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# Fabrication and Performance Evaluation of Rice Polishing Machine

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**Abstract**

This paper focuses on the fabrication and performance evaluation of rice polishing machine. The motor power of the machine is 1.5 hp and rotational speed is 1440 rpm. This motor uses v-belt transmission system to drive the main shaft and blower shaft. The number of two belts are used in this transmission system. The diameter of the main shaft is 22mm. ASME code equation is used to design the main shaft for rice polishing machine. Square key is used and shear and torsional strength of the key are 58.5404MPa. Single-row deep groove ball bearing is selected for left and right bearing of main shaft. The average milling efficiency, broken efficiency and milling capacity and moisture contents for existing and modified blade were compared. The average milling capacity is 35.23 kg/h, 38.41 kg/h and 41.76 kg/h with modified blade and 30.35 kg/h, 32.20 kg/h and 34.03 kg/h with existing blade at the moisture condition of 13%, 12% and 11%, respectively. As comparison results, the modified blade of the machine has more efficient and convenience than the existing blade of the machine.

## A. Introduction

Rice is one of the most important cereal crops in the world. Myanmar has 17.8 million acres of paddy fields and produced around 27 million tons of paddies annually, announced Central Statistics Organization by quoting the Department of Agricultural Land Management and Statistics (DALMS). Rice is normally grown as an annual plant, although in tropical areas it can survive as a perennial crop. The oldest means of removing husk from the rice is through the usage of Pestle and mortar. Hand pounding of paddy in a mortar with a pestle is still practiced in some remote areas. The pounding also results in a high percentage of broken kernels. The final cleaning is done by winnowing and gravity separation by hand. This method is not a reliable means of processing rice and also it does not encourage commercial rice processing with this problem there brings about designing of rice milling machine [1]. A paddy is a whole seed of rice which contains one rice kernel and has many layers; the outermost layer is the husk. The husk consists of two interlocked half shells and each protects one half of the paddy [2]. The nutritive value of rice includes protein, fat, carbohydrates, ash, mineral and vitamins which play an important role in health benefits and disease prevention such as high blood pressure, cancer, Alzheimer's disease and dysentery in mankind [2].

**Figure 1.** Rice polishing machine

The basic ways of hulling include traditional method, animal powered miller, use of pedal powered rice miller, mechanized method and use of rubber rolls to separate the chaff from the seed grains. Traditional method of hulling involves the use of mortar and pestle. It is tedious, has low efficiency and separation of chaff from grain is done by winnowing (Poonam, 2014). The rice hulled through the use of mortar and pestle are known to have stones due to the insanitary environment where the process is done and this predisposes consumer to health risk such as appendicitis as well as low milling efficiency due to breakage of rice during the hulling process[2].

Rice polishing machines are used for family and small unit enterprise. Rice polishing machine is operated by the single person with compact design. The main components of rice polishing machines are main shaft, roller, screen and sieve, power transmission system, bearing and blower. The aim of this paper is to carry out fabrication and performance evaluation of rice polishing machine and compare the performance of the existing blade and modified blade of the machine. Figure 1 shows the rice polishing machine.

## B. Materials and Methods

There are three steps in the fabrication and performance evaluation of rice polishing machine. The first step is to design and calculate the main shaft of the rice polishing machine. The second step is to fabricate the rice polishing machine. And the third step is the performance evaluation of rice polishing machine.

**Table 1.** Material Properties of AISI 1020 [5]

| No | Parameters | Value | Unit |
|---|---|---|---|
| 1 | Tensile strength of AISI 1020, $S_u$ | 429 | MPa |
| 2 | Yield strength of AISI 1020, $S_y$ | 352 | MPa |
| 3 | Modulus of Elasticity, E | 207 | GPa |
| 4 | Poisson's ratio | 0.27 | - |

### Design Consideration of Rice Polishing Machine

### Hopper Design

The design of hopper was made truncated cone shaped to be filled in a vertical position. The top and bottom sections are cylindrical shapes. The middle section is conical shape. The material of hopper is used iron steel sheet, which is available in local market. The hopper is mounted on the top of the housing unit. The volume of hopper is given by;

Volume of hopper= volume of cylindrical shape+ volume of cone

$$= \left(d_{op}^2 - d_{ip}^2\right) \times l + \frac{1}{3}\pi h\left(R^2 + r^2 + R \times r\right) = 5.74 \times 10^{-3} m^3 \quad (1)$$

### Power Transmission System

The electric motor which connected to power supply was use to transmit torque to rotate the shaft for rice hulling and polishing process. The motor power of the rice polishing machine is 1.5 hp and the speed of motor ($N_1$) is 1440rpm. There are many types of transmission system which transmit power from one shaft to another. In this machine selects the v-belt drive transmission system because easy to maintain and operates. The diameter of motor pulley is 70mm and diameter of machine pulley is 140mm. The speed of machine pulley is calculated according to this velocity ratio equation [10],

$$VR = \frac{N_2}{N_1} = \frac{D_1}{D_2} \quad (2)$$

So, the speed of the machine pulley is 720 rpm.

The center distance between two pulleys is [9],

$$C = 3\left(D_1 + D_2\right) - D_2 \quad (3)$$

C=3×(70+140)−140=490mm

The center distance between the motor pulley and shaft pulley is 490mm. The length of the belt using the equation below,

$$L = \frac{\pi}{2}\left(D_1 + D_2\right) + 2C + \frac{1}{4}\left(D_1 + D_2\right)^2 \quad (4)$$

$$L = \frac{\pi}{2}(70 + 140) + 2 \times 390 + \frac{1}{4}(70 + 140)^2 = 1312.4mm$$

The angle of contact for the driver and driven pulleys using the following equations,

$$\sin\beta = \frac{\left(D_2 - D_1\right)}{2C} \quad (5)$$

$$\beta = \sin^{-1}\left(\frac{D_2 - D_1}{2C}\right) = \sin^{-1}\left(\frac{140 - 70}{2 \times 490}\right) = 4.1$$

The angle of lap on the smaller pulley is,

$$\theta = 180 - 2\sin\beta \quad (6)$$

$$\theta = 180 - 2 \times \sin\left(4.1\right) = 3.139rad$$

The centrifugal tension of power transmission system is,

$$T_c = mv^2 \quad (7)$$

$$T_c = 0.096 \times 5.278^2 = 2.67N$$

The maximum tension in the belt is,

$$T_{max} = \sigma \times A = 2.8 \times 10^6 \times 6.43 \times 10^{-5} = 180.04N \quad (8)$$

The maximum tension on the tight side and slack side of the belt using the equations below,

$$T_1 = T_{max} - T_c = 108.04 - 2.47 = 177.34N \quad (9)$$

$$\frac{T_1}{T_2} = e^{\mu\theta\operatorname{cosec}\beta} \quad (10)$$

$T_2$=9.83N

The power transmitted per belt for this system using the following equation,

$$P = \left(T_1 - T_2\right) \times v = \left(177.37 - 9.83\right) \times 5.278 = 884.28W = 1.18hp$$

**Design of Main Shaft**

The weight of blade, weight of cylinder, weight of screw, weight of paddy and centrifugal force are considered uniformly distributed load acting on the main shaft. The weight of pulley and tension of belt on the tight side and slack side are considered point load acting on the main shat. The length of main shaft is 400mm. The weight of blade, weight of cylinder, weight of screw, number of blades and weight of paddy will be the input design factors for calculating the forces acting on the main shaft. The centrifugal force acting on main shaft is also calculated.

The centrifugal force,

$F = mr\omega^2 = 372.6N$ (11)

Maximum permissible shear stress ($S_s$) for AISI 1020 is **[10]**,

$S_s = 0.75 \times 0.18S_{ut} = 51.165$ MPa (12)

(or)

$S_s = 0.75 \times 0.3S_y = 47$ MPa
(Choose smaller value 47 MPa)
Combined shock and fatigue factor applied to bending moment, $K_b = 1.5$
Combined shock and fatigue factor applied to torsional moment, $K_t = 1$
Combined Bending Moment, $M_b = 61.073$ Nm
Maximum Torsional Moment,

$$M_t = \frac{P \times 60}{2\pi N} = 6.1\text{N} \quad (13)$$

ASME Code equation for solid shaft is,

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (14)$$

d=21.6mm

Therefore, the standard shaft diameter is 22 mm. The diameter of main shaft is 22 mm, the blade width and thickness are 10mm and 6mm. The detailed diagrams can be seen in Figure 2. The geometry was created by AutoCAD software. A square key is used in main shaft, key and shaft is made from same material. In this paper selects the right and left bearing number of 6022 single row deep groove ball bearing.

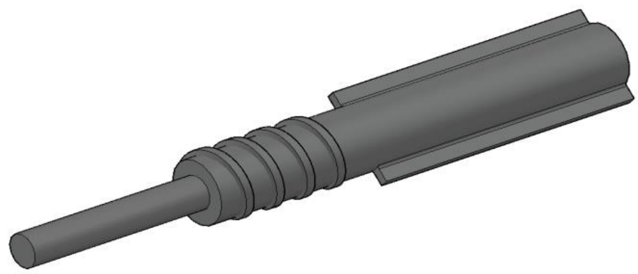

**Figure 2.** Main shaft of rice polishing machine

**Fabrication of Rice Polishing Machine**

In the rice milling process, the rice polishing machine is used to improve production and reduce human power. The main shaft of the machine should be strong to resist the various loads action on the main shaft and screw and blade also should be strong to resist the motion of paddy and friction force during machine operation, so they have made of strong material AISI 1020 carbon alloy steel. The diameter of the main shaft is 22mm. The blade width is 10mm and the thickness of the blade is 4mm are used in this experiment. The lathe machine is used to produce the main shaft and blade of the rice polishing machine. The component of the rice polishing machine is shown in figure (3).

Firstly, the right and left beaing were put on the main shaft. Then, the main shaft with screw and blade was installed in the housing and then put the sieve which it is hexagonal shape with length of 60mm and cross-sectional length of 960mm, above the main shaft. The V-belt pulley 2 is put on the main shaft. The 1.5hp motor with pulley 1 was installed beneath the frame of the rice polishing machine.The pulley 1 and pulley 2 is connected by using V belt with a length 0f 1.3124m. The diameter of the pulley 1 on the motor is 70 mm and the diameter of the pulley 2 on the main shaft is 140 mm. Then the pulley 2 connected the pulley 3 which it is put on the blower shaft. Blower shaft is put below the main shaft frame. The diameter of the pulley 3 on the blower shaft is 50 mm.

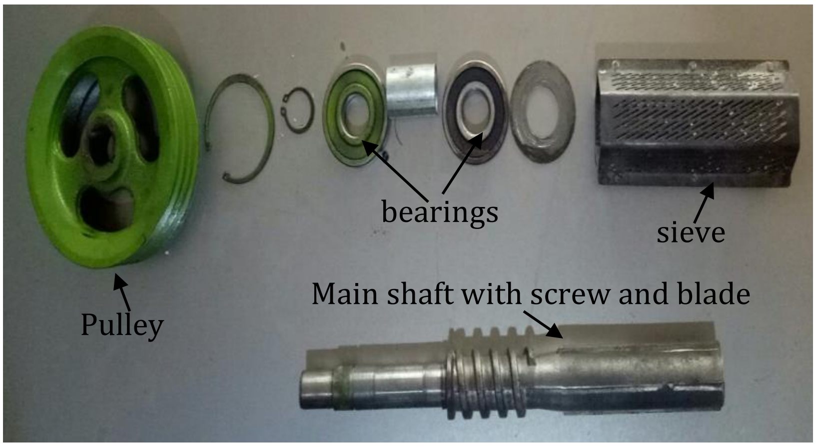


**Figure 3.** Component of rice polishing machine

**Performance Evaluation of Rice Polishing Machine**

The performance test of the rice polishing machine is carried out Ayayermin paddy with three different moisture content. The direct sunlight drying process is used to get the three different moisture contents. Two days of the direct sunlight drying process is used for each different moisture content.The moisture content of the paddys were determined by using moisturemeter. The total running time is five times for each moisture condition. The three different moisture contents are shown in figure 4.

**Figure 4.** Moisture test for Ayayermin paddy

## C. Result and Discussion

The 1000g of each sample paddy is used in the experiment. Firstly, the used of sample paddy is poured into the hopper in the milling process. Paddy through the hopper into the rice mill, and then by passing through the roller or hulling cylinder and the sieve, the paddy become rice. And then through the friction between the rice, the rice change from brown rice to white rice. The weight of well rice and broken rice were recorded for each experiment. Measuring the weight of paddy, well rice and broken rice for modified and existing blade are shown in figure 5. The milling efficiency and milling capacity were evaluated for each experiment. The average milling efficiency at the moisture content of 13% is more than the other two moisture contents but the average milling capacity is less than the other two moisture contents.

(a)Weight of paddy (b) Weight of well rice and weight of broken rice for modified blade

(c) Weight of well rice and weight of broken rice for existing blade

**Figure 5.** Measuring weight of Ayayermin paddy and rice

The performance result of Ayayermin paddy at moisture content of 13% is shown in the table 1.

**Table 1.** Performance result of Ayayermin paddy at moisture content of 13% for Existing blade

| Moisture Content (%) | Input (g) | Well Rice (g) | Broken Rice(g) | Time Taken (sec) | Milling Efficiency(%) | Broken Efficiency(%) | Milling capacity(kg/h) |
|---|---|---|---|---|---|---|---|
| | 1000 | 867 | 80 | 120 | 86.7 | 8.45 | 30.00 |
| | 1000 | 863 | 90 | 117 | 86.3 | 9.44 | 30.77 |
| 13 | 1000 | 860 | 95 | 118 | 86 | 9.95 | 30.51 |
| | 1000 | 865 | 90 | 120 | 86.5 | 9.42 | 30.00 |
| | 1000 | 868 | 95 | 118 | 86.8 | 9.87 | 30.51 |
| Average | 1000 | 864.6 | 90.0 | 118.6 | 86.46 | 9.43 | 30.35 |

The performance results of Ayayermin paddy at moisture content of 12% shown in the table 2.

**Table 2.** Performance result of Ayayermin paddy at moisture content of 12% for Existing blade

| Moisture | Input | Well | Broken | Time | Milling | Broken | Milling |
|---|---|---|---|---|---|---|---|

| Content (%) | (g) | Rice (g) | Rice(g) | Taken (sec) | Efficiency(%) | Efficiency(%) | capacity(kg/h) |
|---|---|---|---|---|---|---|---|
| | 1000 | 840 | 107.3 | 113 | 84 | 11.33 | 31.86 |
| | 1000 | 845 | 110.4 | 115 | 84.5 | 11.56 | 31.30 |
| 12 | 1000 | 850 | 108.2 | 114 | 85 | 11.29 | 31.58 |
| | 1000 | 845 | 115 | 110 | 84.5 | 11.98 | 32.73 |
| | 1000 | 843 | 117 | 107 | 84.3 | 12.19 | 33.64 |
| Average | 1000 | 844.6 | 111.58 | 111.8 | 84.46 | 11.67 | 32.20 |

**Table 3.** Performance result of Ayayermin paddy at moisture content of 11% for Existing blade

| Moisture Content (%) | Input (g) | Well Rice (g) | Broken Rice(g) | Time Taken (sec) | Milling Efficiency(%) | Broken Efficiency(%) | Milling capacity(kg/h) |
|---|---|---|---|---|---|---|---|
| | 1000 | 830 | 121 | 107 | 83 | 12.72 | 33.64 |
| | 1000 | 828 | 118 | 113 | 82.8 | 12.47 | 31.86 |
| 11 | 1000 | 825 | 121 | 106 | 82.5 | 12.79 | 33.96 |
| | 1000 | 827 | 123 | 103 | 82.7 | 12.95 | 34.95 |
| | 1000 | 824 | 125 | 100 | 82.4 | 13.17 | 36.00 |
| Average | 1000 | 826.8 | 121.6 | 105.8 | 82.68 | 12.82 | 34.03 |

The performance results of Ayayermin paddy at moisture content of 11% shown in the table 3.

The performance results of Ayayermin paddy at moisture contents of 13%, 12% and 11% can be seen in tables 4 to 6.

**Table 4.** Performance result of Ayayermin paddy at moisture content of 13% for Modified blade

| Moisture Content (%) | Input (g) | Well Rice (g) | Broken Rice(g) | Time Taken (sec) | Milling Efficiency(%) | Broken Efficiency(%) | Milling capacity(kg/h) |
|---|---|---|---|---|---|---|---|
| | 1000 | 880 | 70 | 108 | 88 | 7.37 | 33.33 |
| | 1000 | 875 | 74 | 100 | 87.5 | 7.80 | 36.00 |
| 13 | 1000 | 872 | 72 | 95 | 87.2 | 7.63 | 37.89 |
| | 1000 | 878 | 69 | 108 | 87.8 | 7.29 | 33.33 |
| | 1000 | 877 | 70 | 100 | 87.7 | 7.39 | 36.00 |
| Average | 1000 | 876.4 | 71.0 | 102.2 | 87.64 | 7.49 | 35.23 |

**Table 5.** Performance result of Ayayermin paddy at moisture content of 12% for Modified blade

| Moisture Content (%) | Input (g) | Well Rice (g) | Broken Rice(g) | Time Taken (sec) | Milling Efficiency(%) | Broken Efficiency(%) | Milling capacity(kg/h) |
|---|---|---|---|---|---|---|---|
| | 1000 | 857 | 93 | 92 | 85.7 | 9.79 | 39.13 |
| | 1000 | 855 | 94.4 | 95 | 85.5 | 9.94 | 37.89 |
| 12 | 1000 | 858 | 92 | 93 | 85.8 | 9.68 | 38.71 |
| | 1000 | 852 | 98 | 100 | 85.2 | 10.32 | 36.00 |
| | 1000 | 857 | 93 | 92 | 85.7 | 9.79 | 39.13 |
| Average | 1000 | 855.8 | 94.08 | 94.4 | 85.58 | 9.90 | 38.14 |

**Table 6.** Performance result of Ayayermin paddy at moisture content of 11% for Modified blade

| Moisture Content (%) | Input (g) | Well Rice (g) | Broken Rice(g) | Time Taken (sec) | Milling Efficiency(%) | Broken Efficiency(%) | Milling capacity(kg/h) |
|---|---|---|---|---|---|---|---|
| | 1000 | 835 | 109 | 85 | 83.5 | 11.55 | 42.35 |
| | 1000 | 838 | 107 | 88 | 83.8 | 11.32 | 40.91 |
| 11 | 1000 | 835 | 110 | 85 | 83.5 | 11.64 | 42.35 |
| | 1000 | 837 | 108 | 87 | 83.7 | 11.43 | 41.38 |
| | 1000 | 834 | 110 | 86 | 83.4 | 11.65 | 41.86 |
| Average | 1000 | 835.8 | 108.8 | 86.2 | 83.58 | 11.52 | 41.76 |

## C. Result and Discussion

In this study, the main diameter of 22 mm and blade width of 10 mm and thickness of 6 mm were investigated. The existing blade width of 8mm and thickness of 4 mm were performed. The experimental tests were carried out by running the machine five times for each moisture content and modified and existing blade.

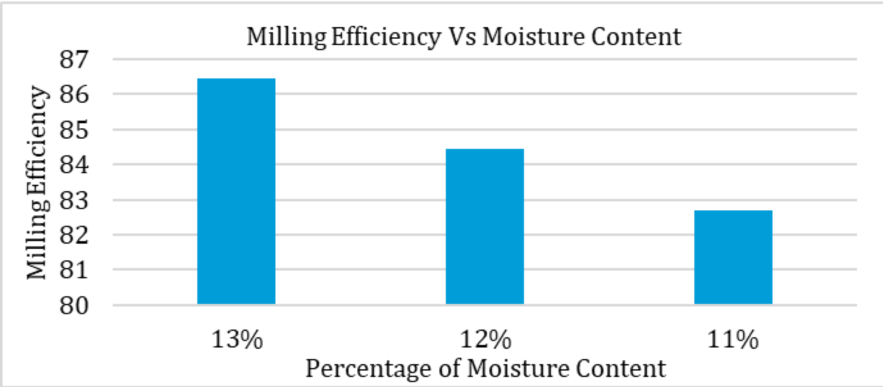


**Figure 6.** Comparison of milling efficiency with moisture contents for existing blade

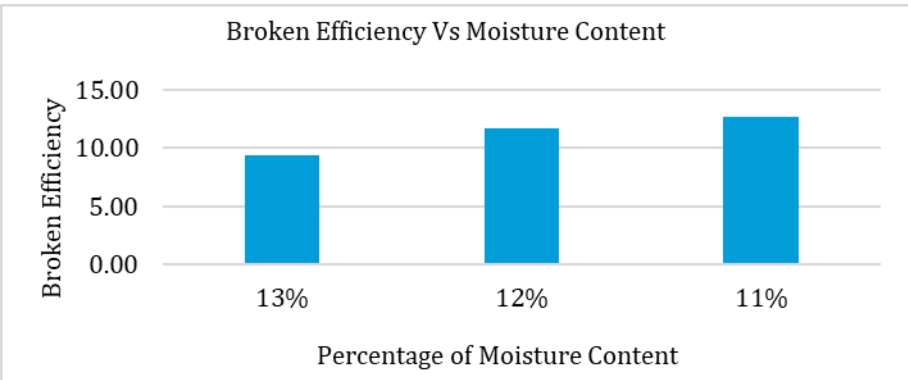


**Figure 7.** Comparison of broken efficiency with moisture contents for existing blade

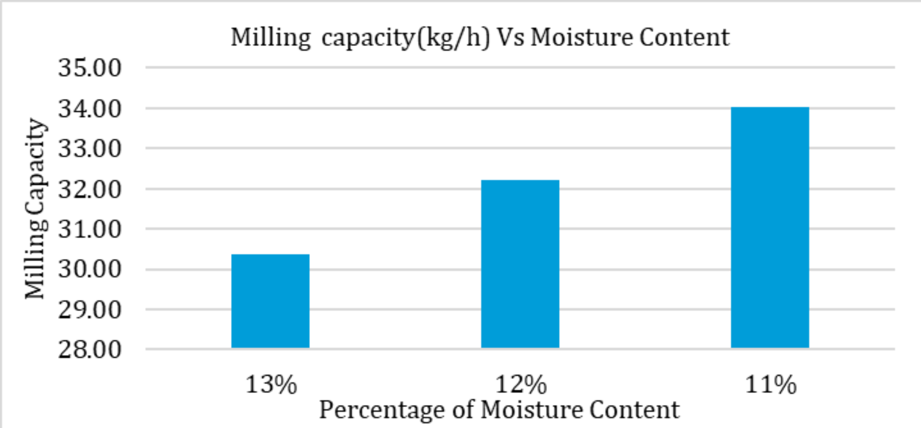


**Figure 8.** Comparison of milling capacity with moisture content for existing blade

The comparison of experimental result for the average milling efficiency and moisture content for existing blade is shown in figure 6. Figure 7 shows the comparison of average broken efficiency and moisture contents for existing blade. And then the comparison of average milling capacity and moisture contents for existing blade also is shown in figure 8. The comparison of average milling efficiency, broken efficiency and milling capacity and moisture content for modified blade are shown in figure 9 to 11. Figure 12 to 14 also show the comparison result milling efficiency, broken efficiency and milling capacity between existing and modified blade with different moisture contents.

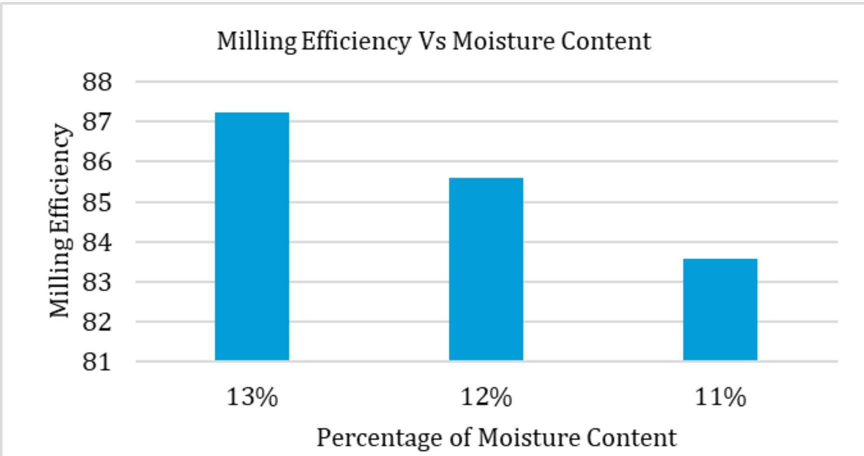


**Figure 9.** Comparison of milling efficiency with moisture content for modified blade

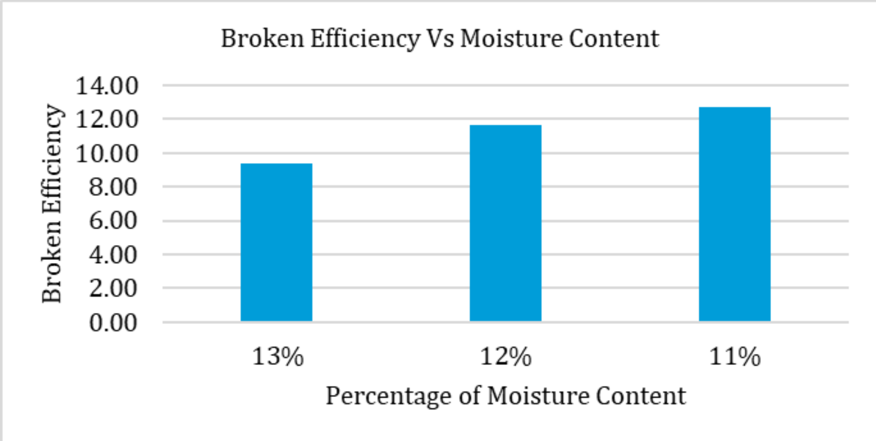


**Figure 10.** Comparison of broken efficiency with moisture content for modified blade

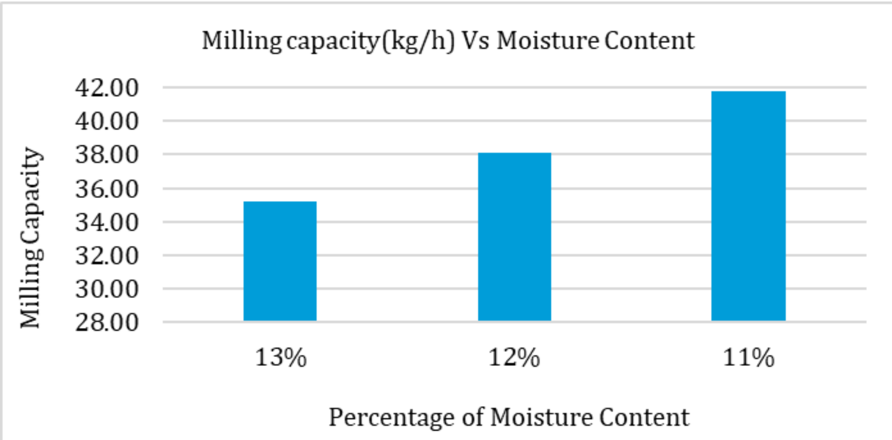


**Figure 11.** Comparison of milling capacity with moisture content for modified blade

According to the experimental results, the average milling efficiencies were 87.64%, 85.58% and 83.58% with modified blade and 86.46%, 84.46% and 82.68% with existing blade at the moisture condition of 13%, 12% and 11%, respectively. The average broken efficiencies were 7.49%, 9.9% and 11.52% with modified blade and 9.41%, 11.67% and 12.70% with existing blade at the moisture condition of 13%, 12% and 11%, respectively.

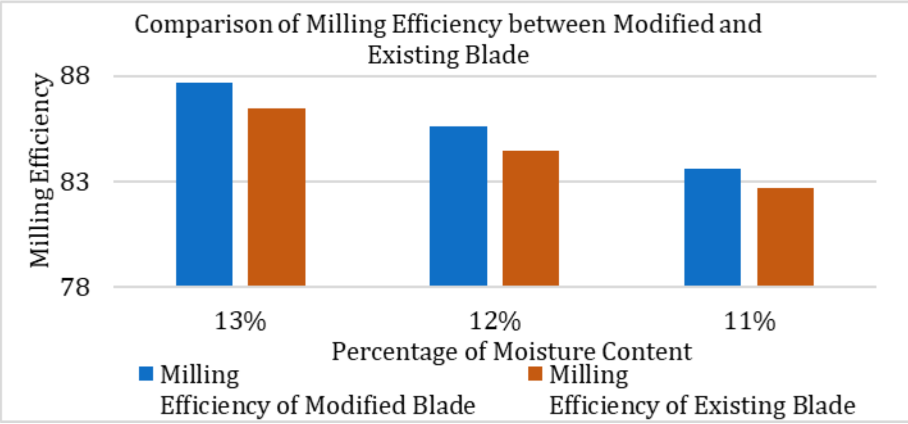


**Figure 12.** Comparison of milling efficiency between modified and existing blade

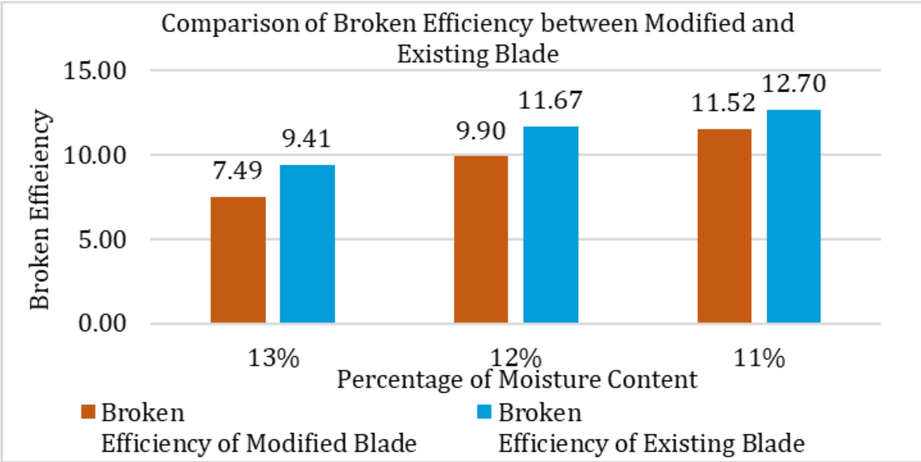


**Figure 13.** Comparison of broken efficiency between modified and existing blade

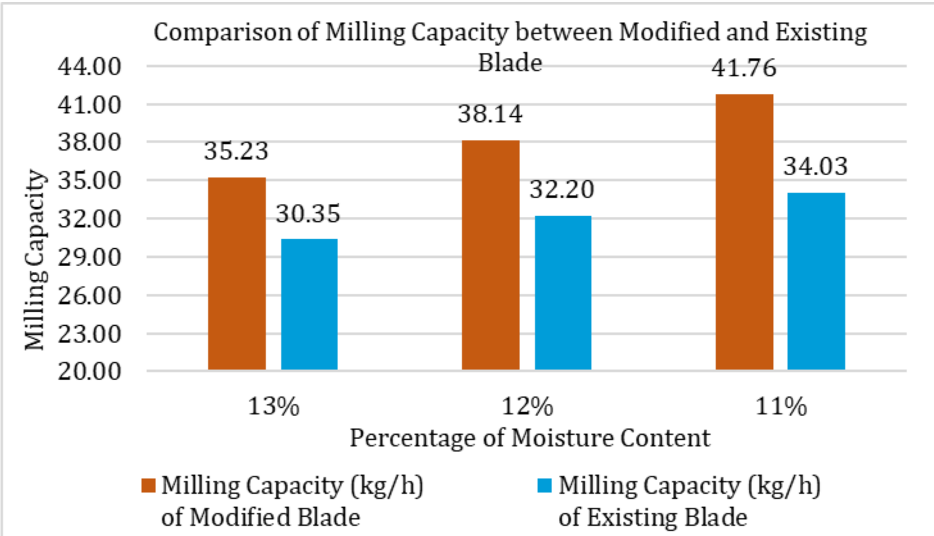


**Figure 14.** Comparison of milling capacity between modified and existing blade

The average milling capacity is 35.23 kg/h, 38.41 kg/h and 41.76 kg/h with modified blade and 30.35 kg/h, 32.20 kg/h and 34.03 kg/h with existing blade at the moisture condition of 13%, 12% and 11%, respectively.

As above results, the milling capacity of rice decreases at the high moisture content and the milling capacity of rice increase at the low moisture content.

## D. Conclusion

This research presents the design of main shaft and the diameter is 22mm and the blade width of 10 mm and thickness of 6mm for a rice polishing machine. The length of belt is 1312.4 mm and the number of two belts are used. The required motor power of the machine is calculated 1.18hp and chosen 1.5hp to save and overcome the required power of the machine. The existing blade width and thickness are 8 mm and 4mm. The milling efficiency, broken efficiency and milling capacity for both modified and existing blades presented and the comparison of the milling efficiency, broken efficiency and milling capacity for both modified and existing blades also presented. In the experiment, the milling efficiency, broken efficiency and milling capacity analyzed by running the machine of five times for each moisture condition both existing and modified blades. The maximum average milling efficiencies are 86.46% for existing blade and 87.64% for modified blade at the moisture condition of 13%. The maximum average broken efficiencies are 12.7% for existing blade and 11.52% for modified blade at the moisture condition of 11%. The maximum average milling capacities are 34.03% for existing blade and 41.76% for modified blade at the moisture condition of 11%. Although, the average milling efficiency of the modified blade is slightly more than the existing blade and the average broken efficiency of modified blade is slightly less than the existing blade, the average milling capacity of the modified blade is dramatically more than the existing blade. So, the modified blade of the machine is more convenience and efficient than the existing blade of the machine.

## E. Acknowledgment

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