pentadecane, tetradecane, ethylbenzene, cumene, isocumene, acetophenone, 1,3-diphenylpropane, and styrene. **[8, 9].** Expanded Polystyrene (EPS) materials derived from crude oil refining processes and 100% can be recycled into alternative construction materials. EPS buildings are fast built, cost effective and have thermal characteristics suitable for areas with extreme weather conditions **[9, 29].** The accumulation of electronic waste has increased tremendously and from various plastics, resinsusi is one of the waste materials disposed of in electronic machinery **[30].** Several innovative construction materials and technologies are being introduced to facilitate unique modular designs, reduction of workforce, reduced depletion of consumable material, savings in time and funds. One of these materials is expanded polystyrene **[9].** The introduction of advanced plastic materials and specifically expanded polystyrene building technology in the Nigerian construction industry will be a very useful and brilliant initiative that will help reduce construction costs and facilitate access to affordable homes for the masses **[31].** Styrofoam is widely used in manufacturing, as packaging materials, construction materials, and in household appliances **[2, 9].** Instead, their waste has a disruptive environmental effect. The solution is to reuse it as an effective product and use it to improve the performance of hot mixed asphalt, chronic toxicity tests on styrofoam waste were not found to have toxic effects on the number of deaths and reproduction of algae after 96 hours of exposure despite seven days of exposure increasing their mortality **[10].** One of the efforts to overcome environmental pollution by manufacturing industry activities in Kenya, polystyrene plastic waste has been used to make house roof building materials **[29].** The same thing was stated that the use of Styrofoam waste as a supporting material for building houses has been realized in Nigeria **[31].** Several innovative construction materials and technologies were introduced to facilitate unique modular design, reduction of workforce, reduction of irreversible material depletion, saving time and funds **[9].** One such material is expanded polystirene. The introduction of advanced plastic materials and specifically the expanded polystyrene building technology in the Nigerian construction industry has become a very useful and brilliant initiative that can help reduce construction costs. Styrofoam industrial waste used in its research is used to produce concrete with a light weight and good resistance to seepage, and the research findings reveal that polystyrene material has good strength potential in building construction **[12].** The accumulation of electronic waste has increased enormously from various types of plastic including polystyrene which comes from the packaging of electronic goods products **[30].** Biodegradation of environmentally friendly plastic waste has significant relevance because of the adverse effects of chemical and oil degradation. Suppressing concerns about product and process sustainability has forced manufacturing to transition from making economic-based decisions solely to imagining more holistic goals that include economic, environmental and social perspectives **[32].** A myriad of research in this field focuses on creating opportunities that will minimize, if not eliminate, the impact of manufacturing activities on the natural environment and society. Sustainable manufacturing practices are traditionally viewed by companies as a burden and thus reduce the opportunities for profit and efficiency of the company, however, reducing operating costs and increasing employee satisfaction are benefits of the company when the initiative successfully implemented **[33].** It is recommended to conduct learning comparisons to ensure significant differences between companies in implementing sustainable manufacturing practices **[4].** In the manufacturing context, creating sustainable value requires system-level products, processes and innovations to enable the flow of adjacent closed-loop material in several life cycles; also requires understanding the complex interactions of the socio-technical system with the natural environment for the synthesis that emerges so that sustainable value creation can occur harmoniously and sustainably. Innovative sustainable manufacturing can be the engine for sustainable growth by not only promoting economic growth, but also enabling social welfare and environmentally conscious practices. Creating value through sustainable manufacturing will require innovation in the product, process and system level throughout the total life cycle and through several life cycles, and presents a system model for the new green manufacturing paradigm **[34].** This model captures various planning activities to migrate from less green to greener and more environmentally friendly manufactures. The proposed model is a comprehensive qualitative approach for designing and / or improving green manufacturing systems and road maps for future quantitative research to better evaluate this new paradigm. Styrofoam is widely used by industry and manufacturing as packaging materials, construction materials, and for furniture in the household, instead their waste has a disruptive environmental effect **[2, 9]**. The solution is to reuse it as an effective product and use it to improve the performance of hot mixed asphalt. Chronic toxicity tests on styrofoam waste were not found to have toxic effects on the number of deaths and reproduction of algae after 96 hours of exposure despite seven days of exposure increasing their mortality rate **[10].** One of the efforts to overcome environmental pollution by manufacturing industry activities in Kenya, polystyrene plastic waste has been used to manufacture roof-top building materials **[29].** The same thing is stated that the use of Styrofoam waste as a supporting material for building houses has been realized in Nigeria **[31].** Some innovative construction materials and technologies introduced support unique modular designs, reduced workforce, reduced use of materials that cannot be updated, save time and costs. One of these materials is the development of the use of polystyrene waste. The introduction of advanced plastic materials and specifically the technology of polystyrene buildings developed in the Nigerian construction industry has become a very useful and brilliant initiative that can help reduce construction costs. Styrofoam industrial waste has been applied in its research to produce concrete with a light weight and good resistance to seepage. The results revealed that polystyrene material has good potential strength in building construction **[12, 29].** The accumulation of electronic waste has increased tremendously from various types of plastic including polystyrene which comes from the packaging of electronic goods products **[2, 3, 9, 30].** Biodegradation of environmentally friendly plastic waste has significant relevance because of the adverse effects of chemical and oil degradation **[32, 33, 34].** Concerns about product and process sustainability have forced manufacturing to move from purely economic-based decisions to more holistic goals that includes economic, social, cultural and environmental perspectives, and a myriad of research in this field is focused on creating opportunities that will minimize the negative impacts of manufacturing activities on the natural environment and society. Sustainable manufacturing practices are traditionally considered by companies to be a burden and reduce profit opportunities and in-efficiency of the company, however, the reduction in operating costs and increased employee satisfaction is a benefit of the company when the initiative is successfully implemented, and significant among companies in implementing sustainable manufacturing practices **[33, 36].** In the manufacturing context, creating sustainable value requires system-level products, processes and innovations to enable the flow of close-loop material that is close together in several life cycles **[4].** It takes an understanding of complex interactions in the socio-technical system with the natural environment to bring about a synthesis so that sustainable value creation can occur harmoniously and sustainably. Innovative sustainable manufacturing can be a driving force for sustainable economic growth, and not only promotes economic growth, but also promotes increased social welfare and environmentally conscious practices. To improve the degree of sustainable manufacturing, product innovation, processes, input systems and product output are urgently needed throughout the life cycle level. The system model for the green manufacturing paradigm, this model captures various planning activities to change from less green to greener and more environmentally friendly manufacturing **[34, 36].** The proposed model is a comprehensive qualitative approach to design and enhance the value of a green manufacturing system and a roadmap for future quantitative research to evaluate this new paradigm **[35].**

3. Methods

In the framework of decision support research methods for environmentally friendly manufacturing use experimental methods **[7].** This system approach considers three manufacturing components: technology, energy and material, which can be used to improve manufacturing sustainability performance by reducing the source of the environmental impact of manufacturing activities or the material produced produces a technological product that is not in accordance with the plan or technological error occurs, then the redesign is immediately carried out and the testing of raw materials used in the production process is carried out **[34].** The experimental design method using a complete block design is presented in the table in below.

Tabel 1. Experiment Matrix of Husk Model:

A	$T + P_1 + W + t_1$	$T + P_2 + W + t_1$	$T + P_3 + W + t_1$
A_1	**1**	**2**	**3**
A_2	**10**	**11**	**12**
A_3	**19**	**20**	**21**
A_4	**28**	**29**	**30**
	$T + P_1 + W + t_2$	$T + P_2 + W + t_2$	$T + P_3 + W + t_2$
A_1	**4**	**5**	**6**
A_2	**13**	**14**	**15**
A_3	**22**	**23**	**24**
A_4	**31**	**32**	**33**
	$T + P_1 + W + t_3$	$T + P_2 + W + t_3$	$T + P_3 + W + t_3$
A_1	**7**	**8**	**9**
A_2	**16**	**17**	**18**
A_3	**25**	**26**	**27**
A_4	**34**	**35**	**36**
	$T + P_1 + W + t_4$	$T + P_2 + W + t_4$	$T + P_3 + W + t_4$
A_1	**37**	**38**	**39**
A_2	**46**	**47**	**48**
A_3	**55**	**56**	**57**
A_4	**64**	**65**	**66**
	$T + P_1 + W + t_5$	$T + P_2 + W + t_5$	$T + P_3 + W + t_5$
A_1	**40**	**41**	**42**
A_2	**49**	**50**	**51**
A_3	**58**	**59**	**60**
A_4	**67**	**68**	**69**
	$T + P_1 + W + t_6$	$T + P_2 + W + t_6$	$T + P_3 + W + t_6$
A_1	**43**	**44**	**45**
A_2	**52**	**53**	**54**

A_3	**61**	**62**	**63**
A_4	**70**	**71**	**72**

The experiment design notation with variations of the Husk Model research experiment:

a. Adhesive (A): 4 Heavy variations on husk material (A_1 = 25%, A_2 = 50%, A_3 = 75%, A_4 = 100%)
b. Pressure (P) : 3 variations (P_1 = 15 kg/cm^2, P_2 = 10 kg/ cm^2, P_3 = 5 kg/ cm^2)
c. Time (t) : 6 variations (t_1 = 30’, t_2 = 60’, t_3 = 90’, t_4 = 120’, t_5 = 150’, t_6 = 180’)
d. Temperature (T) : 1 x 250°C
e. Water (W) : 300 cc

Figure 1. Waste husks in rice mills

Figure 1 shows the source of husk material for this study taken from a rice mill located in Tambak Baya Village, Cibadak District, Lebak Regency. Banten Province.

Figure 2. Styrofoam plastic waste

Figure 2 shows Styrofoam plastic waste from electronic goods stores that are piled up with domestic waste in the Bintaro area of Ciputat Sub-District, South Tangerang City, Banten Province.

4. Result and discussion

4.1. Renewable Material

Renewable materials are materials that can renew themselves naturally such as vegetation and animals. Vegetation material used by manufacturing is cotton or cotton material to be produced into yarn, cloth, clothes, shoes, bags, jackets, belts and so on. Animal-sourced materials such as cow leather for footwear, shoes, bags, jackets, belts and so on. Renewable material is a natural resource that can be renewed by itself naturally, and is a material that has never been used before for various manufacturing needs. The substitute for diesel fuel from vegetation is palm oil, known as bio-fuel. Vegetation is one of the types of vegetation that can be used as renewable material in this study is chaff, where these natural resources can be used as basic material to replace synthetic materials that have been used by manufacturers to be used as part of packaging electronic products (packaging). Waste husk vegetation is a material obtained shortly after rice is harvested, often used to make animal feed, plant media. Some countries have developed the use of husk waste into bio-products such as; fertilizer, fodder, bio-chemicals, paper, handicraft products and so on **[21, 25, 28].**

Rice husk is a renewable material that has a high silicon content and can be used as a substitute for styrene material in the packaging of electronic items in its packaging **[24].** Important contributions of chaff material in industry are the physical and chemical properties and potential utilization of chaff material for various industrial and community needs, namely the value of recycling in industrial products that generally use polystyrene plastic material **[17, 18, 25].** Rice husks can be used as value-added materials for domestic and silicon-based industrial processing such as cleaning agents, animal feed ingredients, activated carbon materials, vibration absorbing materials, heat resistants, polymers, rubber, waste water pollutant absorbers, bioethanol raw materials, for storing goods, ceramic industries, and nano silica materials **[18, 20, 21, 25].** Rice husk contains hemicellulose material 24.3%, cellulose 34.4%, lignin 19.2%, ash 18.85%, and trace elements other 3.25%. Rice husk has a mass density of 96-100 kg / m^3, hardness (Mohr scale) 5-6, ash 22.29%, Oxygen 31-37%, Nitrogen 0.23-0.32%, Sulfur 0.04-0.08%, Hydrogen 4-5**% [18, 21, 26].**

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4.2. Manufacture Systems

Material cycle and energy flow in manufacturing systems can be analogous to the interaction of manufacturing systems with the surrounding natural environment system or referred to as manufacturing metabolism **[28, 38].** Manufacturer metabolism is the same as metabolism in the human body where there is raw material (food), process (digestion), product (work) and entropy (loss in the form of dirt or waste). the physical process that converts raw materials, energy and labor into final products and waste **[36, 37].** Factor in labor output the production process and product output for consumers to act as human components can be used as a tool to control the stability of the production process in manuf activities environmentally friendly acting. The word "metabolism" refers to the internal processes of living organisms needed to maintain and sustain life **[34, 35].** There are many manufacturers that use Styrofoam material as the main raw material and supporting raw materials in the production system. This system consists of input sub-systems, process sub-systems, output sub-systems, and waste sub-systems **[29, 31].** In the manufacture of metabolism that produces electronic rice cooker goods, for example, the main raw material as an input sub-system is iron, zinc, plastic and heating capacitors **[14, 36].** While the auxiliary materials for packaging use Styrofoam, paper, cardboard and plastic materials. Regarding the manufacturing sustainability system, the use of styrofoam materials is something that has been prohibited for use by environmental protection agencies (EPA) because products that use this material can cause environmental pollution **[33, 35].**

4.3. Substitution of Material input in Manufacturing

There are many electronic manufacturers who still use non-renewable natural resources such as Styrofoam or styrene as additional raw materials for packaging electronic goods. The functions of styrofoam and styrene in the packaging of electronic goods include; as sanitary napkins in television packaging, rice cookers, ovens, dispensers, water pumping machines and other electronic goods packaging **[28, 38].** Styrofoam substitutes used in this study are rice husk. Rice husk is engineered to be a substitute for styrofoam material which is usually used by electronic manufacturers as mentioned above. So that national manufacturing products are expected to meet the demands of the global market community that is environmentally friendly, and manufacturing can be developed into sustainable manufacturing **[34, 36]**. The researchers have succeeded in integrating the concept of environmental management into two existing manufacturing strategy models. They first prove that environmental factors are relevant for strategy making from the perspective of order criteria, qualification criteria, and choice process considerations and subsequent bidding on four built-in work agreements developing and integrating manufacturing strategies into strategies that try to integrate issues- environmental issues into a strategy perspective, including manufacturing that is integrated with computers, adds high additional production, saves resources, preserves the production environment, and complies with social production will be an important strategy for manufacturing companies **[14, 36, 37].**

4.4. Making Process in Husk Model

Next below is the order of the process of making chaff material models to substitute Styrofoam plastic materials which are generally used for manufacturing packaging in manufacturing industries.

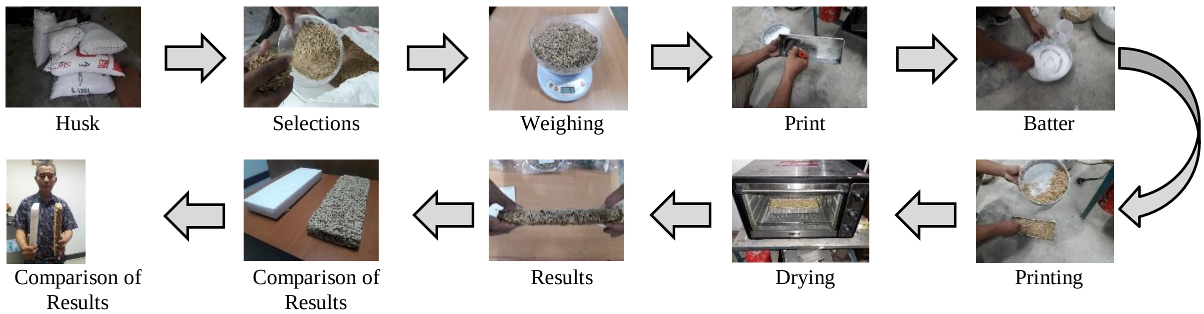

Figure 3. Flow of the Husk Model Making Process

Figure 3 explains the flow of the process of making husk models to substitute Styrofoam plastic material, namely; selecting, weighing, making molds, making dough, printing, drying, and comparing the results of experiments with Styrofoam.

Figure 4. Styrofoam plastic material

Figure 4 describes Styrofoam or styrene plastic material which will be replaced by natural materials.

Figure 5. The husk material model

Figure 5 describes the natural material of this research product Husk to be used as a substitute for Styrofoam which has been used by various industries and manufacturers.

5. Conclusion

The trial design of a model of renewable material substitution for sustainable manufacturing development has been successfully carried out with a level of achievement of research performance of 95%. Models that have physical characteristics that are close to the physical properties of Styrofoam material are $A_4 + T + P_3 + W + t_6$ models. The smaller the amount of adhesive material in the experiment, the greater the probability of failure of the research results. The model that failed in the experiment turned out to be able to be reused as the next experimental raw material for making the same model. Husk material is easily broken down naturally by micro-organisms in the soil so that this material becomes waste that will not disturb the living environment. While Styrofoam material is not able to be decomposed by micro-organisms in the soil, so this material becomes waste that can disrupt the living environment. Thus the Husk material model can be used as a substitute for Styrofoam which is more environmentally friendly than the use of Styrofoam material itself.

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7. References

1. Nukmal, N., Umar, S., Amanda, S. P., & Kanedi, M. (2018). Effect of Styrofoam Waste Feeds on the Growth, Development and Fecundity of Mealworms (Tenebrio molitor) . *OnLine Journal of Biological Sciences*, *18*(1), 24–28. https://doi.org/10.3844/ojbsci.2018.24.28
2. Nassar, I. M., Kabel, K. I., & Ibrahim, I. M. (2012). *Evaluation of the Effect of Waste Polystyrene on Performance of Asphalt Binder*. ARPN Journal of Science and Technology, 2(10), 927–935.
3. Amirshaghaghi, Z., Emam Djomeh, Z., & Oromiehie, A. (2011). Studies of Migration of Styrene Monomer from Polystyrene Packaging into the Food Simulant. *Iranian Journal of …*, *8*(4), 542–549. https://doi.org/10.1289/ehp.1409309
4. Jawahir, I., Badurdeen, F., & Rouch, K. (2013). Innovation in Sustainable Manufacturing Education. *Procedia CIRP*, (July), 9–16. Retrieved from http://www.gcsm.eu/Papers/28/0.3_Jawahir.pdf
5. Molamohamadi, ohreh, & Ismail, N. (2013). Developing a New Scheme for Sustainable Manufacturing. *International Journal of Materials, Mechanics and Manufacturing*, *1*(1), 1–5. https://doi.org/10.7763/ijmmm.2013.v1.1
6. Rosa, S. M. L., Santos, E. F., Ferreira, C. A., & Nachtigall, S. M. B. (2009). *Studies on the properties of rice-husk-filled-PP composites: effect of maleated PP*. Materials Research, 12(3), 333–338. https://doi.org/10.1590/s1516-14392009000300014
7. Yuan, C., Zhai, Q., & Dornfeld, D. (2012). A three dimensional system approach for environmentally sustainable manufacturing. *CIRP Annals - Manufacturing Technology*, *61*(1), 39–42. https://doi.org/10.1016/j.cirp.2012.03.105
8. Castro, N. P., Gallardo, K. C., & Verbel, J. O. (2014). Identification of volatile organic compounds (VOCs) in plastic products using gas chromatography and mass spectrometry (GC/MS). *Revista Ambiente e Agua*, *9*(3), 445–458. https://doi.org/10.4136/1980-993X
9. Osemeahon, S. A., Barminas, J. T., & Jang, A. L. (2013). *Development of Waste Polystyrene as a binder for emulsion paint formulation I: Effect of polystyrene Concentration*. The International Journal Of Engineering And Science, 2319–1813.
10. Aljaibachi, R., & Callaghan, A. (2018). Impact of polystyrene microplastics on Daphnia magna mortality and reproduction in relation to food availability . *PeerJ*, *6*, e4601. https://doi.org/10.7717/peerj.4601
11. Rouabah, F., Dadache, D., & Haddaoui, N. (2012). *Thermophysical and Mechanical Properties of Polystyrene: Influence of Free Quenching.* ISRN Polymer Science, 2012, 1–8. https://doi.org/10.5402/2012/161364
12. Ibrahim, D., Bankole, O. C., Ma'aji, S. A., Ohize, E. J., & Abdul, B. K. (2013). Assessment Of The Strength Properties Of Polystyrene Material Used In Building Construction In Mbora District Of Abuja,Nigeria. *International Journal of Engineering Research and Development*, *6*(12), 80–84.
13. García, M. T., Gracia, I., Duque, G., Lucas, A. de, & Rodríguez, J. F. (2009). Study of the solubility and stability of polystyrene wastes in a dissolution recycling process. *Waste Management*, *29*(6), 1814–1818. https://doi.org/10.1016/j.wasman.2009.01.001
14. Smith, L. dan Ball, P, 2012, *Steps Towards Sustainable Manufacturing through Modelling Material, Energy and Waste Flows*, International Journal of Production Economics Vol. 140 Issue 1: 227-238.

15. Uddin, M. K. (2017). *A study on the potential applications of rice husk derivatives as useful adsorptive material*. https://doi.org/10.21741/9781945291357-4
16. Syuhadah S., Noor and Rohasliney H. 2012. Rice Husk as Biosorbent: A Review**.** *Health and the Environment Journal*, 2012, Vol. 3, No. 1. https://www.researchgate.net/publication/285128159.
17. Abedin, R., & Das, H. S. (2014). Electricity from rice husk : a potential way to electrify rural Bangladesh. *International Journal of Renewable Energy Research*, *4*(3), 604–609.
18. Babaso, P. N., & Sharanagouda, H. (2017). Rice Husk and Its Applications: Review. *International Journal of Current Microbiology and Applied Sciences*, *6*(10), 1144–1156. https://doi.org/10.20546/ijcmas.2017.610.138
19. Nagrale, S. ., Hajare, H., & Modak, P. R. (2012). *Utilization of Rice Husk Ash*. International Research Journal of Engineering and Technology (IRJET), 2(4), 1–5.
20. Raheem, A. A., & Kareem, M. A. (2017). *Optimal Raw Material Mix for the Production of Rice Husk Ash Blended Cement*. *7*(2), 77–93.
21. Minstry, B. (2016). Properties and industrial applications of rice husk : A review. *Int. J. Emerg. Technol. Adv. Eng.*, *6*(10), 86–90. https://doi.org/10.1007/s00606-007-0629-8
22. Subki, N., & Hashim, R. (2011). *Rice Husk as Biosorbent*: A Review. *Health and the Environment Journal*, *3*(December), 89–95.
23. Ummah, H., A.Suriamihardja, D., Selintung, M., & Wahab, A. W. (2015). Analysis of chemical composition of rice husk used as absorber plates sea water into clean water. *ARPN Journal of Engineering and Applied Sciences*, *10*(14), 6046–6050. https://doi.org/1819-6608
24. Viana, C. E. M., Neto, J. W. da S., & Mourad, K. A. (2016). U*sing rice husks in water purification in brazil*. *In*ternational Journal of Environmental Planning and Management, *2* (3), 15–19. Retrieved from https://www.researchgate.net/publication/305688958.
25. Todkar, B. S., Deorukhkar, O. A., & Deshmukh, S. M. (2016). *Extraction of Silica from Rice Husk*. *International Journal of Engineering Research and Development*, *12*(3), 2278–67. Retrieved from http://www.ijerd.com/paper/vol12-issue3/Version-2/H12326974.pdf
26. Olawale, Olamide & Festus Adekunle Oyawale, 2012. *Characterization of Rice Husk via Atomic Absorption Spectrophotometer for Optimal Silica Production*. Ijst, 2(4), 210–213.
27. Thiyageshwari, S., Gayathri, P., Krishnamoorthy, R., Anandham, R., & Paul, D. (2018). *Exploration of rice husk compost as an alternate organic manure to enhance the productivity of blackgram in typic haplustalf and typic rhodustalf*. International Journal of Environmental Research and Public Health, 15(2). https://doi.org/10.3390/ijerph15020358
28. Mohiuddin, O., Mohiuddin, A., Obaidullah, M., Ahmed, H., & Asumadu-Sarkodie, S. (2016). Electricity production potential and social benefits from rice husk, a case study in Pakistan. *Cogent Engineering*, *3*(1), 1–13. https://doi.org/10.1080/23311916.2016.1177156
29. Nyambara Ngugi, H. (2017). Use of Expanded Polystyrene Technology and Materials Recycling for Building Construction in Kenya. *American Journal of Engineering and Technology Management*, *2*(5), 64. https://doi.org/10.11648/j.ajetm.20170205.12
30. Sekhar, V. C., Nampoothiri, K. M., Mohan, A. J., Nair, N. R., Bhaskar, T., & Pandey, A. (2016). *Microbial degradation of high impact polystyrene (HIPS), an e-plastic with decabromodiphenyl oxide and antimony*

trioxide. Journal of Hazardous Materials, 318, 347–354. https://doi.org/10.1016/j.jhazmat.2016.07.008

31. Ede, A. N., Alegiuno, V., & Aawoyera, O. P. (2014). Use of Advanced Plastic Materials in Nigeria: Performance Assessment of Expanded Polystyrene Building Technology System. *American Journal of Engineering Research*, *3*(4), 17–23.
32. Ocampo, L., & Clark, E. (2015). A Sustainable Manufacturing Strategy Decision Framework in the. *Jordan Journal of Mechanical and Industrial Engineering*, *9*(3), 177–186.
33. Nordin, N., Ashari, H., & Rajemi, M. F. (2014). A Case Study of Sustainable Manufacturing Practices. *Journal of Advanced Management Science*, *2*(1), 12–16. https://doi.org/10.12720/joams.2.1.12-16
34. Deif, A. M. (2011). A system model for green manufacturing. *Journal of Cleaner Production*, *19*(14), 1553–1559. https://doi.org/10.1016/j.jclepro.2011.05.022
35. Pathak, Priyanka & M. P. Singh. 2017. Sustainable Manufacturing Concepts: A Literature Review. *International Journal of Engineering Technologies and Management Research,* Vol. 4, No. 6(2017), 1-13. DOI: 10.5281/zenodo.833990. http://www.ijetmr.com©*International Journal of Engineering Technologies and Management Research.*
36. Ceptureanu, Eduard Gabriel., Sebastian Ion Ceptureanu., Razvan Bolog., and Ramona Bologa. 2018. *Impact of Competitive Capabilities on Sustainable Manufacturing Applications in Romanian SMEs from the Textile Industry*. *Sustainability*. 2018, 10, 942; doi:10.3390/su10040942. www.mdpi.com/journal/sustainability.
37. Naghmeh Tagavi. 2015. *Sustainable Manufacturing Strategy; Identifying Gaps in Theory and Practice*. Thesis. Department of Technology Management and Economics Chalmers University of Technology. Gothenburg, Sweden 2015.
38. Marten, Brooke and Andrea Hicks. 2018. *Expanded Polystyrene Life Cycle Analysis*. Literature Review: An Analysis for Different Disposal Scenarios. Journal Sustainability. Department of Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, Wisconsin. Mary Ann Liebert, Inc. Vol. 11 No. 1. February 2018. DOI: 10.1089/sus.2017.0015.
39. Organdi, Iwuozor Kingsley. 2018. Removal of Heavy Metals from Their Solution Using Polystyrene Adsorbent (Foil Take-Away Disposable Plates). International Journal of Environmental Chemistry. 2018; 2(2): 29-38. http://www.sciencepublishinggroup.com/j/ijec. doi: 10.11648/j.ijec.20180202.11. ISSN: 2640-1452 (Print); ISSN: 2640-1460 (Online)