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Research Article

Design, Fabrication, and Performance Evaluation of BRRI Compact Rice Mill

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ABSTRACT

In the past, smaller rice mills such as the Engelberg huller mill were frequently utilized. But caused by technological developments, larger rice mills with rubber roll huskers have shown promise, however at a high initial cost. The BRRI compact rice mill is designed to improve the rice milling system's efficiency. This single-pass hulling machine processes paddy into polished white rice by sequentially lifting, cleaning, de-husking, polishing, and grading the rice into head and broken categories using rubber rollers, blowers, and a size grader. Additionally, husk and bran are separated during the milling process. The rubber-roller spring system, main body shell, and machine base structure were validated using finite element analysis (FEA). From the simulation study, the machine's maximum displacement experienced 0.13 mm, and its base structure safety factor was 6.56. In addition, the FEA study was carried out to analyze the fatigue life, fatigue damage, safety factor, and fatigue sensitivity for the machine rigidity. The analysis showed a deformation of 2.43 mm and a safety factor of 1.74 for the main body shell, while the spring system demonstrated a safety factor of 2.93. These findings confirm the machine's strength, durability, and safe performance under applied loads. The machine is developed using locally available materials from the Bangladeshi marketplace. Its design is created using computer-aided modeling (3D and 2D) with all necessary technical specifications for future manufacturing. The selected materials ensure optimal performance for the compact rice mill. In power transmission, three B105 belts, each with a pitch length of 2667 mm, were used to transfer mechanical power from the main motor pulley to the polisher pulley; moreover, the adjustable motor base prevented slippage during the operation period. The rice milling machine was working at 0.02 kWh per kg of rice, with an 850 kg hr^{-1} capacity for hulling. The milling recovery was only 65%, but husking was better at smaller roller clearances. Thus, in the waters of enhanced milling recovery and lesser power consumption exists the potential for the BRRI compact rice mill to be a substitution for the expensive-type rice mills.

Keywords: Compact rice mill, fatigue analysis, finite element analysis, milling recovery rate, rubber roll husker, structural reliability

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1. Introduction

Rice constitutes the staple cereal food throughout Asia: The most widely consumed cereal in Asia. Rice is third in the world's production list, ranked behind sugarcane and maize [1]. Rice is one of the most-consumed items in Bangladesh. In the fiscal year 2023–2024 (FY2024), the average rice consumption per person in Bangladesh was around 343 kilograms each year [2]. Milling is the process that transforms rice grains into a form that's ready for us to eat, and it requires a delicate touch to reduce kernel breakage and ensure maximum recovery. To create the visually appealing white rice we often see, brown rice goes through some extra milling. After harvesting and drying, paddy rice is put through primary milling, which includes de-husking and polishing to remove the bran layers, making it ready for our tables [3]. Rice milling system's purpose is to remove the husk and the bran layers from paddy rice to gain fully rice kernels that are milled well, free of foreign particles, and carry a

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smaller number of broken rices [4]. The goal of a rice milling system is to remove the husk and bran layers from paddy rice, resulting in whole white rice kernels that are properly milled, free of impurities, and have minimal broken pieces. Rice milling systems can vary quite a bit, from the very simple to the more complex setups. In a one-step milling process, both the husk and bran are removed in one go, which means you get white rice straight from the paddy. In contrast, a two-step process handles these tasks separately, resulting in brown rice as a middle product [5].

The single-pass rice mill is the machining process of the "Engelberg" huller. This type of rice milling is popular in poorer and developing countries for household hulling processes. This milling process includes a steel friction type mill and creates very high pressure to remove the hull and polish the grain. This method often leads to a lot of broken kernels, with a low recovery rate of white rice at around 50-55%, and head rice yields that fall below 30% of the total milled rice [6]. Numerous factors determine milling quality; however, they may generally be categorized into two primary groups: engineering factors and varietal characteristics [7]. Milling recovery varies by rice variety, with the highest rates where milled rice still contains broken grains ranging from 69% to 70%. Some compact-type rice mills achieve only 55% or less milling recovery with 30% head rice, whereas commercial mills can attain 65% milling recovery with 55% head rice [8]. In our country, farmers often depend on traditional Engelberg hullers, which require them to transport paddy from one house to another for milling. Unfortunately, this method leads to a lot of breakage, making it hard to separate the husk from the bran properly. When it comes to processing rice, small-scale farmers in rural areas face some pretty tough challenges. Not only are modern rice mills hard to find and expensive, but they also tend to produce lower-quality rice, leading to significant losses after harvest and a drop in market value [9].

Large-scale auto rice mills, though efficient, are too costly and not suitable for small farmers. To bridge this gap, this research focuses on developing a compact, affordable, and efficient rice mill designed specifically for small-scale farmers and local service providers. By providing a viable alternative, the mill enhances agricultural mechanization and strengthens small-scale rice processing systems. Moreover, this innovation supports global sustainability goals by cutting down on postharvest losses and improving food security in rural communities. The design of the compact rice mill is focused on creating an affordable husking mill that caters to the needs of local farmers and service providers, ensuring it is both accessible and cost-effective.

Therefore, this study was initiated to design, fabricate, and evaluate the performance of a low-cost husking mill that is suitable for farmers and local service providers.

2. Materials and Methods

The Bangladesh Rice Research Institute's Farm Machinery and Postharvest Technology Division developed an innovative compact rice mill with two rubber rollers to effectively separate the bran and husk from the kernel and increase the total quantity of polished head rice produced.

2.1 Design considerations

The following fundamental requirements guided the design of the compact rice mill:

- The machine should be easy to operate, safe for users and affordable for small farmers.
- Separates white rice, bran and husk well for good quality output.
- Energy consumption of the machine should be lower.
- The machine should be strong and rugged for continuous operation and rough handling.
- Durable materials that are not brittle, easy machining ability, good weldability and heat resistant. Sensitive parts should be easy to cast for easy manufacturing.
- Required standard materials are available in the local market for easy manufacturing and repair.
- The machine should be designed for easy maintenance and ensuring cost-effective.

2.2 Technical specifications, and mechanical properties of materials of the rice mill

The technical specifications of the developed rice mill are given below in Table-1:

Table 1: Technical specification of BRRI compact rice mill

Criteria	Description
Name	BRRI Compact Rice Mill
Model	BRRI RM2023
Dimensions	L= 2300 mm, W = 2260 mm, H = 4965 mm
Base structure	l=1850mm, w= 620 mm, h=530mm. Made of (75x40x5) mm mild steel C-channel
Motor	25 hp, 1450rpm, three-phase 440V
Motor pulley	⌀=180mm, t=72.5mm
Pre-cleaner	w=620mm, l=1100mm, h=880 mm
Pre-cleaner motor	1 hp 1450rpm, single phase 220V
Elevator motor	3 hp, 1450rpm, single phase 220V
Elevator	h=4967mm, w=290mm, t=1.5mm
Hopper	⌀=645mm, h=400mm, t=1.5mm
Hopper pulley	⌀=195mm, t=20mm
Cyclone	l=350mm, w=400mm, h=871mm, t=1.5mm sheet needed in each size
Size grader	l=1010mm, w=455mm, h=271mm
Size grader	Bearing housing UCP-204. Quantity 10
Rubber roller setting body	Rubber roller 4 inch. Quantity 02
Rubber roller setting body	⌀=158mm, t=41.9mm
Tension pulley	Model no: B-70, B-104, B-93, A-36, BB-124
V-Groove Type-A and Type-B belts	⌀=180mm, t=72.5mm

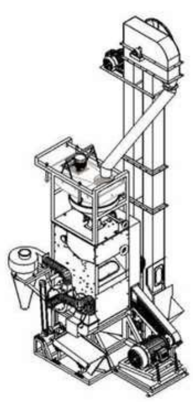
Note: For whole machine, L= length, W= width, H= height; For base structure, l=length, w=width, h=height; t=thickness, ⌀=diameter, r=radius

2.3 Description of the BRRI compact rice mill

This compact rice mill consists of 9 main units: an elevator, an oscillating sieve cleaner or pre-cleaner, a hopper, a body shell, a polyurethane rubber-roller husker and aspirator, a husk separating blower and cyclone separator, a polisher, oscillating grading sieves, and base.

2.4 Assembly design of compact rice mill

The computerized design and real-time views of the machine are shown in Figure 1.



(a) Computer-aided design (CAD) Model of the machine

(b) Real-time image of the machine

Figure 1. BRRI compact rice mill

Working principles of main components:

Elevator: The paddy is persistently conveyed to the pre-cleaner using this unit. The elevator consists of 2 flat belt pulleys (one on the top and another on the bottom side), a flat belt, and buckets. Buckets are adjusted with the flat belts maintaining the required distances. The power transmitting system is managed by a 3 hp single-phase motor (figure 2).

Pre-cleaner: Pre-cleaner is a sub-assembly of its associated components which helps to remove the foreign particles and impurities from the paddy by creating linear oscillating motions. According to calculations, the linear oscillating motion is produced by a 1 hp motor. The machine can receive a fully cleaned paddy from the pre-cleaner (figure 3).

Hopper: The clean paddy gets pushed to the rubber roller using this device. A delivery controller has been installed in the hopper to regulate the amount of paddy that can travel to the rubber roller (figure 4).

Main Body Shell: The body is made of metal (mild steel) sheets. the body shell that contains the spinning parts both inside and outside of the sub-assemblies. Mechanical drawings and simulations (load analysis) were conducted to determine the thickness of sheet metal and finding the safety factors (figure 5).

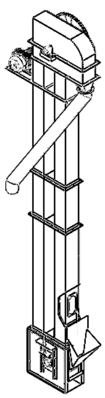


Figure 2. Elevator

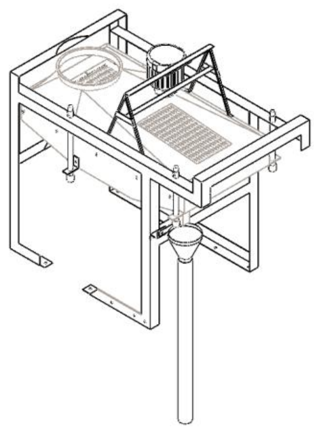


Figure 3. Pre-cleaner

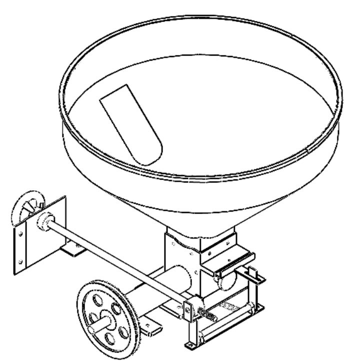


Figure 4. Hopper

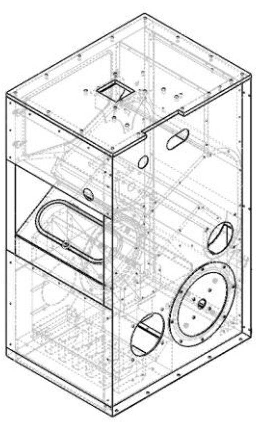


Figure 5. Main body shell

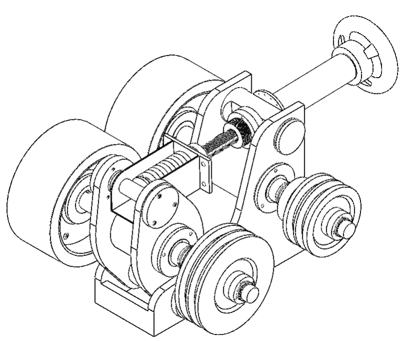


Figure 6. Husker and aspirator

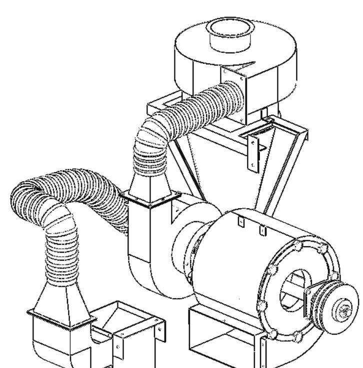


Figure 7. Husk separating blower and cyclone separator

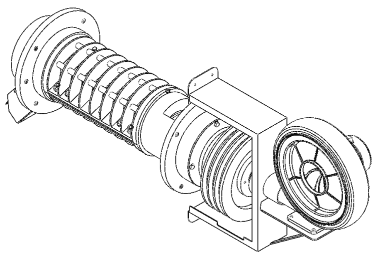


Figure 8. Polisher

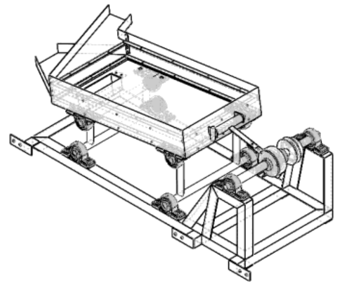


Figure 9. Size grader

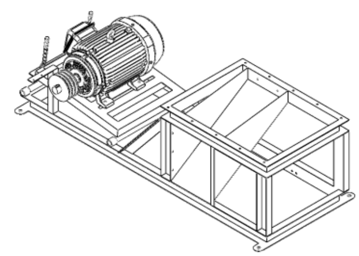


Figure 10. Base

Husker and aspirator: The rubber roller assembly uses two 102 mm rubber rollers. One is fixed to its position with its structure, whereas the other is adjustable. The two rubber rollers rotate at different speeds and are related to pulleys with different diameters. One rotates clockwise and another rotates anti-clockwise. In order to maintain the minimum amount of space between the two rubber rollers, a gap controller spring is installed. The gap varies on the size of the paddy. The frictional forces then prompt the paddy to become unhusked. The required forces to move the gap controller spring are shown in the analysis section and the required speed for both rubber- roller is shown in the power transmission section. This unit is crucial for the rice milling machine. The drawing of husker and aspirator is shown in figure 6.

Husk separating blower and cyclone separator: The blower is used to separate the husk from the brown rice. Due to having weight only, the brown rice can pass to the polisher. The husks are carried outside by a husk conveyor. Before the cyclone separator, there is another suction blower attached. While in functioning, the suction blower extracts the remaining brans which are in very small quantities and sends them outside the machine by the cyclone separator (figure 7).

Polisher: The brown rice gets polished, and rice brans are eliminated with the assistance of the polisher. A nozzle-shaped compact and custom-designed pipe is installed to generate high-density air pressure from the blower, while in rotary state. The pipe has 2 series of holes on it. Rice to the polisher is transferred by a worm gear. The polisher has hex-shaped shell nets made of stainless steel (SS) inside of it. This is a bran removal process also. The bran layer was removed from the rice kernel by the frictional force occurred by individual rice grains and between the grains and the metal screen surface. There is a series of open channels right the bottom side of the polisher, so the air can be exhausted outside from the machine. The drawing of polisher is shown in figure 8.

Size grader: The grader separates the broken kernels from the head rice and helps to store them separately. Filtering for the head rice was performed by using the 2.5 mm opening sieves, oscillating directly to the outlet, and stored. The oscillating frequency for this unit was kept 160-190 double strokes per minute to obtain the optimum performance (figure 9).

Base: The base is heavy and strong structure, providing stable support to all the machine components. A 25 hp 3-phase 440V motor mounted on the machine base structure which provides the mechanical power to the other shafts and operates the operations (figure 10).

The belt and pulley systems have been used for transmitting power to the machine. V-groove pulleys (Type-A and Type-B) and flat belt pulleys were used, considering there were no slips. The basic equation for the power transmission through the belt and pulley is:

$$N_1 D_1 = N_2 D_2 ----------- (1)$$

Here,

D_1 = Diameter of driver pulley, N_1= Speed of driver pulley

D_2 = Diameter of driven pulley, N_2 = Speed of driven pulley

2.5 Power requirement

It is necessary to compute the torque to determine the motor power for the rice mill. The following equation is used to calculate the torque:

$$M_C = 4\pi^2\mu_c M_g \omega^2 R^3 t \text{ ------------ } (2)$$

$$P = \frac{2\pi NT}{60000} \text{ ------------ } (3)$$

$$T = Fr\sin\theta \text{ ------------ } (4)$$

The clearance between the two rubber rollers was kept at 1, 0.5, and 0.2 mm. At 0.5 mm the overall result was good. Equations 2 and 4 for rubber-roller 1, and rubber-roller 2. Equations 3 and 4 for polisher, husk conveyor, and husk conveyor blower required power calculations.

$$v = \frac{\pi DN}{60} \text{ ------------ } (5)$$

$$F = \frac{P}{v} \text{ ------------ } (6)$$

$$L = 2C + 1.57 \times (D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C} \text{ ------------ } (7)$$

Here,
M_C = Torque in Nm, μ_C = Dynamic coefficient of friction of rice grains, M_g = Bulk mass of grain (kg), ω = Angular velocity of shaft (rad s^{-1}), R = Shaft radius (m), P = Power (kW), T = Torque (Nm), D_2 = diameter of larger pulley, D_1 = diameter of smaller pulley, C = center to center distances, L = Length of belt, v = Belt velocity, F = Belt tension.

2.6 Finite element modelling

This process involves taking a geometric shape and breaking it down into smaller pieces, known as elements, which connect at specific points called nodes. This technique is a numerical approach used to solve problems involving structures or complex shapes in a continuous region. This method provides an approximate solution. The process of solving problems using the finite element method is systematic and follows a clear, step-by-step approach. All the structural analysis were performed with ANSYS Workbench simulation software using the static structural module and fatigue tool. The computer-aided design (CAD) model was imported in Parasolid format, and high-quality tetrahedral mesh elements with h-adaptive refinement were used. The proper materials were defined for the models. The fixtures, load applying places, and all necessary properties were applied on the components.

2.7 Goodman Mean Stress Theory

To account for the effect of non-zero mean stresses on high-cycle fatigue life, we applied the Goodman mean-stress theory. In Goodman's theory, the alternating stress σ_a and the mean stress σ_m are related to the material's endurance limit σ_e and ultimate tensile strength σ_{UTS} by the linear Goodman line:

$$\frac{\sigma_a}{\sigma_e} + \frac{\sigma_m}{\sigma_{UTS}} = 1$$

Therefore, for a given mean stress σ_m, the allowable altering stress is

$$\sigma_{a,allow} = \left(1 - \frac{\sigma_m}{\sigma_{UTS}}\right)$$

In our FEA analysis, the peak stresses σ_{max} and σ_{min} at each critical node were used to compute

$$\sigma_m = \frac{1}{2}(\sigma_{max} + \sigma_{min}), \quad \sigma_a = \frac{1}{2}(\sigma_{max} - \sigma_{min})$$

These values were then used into the Goodman equation above to get a corrected stress amplitude $\sigma_{a,allow}$. Then the corrected amplitude was compared to the material's baseline S-N curve (endurance limit σ_e) to estimate the number of cycles to failure under fully reversed loading (fig 16) [12].

2.8 Spring compression model for simulation

The spring keeps the gap distance between the rubber rollers and holds them together. The distance of both rubber rollers can be increased and decreased by controlling the hand. This gap will always depend on the size of the paddy (small, medium, and big). In this analysis, the force required to compress the spring has been shown. The spring model was designed in SolidWorks for performing the simulation in ANSYS. The necessary data were used for designing the part: wire diameter: 7mm, mean coin diameter: 51mm, length of spring: 98mm; number of coils: 10. Material for spring is austenitic stainless-steel grade 1.4310 (X10CrNi18 8).

Boundary conditions and loading: The bottom surface of the spring end was fully fixed in all degrees of freedom. The top coil end is subjected to a prescribed axial displacement of up to 20 mm (to achieve the required gap variation). Large deflection (geometric nonlinear) static analysis activated.

Output: Nonlinear static solver with automatic load stepping (max displacement = 1 mm/step) Reaction force at the constrained bottom nodes recorded at each increment to generate the force-displacement curve. The reaction force required to achieve the design compression was read off that curve (figure 18 and figure 19).

2.9 Performance of compact rice mill

High-yielding rice varieties were used for testing the performance of the developed machine. The following equations were used to calculate the performance [10].

$$\text{Husking efficiency (\%)} = \frac{\text{Weight of miller rice}}{\text{Weight of paddy}} \times 100 \quad ------------ \quad (8)$$

$$\text{Head rice (\%)} = \frac{\text{Weight of head rice}}{\text{Weight of paddy}} \times 100 \quad ------------ \quad (9)$$

$$\text{Broken rice (\%)} = \frac{\text{Weight of broken rice}}{\text{Weight of paddy}} \times 100 \quad ------------ \quad (10)$$

3. Results and Discussion

3.1 Working principle of the machine

The paddy is consecutively lifted and conveyed to the pre-cleaner by using the elevator. Cleaned paddy then supplied to the hopper. A control gate that controls the amount of paddy to be supplied to the rubber-rollers. The two rubber rollers rotate at different speeds in different directions and maintain the required gap distance between both rubber rollers. Outputs are brown rice and husk from the rubber rollers. By generating air pressure inside the machine shell, the husk-separating blower is mounted to separate the husk from the rice. The husk conveyor continuously carries out the husk from the machine. After that, brown rice is delivered to a polisher to be polished. An internal nozzle-shaped MS pipe (custom-designed and casted) is installed to generate high-density air pressure and a smooth polishing operation. It draws air from a 0.5 hp centrifugal blower and constantly passes compressed air inside the polisher. Inside the polisher, compressed air circulates in a circular motion due to the pulley that is fixed to the polisher shaft. Thus, a fine bran removal technique is applied to the machine. The separated rice brans are sent outside from the machine shell via a drain line. The outputs from the polisher are white and polished rice. Polisher pulley rotation is provided by the 25 hp motor. Other pulleys on the machine are subsequently rotated by the polisher pulley. Delivering the rice to the size grader is now feasible. This suction blower is directly mounted on the husk-separating blower shaft which continuously sucks the remaining rice brans from the polished rice and sends them outside from the machine by using the cyclone. The brown rice eventually reaches the size grader. The grader is a sub-assembly that oscillates linearly and is positioned alongside the main body. The husk conveyor shaft rotates the size grader shaft. To provide linear oscillating motions, a cam was designed and constructed. The linear oscillating size grader processes the brown rice. The broken and head rice is kept apart from the size grader. The broken and head rice is kept apart from the size grader. The workflow diagram of compact rice mill is shown in figure 11.

3.2 Power transmission analysis

A three-phase 25 hp motor operating at 1450 rpm drives the system using V-groove pulleys, transferring power to the polisher running at 1023 rpm. The polisher distributes power to essential components: Rubber rollers 1 and 2, operating at 1248 rpm, manage the initial shelling process, with roller 1 channeling material to a hopper spinning at 518 rpm. Additionally, the polisher drives the husk separating blower at 890 rpm and the husk conveyor at 532 rpm, which directs the material to the size grader functioning at 548 rpm. This design ensures effective power allocation for polishing, husk separation, and size grading. The flow diagram for the main shell power transmission is shown in figure 12.

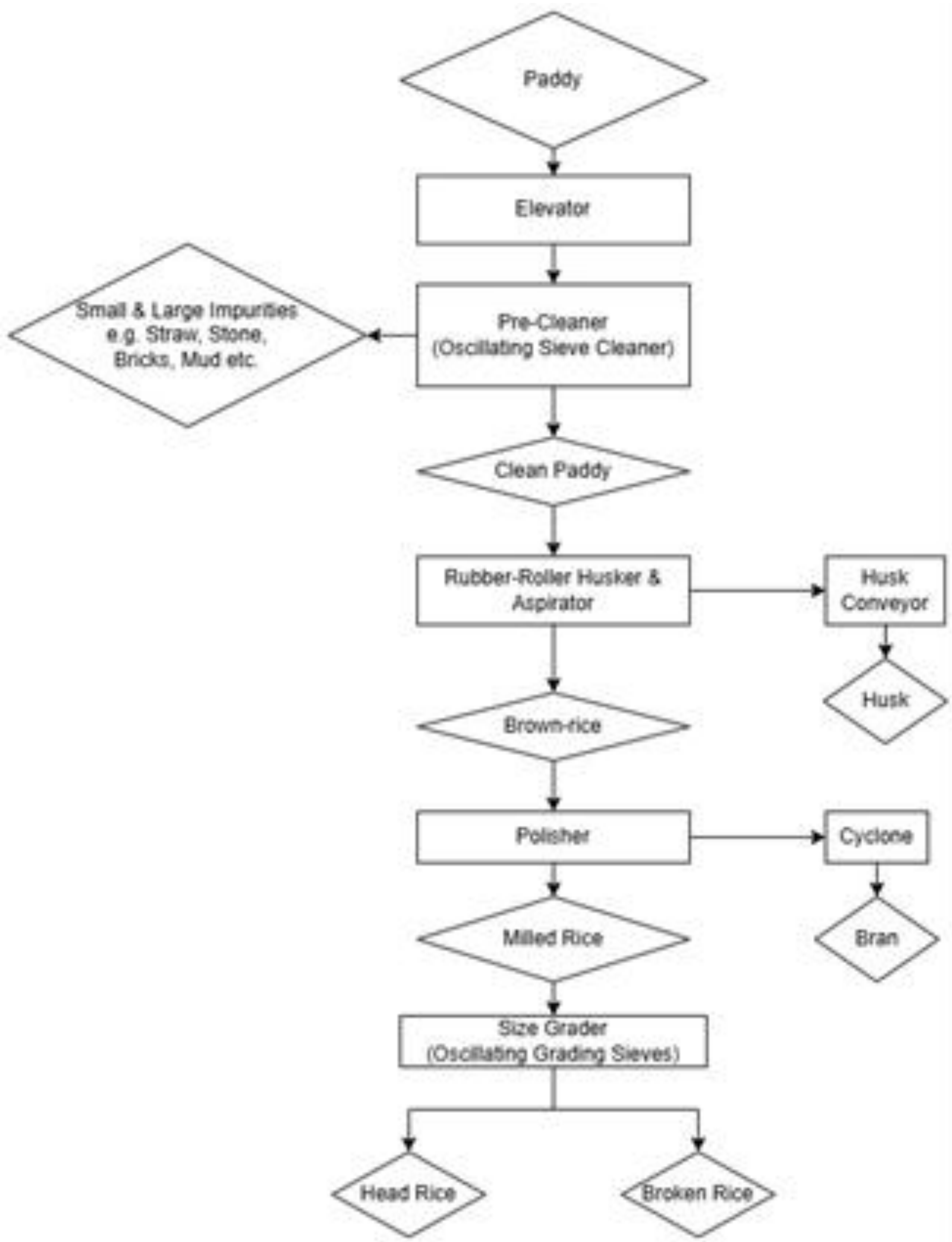
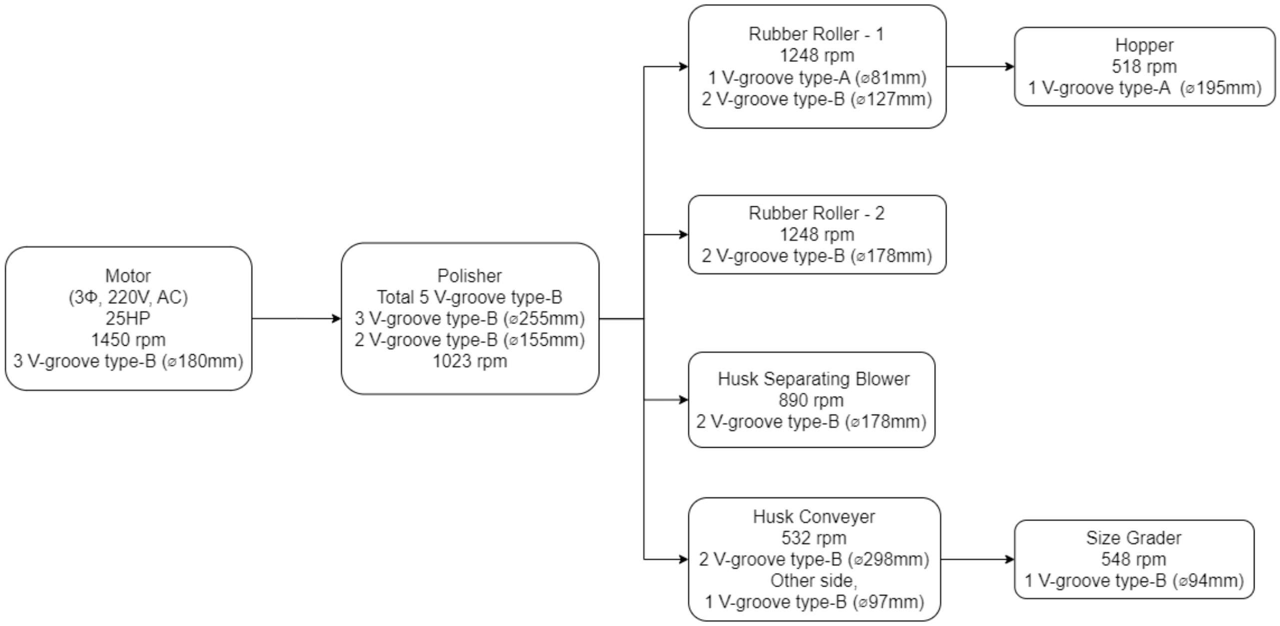
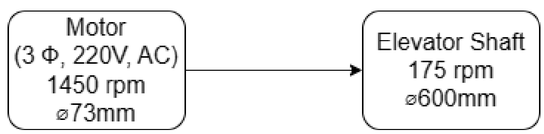


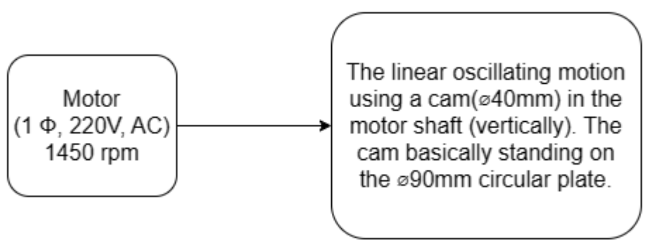
Figure 11. Work flow diagram of BRRI compact rice mill



a) Main body shell power transmission



b) Elevator power transmission



c) Pre-cleaner power transmission

Figure 12. Flow diagram for power transmission systems

Table 2. Power requirement of the components

Components	Required power (hp)
Rubber-roller 1	4.05
Rubber-roller 2	1.47
Polisher	3.10
Husk conveyor	0.62
Conveyor Blower	3.24
Elevator	1.94
Pre-cleaner	0.60

Source: [11]

The compact rice mill has a combination of 3 separate power sources. (1) machine shell, (2) elevator, (3) pre-cleaner. The rice mill machine has several rotating shafts, conveyors, machine tools, rotating blowers, etc. Matching with all the information regarding the rice mill machine and the design; also, if the machine runs over 16 hr/day.

Total transmitted hp from the machine shell = (4.05 + 1.47 + 3.1 + 0.62 + 3.24) = 12.48 hp

Service factor, Nsf = 1.4+0.2=1.6 (Faires, 1965)

$$Design\ hp = Transmitted\ hp \times Service\ factor ----------- (11)$$

Design hp for the machine shell = 19.97 hp ≈ 20 hp

(A 25 hp and 1450 rpm motor were installed to reduce friction, enhancing overall performance and efficiency.)

Design hp for the elevator = 3 hp

Design hp for the pre-cleaner = 0.96 hp ≈ 1 hp

Figure 13 shows the chart for belt type and belt number calculation.

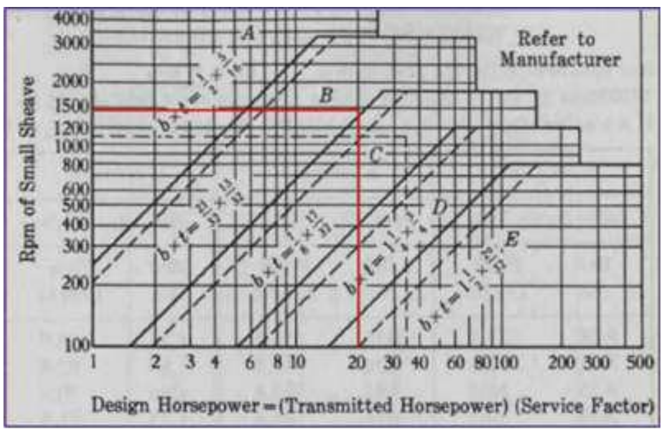


Figure 13. Belt type and belt number calculation (Faires, 1965) [13]

Type-B belt has been selected.

$$\text{No. of belts} = \frac{\text{Design hp}}{\text{Adjusted rated hp}} ------------ (12)$$

$$\text{Adjusted rated hp} = k_\theta \times k_L \times (\text{Rated hp}) ----------- (13)$$

$$Rated\ hp = [\, a \times (\frac{10^3}{V_m})^{0.09} - \frac{c}{K_d D_1} - e\frac{v^2 m}{10^6}] \times \frac{V_m}{10^3} ------------ (14)$$

$$\text{Belt speed}, v_m = \pi D_1 N ----------- (15)$$

Here,

K_θ = arc of contact factor;

K_L = length of belt factor;

K_d = small diameter factor;

D_1 = smaller pulley diameter = 180 mm = 7.09 in

D_2 = larger pulley diameter = 180 mm = 7.09 in

C = center to center distance = 1014 mm = 39.92 in

Here,

Rated hp constraints,

a= 4.737, c = 13.962, e = 0.0234, K_d = 1.10, Kθ = 1, K_L = 1.04, V_m = 2691 fpm

Rated hp = 6.32 hp

Adjusted rated hp = 1×1.04×6.32 = 6.57; No. of belts = 3

The pulley needs 3 V-grooves on the motor pulley for the calculated 3 belts as a driver pulley. The power transmission will be initiated from here.

Pitch length =105 inches = 2667 mm

Belts number =B105 The motor base was designed to be adjustable. So, no slip is seen (Faires, 1965).

3.3 Power consumption

Power consumption (kW h) = (Machine base motor power + Elevator motor power + pre-cleaner motor power) × 0.746 × Time (hours)= (25 + 3 + 1) × 0.746 × 1 = 21.634 kW h

$$\text{Energy per kg} = \frac{\text{Power consumption per hour}}{\text{Milling capacity}} = \frac{21.634}{850} = 0.02545\ kW\ h\ kg^{-1}$$

1 kW h = 3.6 × 10^6 J

So, 0.02545 kW h kg^{-1} × 3.6 × 10^6 J $(kWh)^{-1}$ = 91,620 J kg^{-1}

3.4 Load analysis

The load analysis is an essential analytical study to test the structural stability and rigidity before manufacturing process to minimize the losses of materials, and finance. The weight of all sub-assembly (Table 3) was measured properly to perform the computer simulation tests.

Table 3. Weight of the sub-assembly component

Details of parts/sub-assembly	Weight (N)
Base structure	1714.4
Main body shell	1944.54
Pre-cleaner	1010.1
Hopper	223.1
Polyurethane rubber-roller husker and aspirator	769.3
Husk separating blower and cyclone separator	775.52
Polisher	1189.2
Husk conveyer	252.6
Tension	85.2

3.5 Base structure

Base structures are crucial for a machine cause this component holds the whole machine together. Excellent displacement, factor of safety, fatigue life, fatigue damage, fatigue safety factor, and fatigue sensitivity have been observed while performing the analysis on ASTM A36 industrial-grade material, 75x40x5 mm sized frame. The frame is locally available and passed all the necessary tests for the use as the machine base structure. High-quality mesh was used in the simulation (2.6). The total nodes are 2,139,552 and the total elements are 1,293,461. The applied load is 6,249.56 N on the top face. 395.75 N load is applied on the four faces individually. The fixture is the bottom face. The mesh and simulation setup are expressed in figure 14.

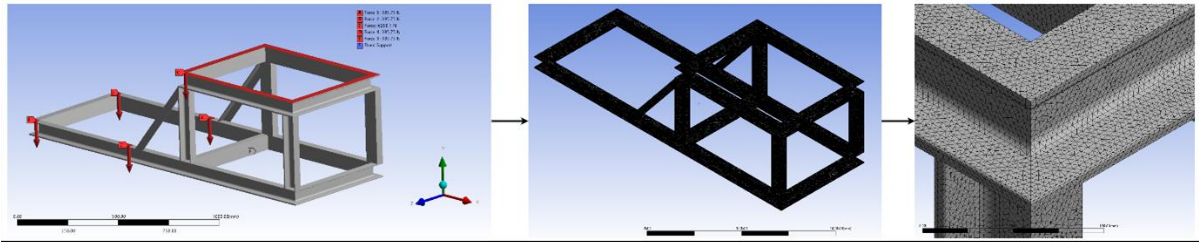


Figure 14. Mesh and simulation setup

3.6 Total displacement and safety factor

Maximum deformation of 0.13 mm has been observed if the machine is loaded condition. The finite-element model provides a safety factor of 6.5627 for the loaded base frame by using the simulation software ANSYS, which exceeds the recommended range of 4–6 for static steel machine components (Faires, 1965, pp. 142–143). So, the base structure can be considered as safe under the applied loads. Maximum deformation and minimum safety factor are shown in figure 15.

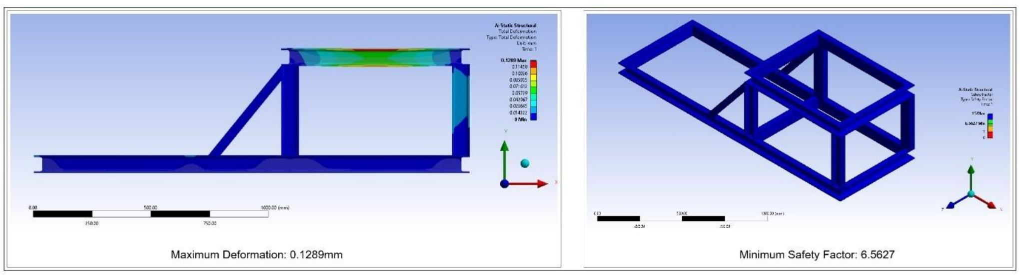


Figure 15. Safety factor analysis

3.7 Fatigue analysis

In the fully reversed loading type fatigue study, the Goodman mean stress theory was used to calculate the stress life. From the SN-curve and analysis data, the base component is experiencing high cycle fatigue (>105). So, the model achieved an endurance life. Fatigue sensitivity was checked by reducing 50% and increasing the 400% load. The increased load decreases the fatigue life. Fatigue life, sensitivity, factor of safety (FOS), biaxiality indication analysis are shown in figure 16.

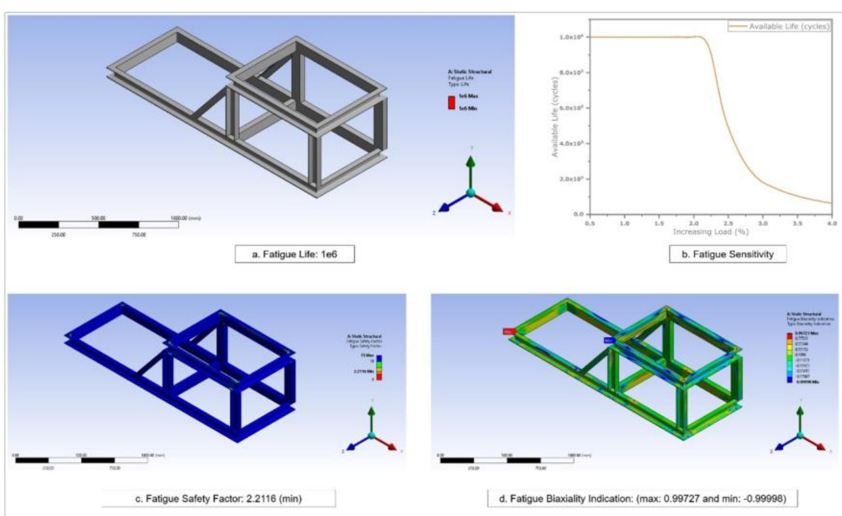
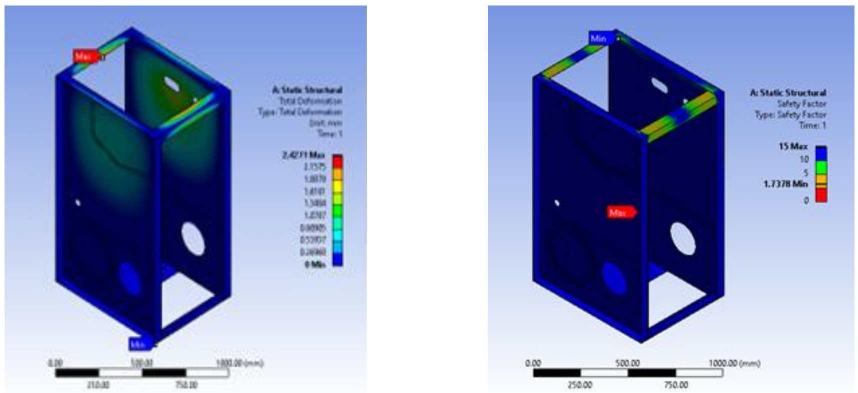


Figure 16. Fatigue life, sensitivity, FOS, biaxiality indication analysis

3.8 Main body shell

This unit holds all the necessary and sensitive components. The total weight act from the top is 2300 N, and the fixture is the bottom face. The total number of nodes 1,576,301 and elements 804,053 have been found from high- quality tetrahedron type mesh. The thickness of the mild steel sheet is 2 mm for the machine body shell. Another 3 mm thick metal plate has been welded at the polisher setting place. The overall thickness of the sheet is 5 mm at the bottom side of the main body shell. The body length, l= 805 mm; width, w= 617 mm; height, h= 1313 mm. Total deformation: The total deformation of 2.43 mm has been observed from the simulation analysis when the body is fully loaded with its components and weight of paddy (figure 17). This deformation is very minimum for this machine, increases machine stability, and quality. Factor of safety analysis: Good safety factor = 1.74 has been found. The machine will be safe.

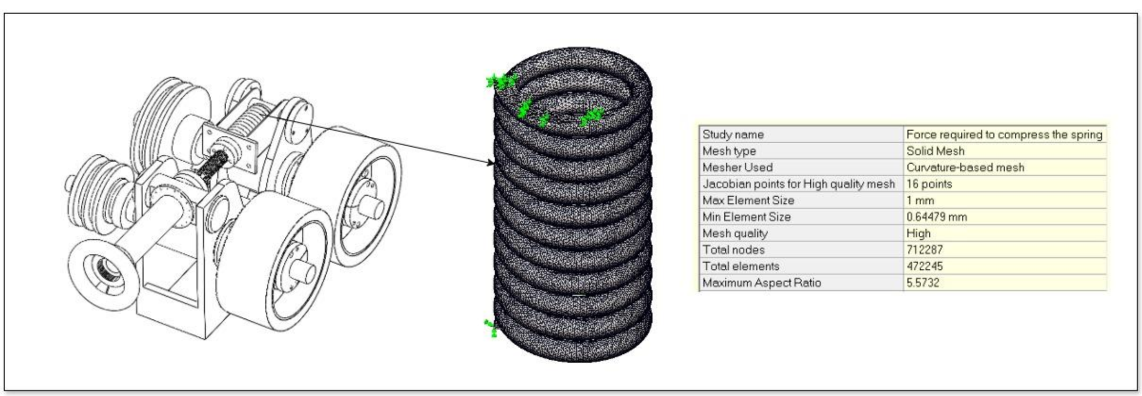


a b

Figure 17. Maximum and minimum FOS analysis for the body shell

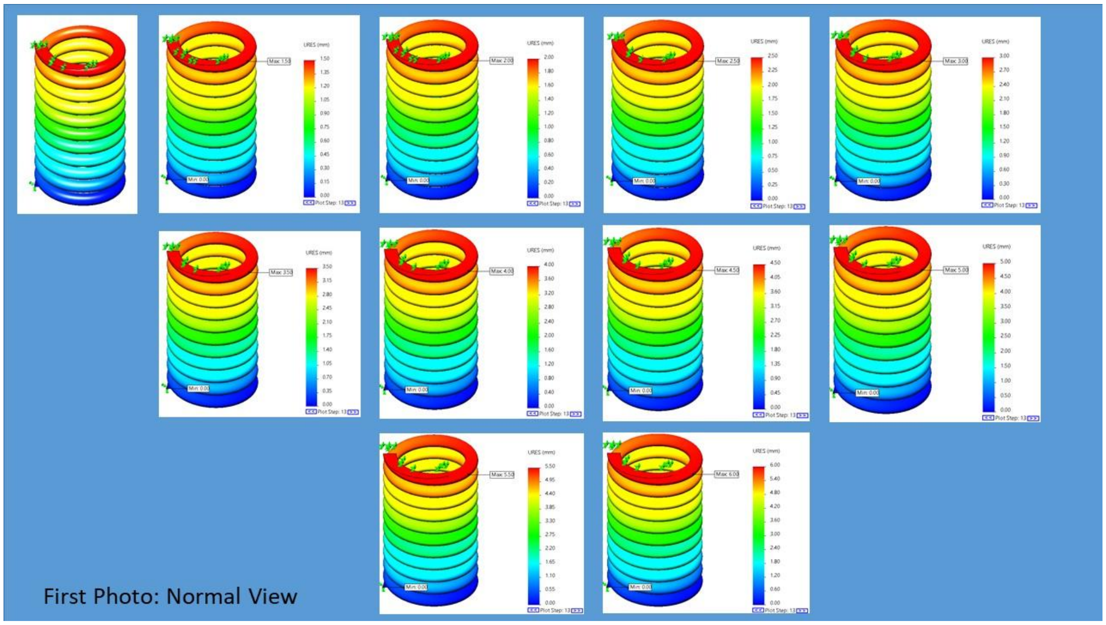
3.9 Force required to compress the spring of rubber-roller husker

High-quality curvature-based, h-adaptive mesh has been taken. Mesh data of force required to compress the ring are shown in figure 18. The rubber rollers mates together parallelly maintaining a gap between their rubber roll surfaces. The distance is expressing the gap between two rubber rollers. The gap between two rubber rollers will vary depending on the size of paddy. Paddy with high thickness will require more gaps between the rubber rollers. There is a spring installed into the rubber roller assembly. That spring absorbs the force applied to it and continuously keeps the both rubber rollers at required position. Higher thickness paddy needs more gaps between rubber rollers, so higher force is required to move the roller. The safety factor = 2.93 found from the analysis, which is safe. The greater the spring's compression, the greater the force required. Distance between rubber rollers depends on the paddy sizes. The following simulation data in figure 19 shows the amount of force required to compress the spring at different distances between the rubber rollers.



Study name	Force required to compress the spring
Mesh type	Solid Mesh
Mesher Used	Curvature-based mesh
Jacobian points for High quality mesh	16 points
Max Element Size	1 mm
Min Element Size	0.64479 mm
Mesh quality	High
Total nodes	712287
Total elements	472245
Maximum Aspect Ratio	5.5732

(a)



(b)

Figure 18. Mesh data of force required to compress the ring

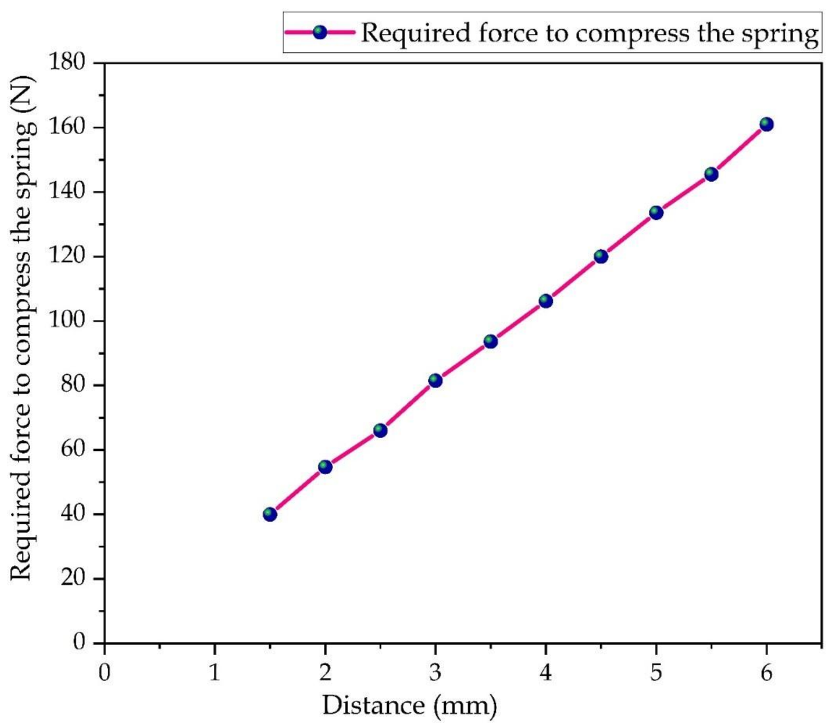


Figure 19: Simulation data of required force to compress the spring

3.10 Performance of compact rice mill

Field performance was measured at 11-14% moisture content. Husking efficiency and head rice recovery of BRRI dhan71, BRRI dhan80 and BRRI dhan81 were measured. Husking efficiency test (for a single pass) with keeping the clearance or distance between two rubber rollers setting at 0.2 mm, 0.5 mm, and 1 mm. Both unparboiled and parboiled rice were used. Husking efficiency is shown in Table 4.

Table 4. Performance test of the BRRI compact rice mill

Variety	Gap between two rubber rollers								
	0.2 mm			0.5 mm			1 mm		
	Head rice, %	Broken rice, %	Unhusked paddy, %	Head rice, %	Broken rice, %	Unhusked paddy, %	Head rice, %	Broken rice, %	Unhusked paddy, %
BRRI dhan71	79	6	15	42	3	55	25	3	72
BRRI dhan80	78	5	17	35	7	58	23	6	71
BRRI dhan81	68	6	26	35	6	59	18	3	79

The developed machine efficiently mills rice varieties with 13-14% moisture, achieving a 65% average milling recovery rate. The percentage of broken rice might be caused by the quality of paddy or operator skills during clearance adjustment between rubber rollers. The obtained result was satisfactory. The milling capacity of the BRRI compact rice mill is 850-900 kg hr^{-1}. The milling outturn of three types of rice verities for different periods is shown in Table 5.

Table 5. Milling outturn of different varieties of rice

Period	Rice variety	Paddy, kg	kg of brown rice, (%)	kg of broken grains, (%)
Week-1	BRRI dhan71	30	21 (70)	(N/A)
	BRRI dhan80	37	20.4 (55)	7 (18.9)
	BRRI dhan81	120	76 (63.3)	9 (7.5)
Week-2	BRRI dhan71	50	28.5 (57)	5 (10)
	BRRI dhan80	87	51 (58.6)	6.5 (7.4)
	BRRI dhan81	315	224.8 (66.1)	24 (7)
Week-3	BRRI dhan71	180	114.7 (63.7)	13 (7.2)
	BRRI dhan80	85	58.5 (68.8)	5.2 (6.1)
	BRRI dhan81	67	46.5 (69.4)	4.4 (6.5)

3.11 Performance comparison of BRRI Compact Rice Mill with Traditional Engelberg Huller

The study found that traditional Engelberg huller produced 62.5% whole rice and 7.5% broken rice [14]; whereas in BRRI compact rice mill, taking BRRI dhan71 and keeping gap between two rubber roller 0.2 mm, the whole rice was found 79% and broken rice was found 7.5%. Below a comparison chart is shown (figure 20).

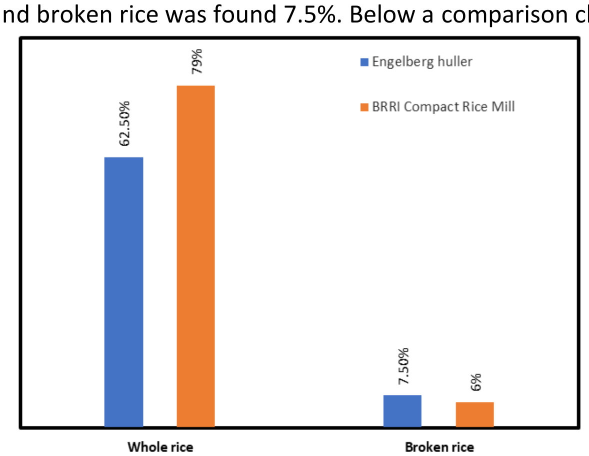


Figure 20. Performance comparison of BRRI Compact Rice Mill with Traditional Engelberg Huller

4. Conclusion

The BRRI Compact Rice Mill offers an hourly hulling capacity of 850–900 kg of paddy, offers a good solution for rice milling, ensuring high-quality output while keeping lower production costs. It functions as a complete system, cleaning, hulling, husk separation, polishing, grading, and packing, and enables users to generate income from main product head rice, along with three by-products: broken rice, husk, and bran. Powered by a 25 hp, three-phase (3Φ, 440V, AC) motor and 3 hp and 1 hp single-phase motors for paddy lifting and cleaning. The system uniquely uses Type-A and Type-B pulleys (V-groove) to transfer mechanical power efficiently. With its low-maintenance design and straightforward, continuous processes, this compact rice mill is perfect for small-scale rice milling in rural areas, boosting productivity and supporting local farmers and service providers.

Authors Contribution: AKM Saiful Islam led the research planning, design and development, fabrication, and physical testing of the rice mill. Shafier Jahan Khan contributed to writing the paper, load calculations, computerized simulation analysis, computer-aided design (3D) and manufacturing drawing book (2D), drafting, and review. Md Golam Kibria Bhuiyan provided the conceptual design, along with review and editing. Fariha Akhter assisted with the review, formatting, and checking of the paper. Arafat Ullah Khan contributed to the review and editing.

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References

1. Food and Agriculture Organization of the United Nations, "Home," FAO. [Online]. Available: https://www.fao.org/home/en. [Accessed: Jan. 22, 2025].

2. IndexBox, *Asia-Pacific - Rice - Market Analysis, Forecast, Size, Trends and Insights*, 2024. [Online]. Available: https://www.indexbox.io

3. A. K. M. S. Islam, *Structural Designs for the BRRI Compact Rice Mill*, Gazipur, Bangladesh: Publication and Public Relation Division, Bangladesh Rice Research Institute, 2024.

4. B. K. M. Caringal, Z. S. D. Rosa, K. V. R. Maan, and N. C. Camello, "Design and development of rice milling and grinding machine," *EPH-International Journal of Science and Engineering*, vol. 2, no. 3, pp. 5–12, 2016.

5. R. Barker and R. Herdt, *The Rice Economy of Asia*, Washington, D.C.: Resources for the Future, 1985. [Online]. Available: http://books.irri.org/0915707152_content.pdf. [Accessed: Apr. 28, 2016].

6. N. Tangpinijkul, "Rice Milling System," Pathum Thani, Thailand, 2010. [Online]. Available: http://goo.gl/zDPE1o.

7. International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines, Dec. 2014. [Online]. Available: http://goo.gl/5G4ftd.

8. A. Gbabo and B. Ndagi, "Performance Evaluation of a Ricemill Developed in NCRI," *International Journal of Engineering Research*, vol. 3, no. 8, pp. 482–487, 2014.

9. D. Thangphisityothin, J. Phongsitong, U. Prangudomsub, K. Rattanachitra, W. Ruengdetchaisakun, and C. Yuvaniyama, "Design and development of a compact and highly efficient small-scale rice mill machine: A case study," *Journal of Current Science and Technology*, vol. 10, no. 2, pp. 131–142, 2020.

10. H. F. Khan, "Design and fabrication of a portable low-cost rice milling machine with automatic feeding mechanism," *Jurnal Kejuruteraan*, vol. 35, no. 4, pp. 869–879, 2023.

11. B. Yadav and V. Jindal, "Changes in head rice yield and whiteness during milling of rough rice (Oryza sativa L.)," *Journal of Food Engineering*, vol. 86, no. 1, pp. 113–121, 2008.

12. R. S. Khurmi and J. K. Gupta, *A Textbook of Machine Design*, New Delhi: Eurasia Publishing House, 2005.

13. V. M. Faires, *Design of Machine Elements*, 4th ed., New York: The MacMillan Company, 1965.

14. Das, A. K., C. K. Saha, and M. M. Alam. "Evaluation of a traditional rice husking mill." *Journal of Agricultural Machinery and Bioresources Engineering* 7.1 (2016): 41-46.