Design and Analysis Rolling Press Mechanism for producing Banana Stem as Natural Fiber

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***Abstract*—Materials for structural engineering are divided into four types, including ceramics, polymers, and composites. Composite material is a combination of reinforcement and matrix. Composite technology has progressed so rapidly. The development was mainly triggered by the demand for high quality materials. In its development, the fiber used is not only synthetic fiber (glass fiber) but also natural fiber (natural fiber). The advantage of natural fibers compared to synthetic fibers is that natural fibers are more environmentally friendly because natural fibers are able to decompose naturally, while synthetic fibers are more difficult to decompose. In this paper, banana midrib fiber is used and taken from the kepok banana tree (Musa paradisiaca) is a fiber that has good mechanical properties. Banana midrib fiber has a density of 1.35 g/cm3, the cellulose content is 63-64%, hemicellulose 20%, lignin content is 5%, the average tensile strength is 600 MPa, the tensile modulus is 17.85 GPa and the fracture strain is 3, 36%. Because of the advantages of the banana midrib fiber, hence this paper is made for support the production of the banana midrib fiber by designing and analyzing concept design of the machine for processing natural fibers, especially when the material is banana stems, it is called ZEUS MACHINE: Banana Stem Rolling Press Machine as Natural Fiber by Using Manual Power from Pedaling. This machine can help increase the productivity of natural fiber manufacture and can support the development of technology engaged in industry.**

***Keywords*—Composite, Natural Fiber, Banana Stem, Press Machine, Rolling Machine**

I. Introduction

Industrial growth in Indonesia is growing rapidly, this can be seen from the increasing number of foreign companies investing in building factories in this country. The manufacturing industry is a potential industry, the results of which are widely used by the community, both at home and abroad. In the manufacturing industry, the use of metal in various product components is decreasing. This is caused by the weight of components made of metal, the relatively difficult formation process, corrosion and high production costs.

Indonesia is an agricultural country that has various natural resources that should be used optimally for the benefit of the community. Therefore, the manufacturing industry innovates to use natural fiber as a material that is safe to use and reduces the use of metal, so that environmental waste in the form of metal waste can be reduced. We can call this natural fiber as a composite material, which is a material formed from a combination of two or more materials that have stronger mechanical properties than the constituent material. Natural fiber is a fiber that comes from plants or animals that tend to be like threads. In order to use natural fibers as a composite material, it is necessary to study banana stem fibers as a substitute for synthetic fibers in the manufacture of composite materials. In this paper, the banana stems are used as the main component of the natural fiber because it was agricultural waste that has not been widely used.

Banana midrib also has cellular tissue with interconnected pores, and it will become solid when it is dried, and that is why the material has quite good absorption. The matrix or adhesive in the composite serves to bind the fibers into a single unit with the structure, protect the fibers from damage due to environmental conditions, distribute the load to the filter and provide properties such as stiffness, resilience, and resistance.

The advantages of natural fibers compared to synthetic fibers include:

- Natural fibers have high specific strength because natural fibers have low density.
- Natural fiber is easy to obtain and is a source of natural fiber that is easily obtained and is a natural resource that can be reprocessed.
- The price is relatively cheap
- Non-toxic material.

Common uses and processing of natural fibers include the use of textiles where the fibers are spun into yarn and then woven or knitted into cloth, other uses are also as woven products, natural fabrics, artificial fibers, building roofs as well as building and construction materials. In the banana sheath that will be processed into natural fiber, it can be applied as a woven product such as pressed fiber and can be woven wide evenly and flexibly that are intertwined to make hats, sandals, baskets and others. On the other side, building materials and construction materials where natural fibers are processed into particleboard or fiberboard (MDF).

Based on the description above, it can be concluded that natural fiber, especially in banana stems in Indonesia has the potential to be used as raw material for various industries by increasing the amount of supply and quality so that it can meet domestic natural fiber needs and reduce imports. The use of natural fibers is not only for conventional use but continues to grow along with the development of science and technology to create natural fiber-based innovations and awareness of the importance of environmentally friendly products. Natural fibers have good prospects to be developed as raw materials for various industries to meet domestic needs, reduce imports, and increase their utilization.

Therefore, ZEUS MACHINE is made to help the processing of the natural fibers, especially if the material is banana stems, and this machine is adapting rolling press mechanism for producing banana stem as natural fiber by using manual power from pedaling. This paper describes the conceptual and actual design, as well as design analysis from ZEUS MACHINE especially in terms of displacement, von mises stress, and safety factor to determine the most optimal design concept for ZEUS MACHINE.

II. Methodology

As a reference for literature and theory for the methodology used journals, papers, books, articles, and other reading media that contain the material. This methodology has a begin with determining the idea or title of this writing and then continues by making the needs desired by the customer and alternative design concepts that, if possible, will be the solution to the realization of the ideas.

In the line of thought of this research, there are several things to do, including; First, application of the banana midrib and then prepared the instruments and research steps. Second, choose a sample. And the third is data collection through interviews, observation and documentation, followed by analyzing the data obtained and the meaning of the data. Data collection can be done repeatedly according to the needs of the researcher. And then make conclusions from the data that has been analyzed. In conducting this research, the line of thought that will be explained in Fig. 1 is used.

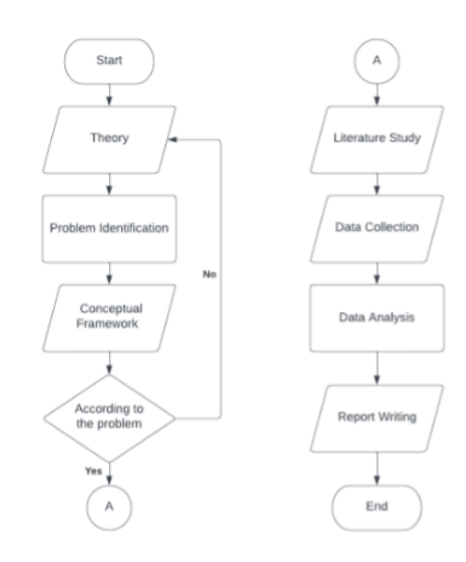

Fig. 1. Research Flow Chart

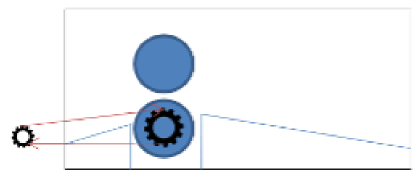

Fig. 2. Alternative Design for First Concept

III. Result and Discussion

A. Conceptual Design

A plate rolling machine is a machine that will turn various types of metal sheets or materials into sheets. It can also be called "Roll Bending Machine" or "Plate Bending Machine" or "Rolling Machine". The working principle of this machine is very simple, the workpiece in the form of small diameter material is clamped between the upper roll and lower roll and rotated so that it reaches the desired diameter size.

In this journal, we are designing and analysing a rolling machine that we fabricate using manual power from pedaling. Furthermore, we will refer to this machine as the ZEUS MACHINE. In this case, we will make banana stems that have the potential as natural fibers into thinner sheets using a rolling machine that we have fabricated on the strength side. Banana stems that are processed using a rolling machine will widen or increase in diameter according to the required diameter. Banana stems that are already in the form of sheets will be used as natural fibers that are ready to be processed as raw materials for a mixture of artificial fibers.

In concept 1 shown in Fig. 2, we made a roll machine using only 1 roll stage. The advantages of this machine are economical in terms of materials and facilitate the manufacturing process due to fewer parts. The disadvantage of a single-stage roll machine is the limited human power when the machine is used for hard materials, so it requires several rolls to get the desired thickness.

In the second concept shown in Fig. 3, this concept has the advantage of being thinner in thickness in one roll

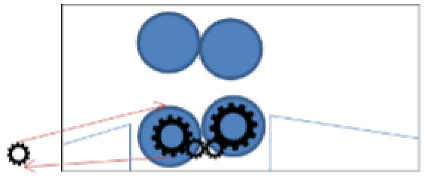

Fig. 3. Alternative Design for Second Concept

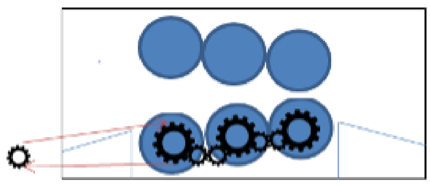

Fig. 4. Alternative Design for Third Concept

for even hard materials than concept 1. The drawbacks of using more materials in production and complexity in design and manufacture are more difficult.

The third concept shown in Fig. 4, this concept has the advantage of being thinner and more used for one roll, but the drawback is that it has complexity in the design which is more difficult than concepts 1 and 2. As well as a more difficult manufacturing process that requires more literature on kinematics and dynamics on this engine.

The points given in the Table 1 are obtained using a scale of 1-10 where the consideration is that when the variable is more profitable, the points are higher and vice versa if the variable is more detrimental, the points given are also lower. The weights used for each variable have the same value. In this case, we use favorable criteria, namely Power Efficiency and Results, while for unfavorable criteria we use Cost Investment, Complexity, and Risk. In determining the right number or assessment, we conduct research on alternative designs that we have made and are determined subjectively based on the results of research or studies and experiences that have been carried out. From the Table 1, we can conclude that the concept that fulfills the requirements is **The First Concept**.

TABLE 1
DESIGN SELECTION USING A DECISION MATRIX

Criteria	**Concept**		
	1	**2**	**3**
Cost Investment	9	7	5
Power Efficiency	7	7	7
Complexity	9	7	5
Results	5	7	9
Risk	7	7	5
TOTAL	**37**	**35**	**31**

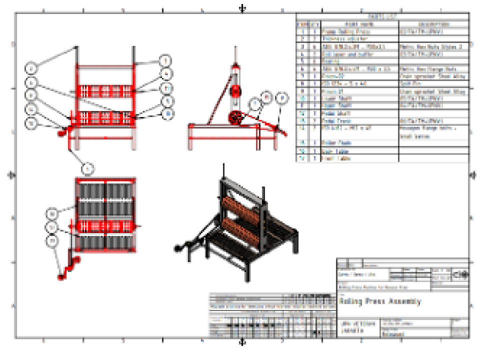

Fig. 5. Detailed Design of ZEUS Machine

B. Detailed Design

The geometry of the frame shape of the ZEUS machine has overall dimensions with dimensions of 1553 mm in length, 1182 mm in width, and 1424 mm in height. So the maximum load that can be borne by the Zeus machine in each roll is 100 Mpa. In addition, one of the mechanical properties, namely the density of the Zeus machine, is $7.311 \quad g/cm^3$. ZEUS machine uses several different materials in each part as shown in Fig. 5. The frame uses mild steel material, the roll section uses stainless steel material, and the roll frame and shaft uses steel material. In conducting FEA (Finite Element Analysis), we use 3 types of variables, namely torque moment of 1 Nmm, force distribution of 1 N/mm, and considering gravity in the process of analyzing Von Mises Stress, Displacement, and Safety Factor.

C. Von Mises Stress Analysis

Von Mises stress is a value used to determine if a given material will yield or fracture. It is mostly used for ductile materials, such as metals. The von Mises yield criterion states that if the von Mises stress of a material under load is equal or greater than the yield limit of the same material under simple tension then the material will yield. The elastic limits discussed before are based on simple tension or uniaxial stress experiments. The maximum distortion energy theory, however, originated when it was observed that materials, especially ductile ones, behaved differently when a non-simple tension or non-uniaxial stress was applied, exhibiting resistance values that are much larger than the ones observed during simple tension experiments. A theory involving the full stress tensor was therefore developed. Based on the results of the analysis shown in Fig. 6, the von Mises stress is minimum or equal to 0 MPa in all parts so that there is no area that has the greatest stress which causes the area to be the most critical because it receives a very large load.

D. Displacement Analysis

Finite element analysis involves modeling structural components using small, discrete interconnected ele-

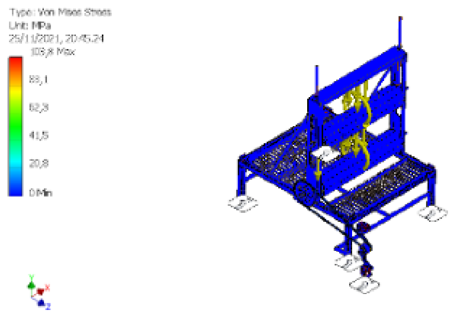

Fig. 6. Von Mises Stress Analysis

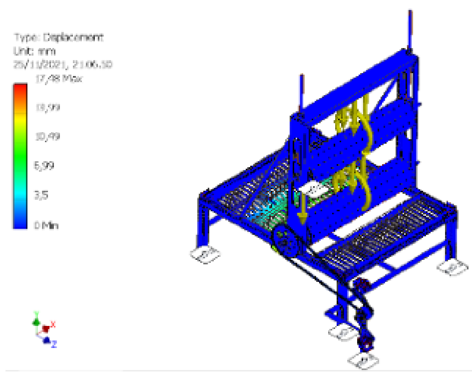

Fig. 7. Displacement Analysis

ments. A displacement interpolation function is assigned to each finite element and every element is directly or indirectly connected to all other elements through common interfaces that are typically nodes, and/or common boundaries (lines or surfaces). Based on the analysis that has been carried out, the highest displacement value is found in the part of the table closest to the roll according to Fig. 7, which is around 3.5-10.49mm. Then, the other part is worth 0 or the minimum value. Displacement is very influential on the distribution of forces that occur in the geometry of the object being modeled [6]. The area that has the minimum stress will have the highest displacement.

E. Safety Factor Analysis

In engineering, a factor of safety (FoS), also known as (and used interchangeably with) safety factor (SF), expresses how much stronger a system is than it needs to be for an intended load. Safety factors are often calculated using detailed analysis because comprehensive testing is impractical on many projects, such as bridges and buildings, but the structure's ability to carry a load must be determined to a reasonable accuracy. The safety factor is one of the most important parameters in designing and testing stress on a geometric model of the shape of the test object to determine whether or not the shape is safe. Based on the analysis that has been carried out which is shown in Fig. 8, the maximum safety

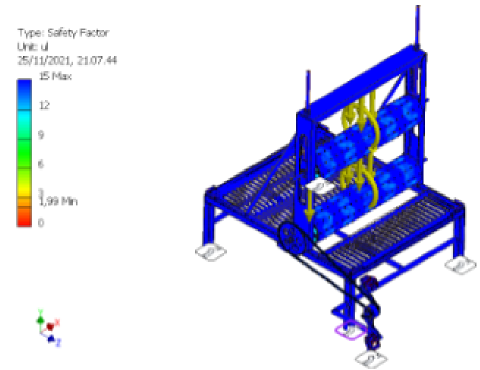

Fig. 8. Safety Factor Analysis

TABLE 2
SIMULATION RESULTS

Concept	Category Analysis	Simulation Results	
		Minimum	Maximum
1	Von Mises Stress	0 MPa	103,8 MPa
2	Displacement	0 MPa	17,48 MPa
3	Safety Factor	1,99 Ultima	15 Ultima

factor value obtained is 15ul (ultima) on the table and the safety factor value is obtained with an interval of 9-12ul (ultima) on the roll section. This indicates that there is no material failure on the Zeus machine and will not fail when applied to a torque moment of 1 Nmm and a force distribution of 1 N/mm.

IV. CONCLUSIONS

Analysis of the rolling press machine, especially on the workbench, on the variables used for the distribution of the force of 1 N/mm, the torque moment of 1 Nmm, and considering gravity, it can be concluded that the workbench will not easily deform or fail. The value of the safety factor is very large in all parts of the Zeus machine, both in the table frame and other parts. The results of the simulation carried out on the Zeus Machine with a maximum load that can be borne by the frame of 100MPa in each roll are as presented in Table 2.

Based on the results of the analysis that has been carried out and according to the contours obtained through the Finite Element Analysis process on the Autodesk Inventor software, the von Mises stress is minimum or equal to 0 MPa in all parts so that there is no area that has the greatest stress that causes the area to become damaged. the most critical because it receives a very large load, the highest displacement value is on the part of the table closest to the roll which is worth about 3.5-10.49mm then on the other part it is 0 or the minimum value, the maximum safety factor value obtained is 15ul (ultima) on the table and the safety factor value with an interval of 9-12ul (ultima) on the roll section is obtained.

The addition of variables such as stress distribution is very much needed in the ZEUS engine design analysis for the sustainability of the research and to answer the solutions of this research. In addition, it can also add analyzed aspects such as working stress in each axis when the machine receives a workload so that it can determine critical points concretely on the Zeus machine and can be used to predict the life of the machine. It is hoped that this machine can help increase the productivity of natural fiber manufacture and can support the development of technology engaged in industry.

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References

[1] Khotimah, K.; Susilawati; Soeprianto, Harry. (2014). Komposit Serat Batang Pisang (SBP) – Epoksi sebagai Bahan Penyerap Bunyi. NATURAL B, Vol.2, No.4.

[2] Jaya, D.; Putri, R.; Nack, H..(2019). Pemanfaatan Serat Pelepah Pisang sebagai Bahan Komposit.

[3] Development of Chemical Technology for Processing Indonesian Natural Resources. ISSN 1693-4393.

[4] Ilmal, R.; Preston, J.; Haryo, S.. (2019). Analisis Tegangan Propeller Kapal Penangkap Ikan di Kota Dumai menggunakan Finite Element Analysis. ISSN 2549-1938.

[5] Wandono, F. A. (2017). Permodelan Metode Elemen Hingga Untuk Menentukan Tegangan Von Mises Pada Poros Roda Lsu-05. Seminar Nasional Iptek Penerbangan Dan Antariksa XXI, 222–231.

[6] Pranoto, S. H., & Mahardika, M. (2018). Design and Finite Element Analysis of Micro Punch CNC Machine Modeling for Medical Devices. AIP Conference Proceedings, 1941, 1-7.

[7] Pratama, J., & Mahardika, M. (2018). Finite Element Analysis to Determine the Stress Distribution, Displacement and Safety Factor on A Microplate for The Fractured Jaw Case. AIP Conference Proceedings, 1941, 1–7.

[8] Saputro, A. H., Hidayat, T., & Qomaruddin. (2017). Analisa Poros Alat Uji Keausan Untuk Sistem Kontak Two-Disc Dengan Menggunakan Metode Elemen Hingga. Simetris: Jurnal Teknik Mesin, Elektro Dan Ilmu Komputer, 8(1), 283–290.

[9] Fadiji, T., Coetzee, C. J., Berry, T. M., Ambaw, A., & Opara, U. L. (2018). The Efficacy of Finite Element Analysis (FEA) as A Design Tool for Food Packaging: A Review. Biosystems Engineering, 174, 20–40.

[10] Ismail, R., Munadi, M., Ahmad, Z. K., & Bayuseno, A. P. Analisis Displacement dan Tegangan von Mises Terhadap Chassis Mobil Listrik Gentayu. ROTASI, 20(4), 231-236..

[11] Arif, F.; Septiyanto, A.; Sudiyono; Dwi, A.; Setiadi, R.. April 2021. Analisis Tegangan Von Mises dan Safety Factor pada Chassis Kendaraan Listrik Tipe In-Wheel. Jurnal Rekayasa Mesin. ISSN: 2540-7678