Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/AP06.20250159
Published: August 5, 2025

Parametric Analysis & Iterative Engineering Blueprints for Low-Cost Sago Bark Processing Machine

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Abstract

The development of a low-cost Sago Bark Processing Machine in Papua New Guinea aims to reduce human effort and time required for local Sago farmers. The machine would replace the tedious and time-consuming traditional methods of extracting sago starch, which are currently used for rice production. The machine would consist of an actuator, a grinding wheel, and pulley systems that turn the mixing shaft into a housing filled with grinded sago bark and water mixture. The straining mechanism would separate the starch and fiber into starch and fiber. The machine would be simple, portable, and cost-effective, making it suitable for local and subsistence farmers or anyone who prefers to plant and harvest sago in their backyards. This could potentially reduce the percentage of imported energy foods in Papua New Guinea.

Keywords
Sago, parametric, blueprint.

1. Introduction
1.1 Introducing Small-Scale Rice Milling
Sago is a staple food in Pacific regions like Indonesia, Malaysia, and Papua New Guinea, with forests covering over a million hectares. Local communities rely on its starch, which is extracted using traditional methods. The process involves identifying mature palms, felling them, and separating the bark from the pith. The starch is then washed and filtered. The process is carried out through manual kneading and treading, with men handling the initial stages and women handling the later stages. This project aims to provide a cost-effective solution for processing sago palm and extracting the edible component, ensuring farmers can maximize yield and quality without relying on traditional methods.

2. Literature Review
2.1 A Brief Discussion on Similar Projects
Modern sago-processing machines have not gained significant traction in food technology, as sago is mainly consumed in regions without such equipment. Pacific Island nations rely on manual methods for extracting sago starch, with the exception of the Stirrer Rotary Blade Sago Starch Extraction Machine (Figure 1).

Figure 1. Overall structure of improved cylinder-type sago rasping machine.

The project aims to reduce processing time and effort for sago starch extraction, particularly beneficial for small-scale farmers with limited manpower. It designs a portable, affordable, and efficient machine that can operate without large power sources. The efficiency ranges from 65% to 70%, and by-products can be collected and processed into fertilizer for gardens.

2 Methodology

2.1 Parametric Analysis for Power Requirement & Determination of Dimensions of Parts

Power Calculation

Here we Calculate Power Requirement (Output Power of Engine) Required for Grinding (and straining). In this paper we only show calculation made to yield the equation for Cutting Resistance.

To calculate the output power, we require:

Cutting Resistance which is the force required to cut through the material, we'll need cutting speed, area of contact and density of the material (sago trunk).

$$Cutting\ Resistance = A\sigma$$

$$where\ \sigma = Maximum\ Shearing\ Strength\ for\ Sago\ Bark\ (N/m^2)$$

$$A = Area\ of\ Contact$$

Since the Sago palm does not have reliable sources for its Shear strength that we could find, we decided to use the Shear strength of Cedar Tree (www.engineeringtoolbox.com) because it's stronger than the sago palm but is a softwood, typically having the least shear strength among its other softwood counterparts (Figure 2).

	CEDAR TREE PROPERTIES	
1	Density	470 kg/m^3
2	Modulus of Elasticity	11.7 GPa
3	Shear Strength	5.5 MPa

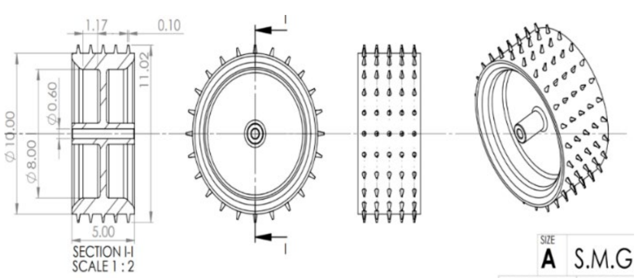

Figure 2. Design of Grinding Wheel in SolidWorks.

Therefore, we use 5.5 MPa as our Shear Strength value for the sago trunk

$$Cutting\ Resistance = A\sigma$$

$$Cutting\ Resistance = \pi\left(\frac{d^2}{4}\right) \times n \times \sigma_{max}$$

Where $d = diameter\ of\ tip\ of\ nail\ that\ in\ contact\ with\ sago\ trunk = 1mm$

$$n = Max\ number\ of\ nails\ installed\ across\ length\ of\ grinding\ wheel\ that$$

$$will\ be\ in\ contact\ with\ sago\ truck\ = 15$$

$$\sigma_{max} = Maximum\ Shear\ Stress\ of\ Sago\ Trunk = 5.5\ MPa$$

$\therefore Cutting\ Resistance = A\sigma_{max}$

$$= 5.5 \times 10^6\ Pa\ \times\ \pi\left(\frac{d^2}{4}\right) \times n\, m^2$$

$$F_{CR} = \frac{5.5\pi d^2 n}{4} \times 10^6\ N$$

Now this is the equation for cutting resistance of the grinding wheel.

The first prototype of a Sago Machine-Straining Phase (S.M.S) is designed to produce 10 grams of edible sago per second, with a total processing time of 14.2 hours for an entire sago tree containing 300 kg of stored starch and fiber. The machine is designed to be small and portable, considering the harsh conditions farmers face. The hardest part of producing sago is the beating of the bark, which consumes the most time. The required power output for the machine is 2.01 HP, and five important parameters are crucial for its success.

- Minimum Engine Power Required: 2.01 HP or 1.5267 kW
- Maximum Grinding Wheel Frequency: 4500-3000 RPM
- Maximum Grinding Wheel Radius: 50 mm (Independent Variable)
- Maximum Mixing Shaft Radius: 56 mm
- Maximum Mixing Shaft Frequency: 120 RPM

The diameter of the grinding wheel shown in Figure 2 is 100mm, this parameter was determined using the above values in a fourth-degree equation. The solution is shown below in Figure 3 which was done using the help of Desmos, an online graphical math tool.

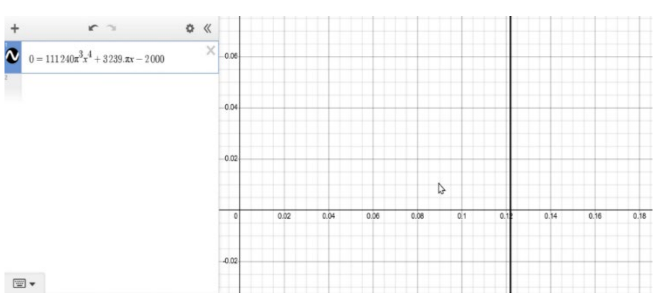

Figure 3. Desmos, an online graphical math tool.

2.2 Computer Aided Design (CAD)

SolidWorks is the design software used to design the components and entire assembly blueprints, including other important analyses such as simulation and force analysis for material selection.

The following desired features were considered in our Design: Portability; High Efficiency; Affordability; Simplicity; Quality.

3. Results and Discussions

2.3 Overall Assembly

The Engineering Blueprint for the first prototype MARK 1 was created using SolidWorks 2023, consisting of three main phases. The machine, designed by Daniel Kale from 12-03-2025 to 15-04-2025, requires a size 13 spanner to switch between phases, as per the simple manual instructions.

Sago Machine Actuator (S.M.A)-this is made up of the driving factor which is the 2.01 HP engine, the modified shaft, and added components for enabling the two other phases to be assembled respectively (Figure 4).

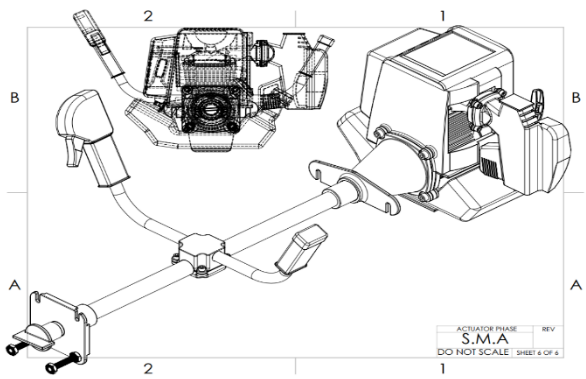

Figure 4. Sago Machine-Actuator (S.M.A).

Sago Machine Grinder (S.M.G)- the phase that grinds or shreds the Sago fibers off the bark for further processing. This phase contains the grinder is responsible for converting the fibrous bark into smaller chunks or fragments (Figure 5 and Figure 6).

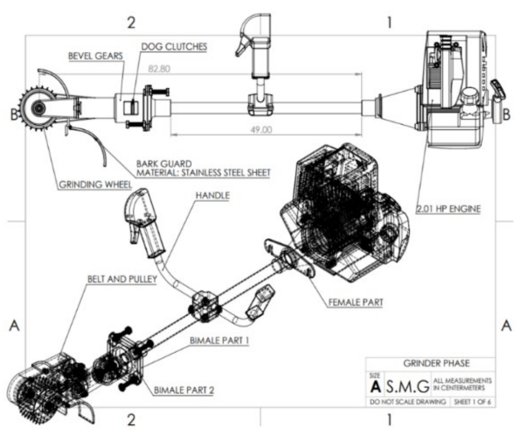

Figure 5. Sago Machine-Grinder (S.M.G).

Sago Machine Grinder (S.M.G)- the phase that grinds or shreds the Sago fibers off the bark for further processing. This phase contains the grinder is responsible for converting the fibrous bark into smaller chunks or fragments.

Sago Machine Strainer (S.M.S)- The Sago Machine Strainer (S.M.S) is a crucial stage in the sago making process, where sago bark fragments are mixed with water and transported along a shaft using threads. The sago starch is transferred from the fibers into the water, similar to how dirt is separated from clothing in a washing machine. The second cylinder has a strainer for starch separation, while residue fibers move along the shaft (Figure 6).

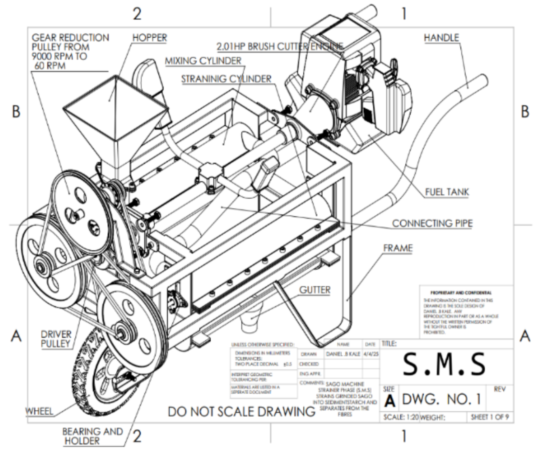

Figure 6. Sago Machine-Strainer (S.M.S).

2.4 Force Analysis of Mixing Shaft

While creating the blueprints for our prototype, we require a thorough investigation of the mixing shaft to prevent failure due to torsional stress. As a result, our findings have been included in the results (Table 1).

Table 1. Shows the data required for the force analysis of the machine

Parameter	Quantity	Units
Thread length	2220	mm
Total Shaft length for mixing	500	mm
Outside Diameter Inside Diameter	70 52	mm mm
Thread wideness	32	mm
Inside Circumference	164	mm

The shaft should rotate at a frequency of 2 Hz according to pulley calculations. After 10 rotations of the shaft, a particle from one end of the mixer traveling through passes to the other end, the time taken is 5 seconds, take note that there are 10 full thread rotations on the shaft design. This is based on the fact that in one rotation of the shaft, the shaft does one thread revolution (Figure

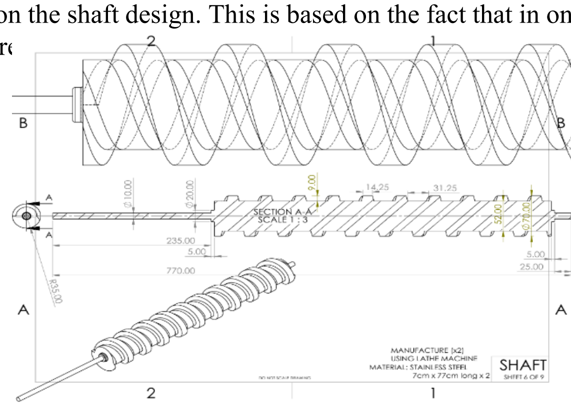

Figure 7. The mixing shaft and dimensions in millimeters.

The expected stress induced on the shaft is torsional stress which will be treated as the design stress. driving and driven wheel Gear ratio is given by (driving pully diameter/driven pulley diameter)

$$GR = \frac{driving\ pulley\ diameter}{driven\ pulley\ diamter}$$

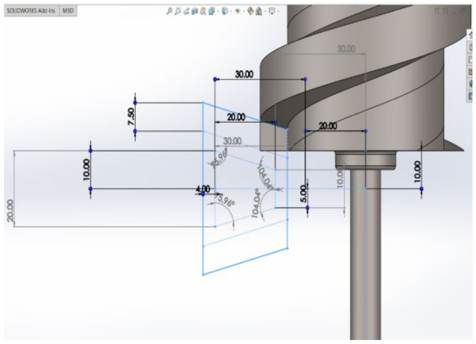

Figure 8. Dimensions of Cross-section of Helical cut on the Mixing shaft.

According to the Design for mixing shaft, the volume of water and sago mixture that can be contained at any instant of time in one of the cylinders is 1,003,300 cubic millimeters. This was done by subtracting the volume of the shaft by volume of its corresponding cylinder.

Power rating on shaft is given by the power rating of the motor assuming torque resistance is negligible.

From the power equation, we know that:
$Power = \frac{Work}{time} = Force \times \frac{distance}{time} = Force \times velocity$,
note that $Torque = Force \times radius,$
and angular velocity $\omega = 2\pi f$

Therefore $Power = Torque \times \omega = T \times 2 \times \pi \times f$

$$We\ solve\ for\ torque\ since\ f = 2\ Hz$$

According to our designs for pulley calculations, the mixing shaft spins at 2 Hz and maximum engine throttle power assumed to be 2000 W:

$$T = \frac{P}{2 \times \pi \times f} = \frac{2000\ W}{2\pi \times 2Hz} = 159.15 \approx\ 160\ \ Nm$$

Using Torque and internal diameter of shaft (minimum value 4mm), we can now calculate torsional stress

$$Torsional\ Stress = \frac{16 \times T}{D^3 \times \pi}$$

$$\tau = \frac{16 \times 160Nm}{(0.04m)^3 \times \pi} = 12{,}732{,}395.45Pa = 12\ 732.4\ kPa$$

Therefore, the design stress is approximately 1 773 kPa
The material we are using for our shaft is Steel

4.3. Factor of Safety

Finding the factor of safety

$$Factor\ of\ safety = \frac{yield\ strength\ of\ Stainless\ steel}{design\ stress}$$

$$Factor\ of\ Safety = \frac{205MPa}{12\ 732.4\ kPa} = 16.1006 \approx 16$$

Therefore, the shaft is 16 times stronger than it actually is required to be. The factor of safety computed is reasonably large due to the machine having infinite life. This means the shaft will be able to theoretically withstand an infinite number of cycles without fracture. In simple words, our shaft has genuine quality (Table 2).

Table 2. shows the estimated cost of Mark 1 for materials required for the production of its prototype. This list of materials was taken on 27-04-2025 in Lae, Morobe Province.

Code	Item	Quantity		Cost PGK	Total Cost PGK	Hardware	NO
100-EAC4012	W/SCW PHL BR CS 4GX 12 SP30	5	EA	7.24	36.2	CASA Hardware	4
020-50-40-005	FLAT SHEET 0.4*1200*2400MM ZINCALUME	2	SH	54.45	108.9	CASA Hardware	5
301582	BEARINGS 6203 2RS (KJYJ)	6	PCE	7.9	47.4	LEON BUILDINGS SUPPLY LTD	6
301581	BEARINGS 6202-Z	8	PCE	3.9	31.2	LEON BUILDINGS SUPPLY LTD	7
301569	BEARINGS 6001-2RS (KJYJ)	12	PCE	6.9	82.4	LEON BUILDINGS SUPPLY LTD	8
301816	BOLT & NzUT HEX HEAD6MMX50MM 2HR650C 230's	50	PCE	0.61	30.5	LEON BUILDINGS SUPPLY LTD	9
301768	BOLT & NUT HEX HEAD 8X60MM 2HR860C 100's	50	PCE	0.76	38	LEON BUILDINGS SUPPLY LTD	10
300777	2.40M FLAT SHEET IRON PLAIN	2	EA	38.4	76.8	LEON BUILDINGS SUPPLY LTD	11
GG242	FLAT IRON GALV 2400X1200X0.40	2	SH	118.67	237.34	MAINLAND PLUMBING&HARDWARE	12
TOTAL		141			1231.16		

3. Conclusion

The project aims to develop a machine that can increase sago production by reducing manual labor. The prototype, made of steel, has a high safety factor and is expected to help local farmers increase production. The estimated cost is K1250, but mass production could reduce it further. Mark 1, made from recycled materials and metals, is under construction at the Central Engineering Workshop. The findings suggest that a machine that can extract edible sago using available resources is theoretically possible. This could lead to new opportunities for Papua New Guinea and the Pacific.

Acknowledgements

We would like to thank all the technical staff of the Central Engineering Workshop present in 2025, the Maintenance staff of Unitech, especially Mr. Foxy.

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Biography

Daniel B. Kale is a final-year Mechanical Engineering student at the Papua New Guinea University of Technology, based in Lae City, Morobe Province. With a strong background in science and creativity, he excels in practical innovation and aims to improve everyday life through engineering. Kale achieved A grades in all subjects and ranked in the top 10 nationally in physics. He has developed skills in technical drawing, welding, machining, grinding, and lathe operations and applied them to various projects.A notable achievement was during his third year in a Machine Design course taught by Dr. Mohamed, where he proposed and led a team to design a low-cost mini rice milling machine, which won an award at the 7th National Science Conference in 2024.