A Conceptual Modification Design for the Commercial Small Rice Milling Machine

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2023 8th International STEM Education Conference (iSTEM-Ed) | 979-8-3503-4262-8/23/$31.00 ©2023 IEEE | DOI: 10.1109/ISTEM-ED59413.2023.10305732

***Abstract*—A small rice milling machine is wildly used by farmer in Thailand of many purposes such as a reservation, a commercial or a nutrition purpose. After the Covid-19 situation, many companies want to recovery their own business. Many strategies were applied and one of their strategy is to modify their own product. This project was started to modify the commercial small rice mill from A R C GLOBAL CO., LTD. To serve their customer's requests survey. There are three main topics that need to be improved 1) the milling rate 2) rice and broken rice sorting and 3) the waste sorting. A strategy which is applied to modify the commercial small rice mill, is easy and less modification. The machine was disassembled and observed its mechanism. Finally, the milling and the sorting mechanism were modified. The simulation result shown that the milling rate is improved to become 120 kg/hr. and the sorting mechanism can sorting the rice, broken rice and waste. Finally, the owner purposed were satisfied by this conceptual design to improve their product. The good products for commercialize mean the functional with the easy manufacture.**

Keywords—Commercial Small Rice Milling Machine, Screw Conveyer, Rice Sorting, and Milling

I. INTRODUCTION

A small rice milling machine that classified by the Thai Industrial Standard institute [1], is wildly used by the farmer in Thailand. Some farmers use the machine for reservation, in the meanwhile for the value added to their product (paddy or husked rice is cheaper than rice) [2]. Another purpose come from the end users, they focus on the nutrition of rice by manipulation the milling process [3]. However, many companies had to stock their own machines for more than 3 years, because of the Covid-19 situation, the customers stopped their activity, the buyers were significantly decreased. After pandemic situations, customers and companies started to recovery their business [4-5]. Many strategies were applied, one strategy they choose is modified their stocked machines.

A R C Global Co., Ltd is a manufacturer for agriculture machines such as small rice mill. The company want to improve their small rice mill. They did the survey from their own customers. The survey result shown in Table I. are the customer requirements for a new machine model:

1. Improve the milling rate
2. Sorting the rice and broken rice
3. Remove the waste

"Development of a small rice milling machine of A R C Global Co., Ltd. for commercial production and distribution" funding by the Talent Resource Managements (TRM), Rajamangala University of Technology.

TABLE I. CUSTOMER REQUIREMENTS FOR A NEW MACHINE MODEL

Requirements	Goal
1. Milling rate (paddy weight)	More than 100 kg/hr.
2. Rice and broken rice mixing by weight	Less than 10%
3. Rice and waste mixing	Remove

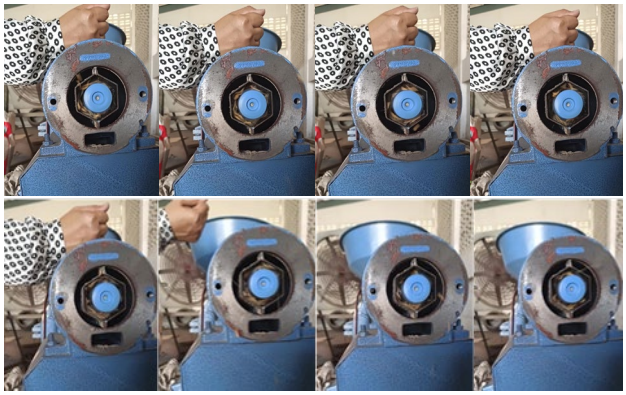
This research was started by a co-operation between an academic and a company (new academic research style in Thailand). This model, researchers have to concern not only a technical side but also a manufacturing and a financial. Thus, conceptual design to modify the small rice milling machine is to reach requirements with less modify and easy for manufacturing. The A R C GLOBAL CO., LTD. small rice milling machine is shown in Fig. 1. The right-hand side of Fig. 1 on top of the blue motor is the milling system and on the other hand is a crusher to crush small piece of woods, leaves and husks. The modification processes were applied to 3 main parts of the machine 1) milling chamber to increase the milling rate 2) rice and broken rice sorting to reduce the mixing of rice and broken rice and 3) paddy funnel to remove the waste.

Fig. 1. A small rice milling machine of A R C GLOBAL CO., LTD.

Next session the machine was disassembled an observed its milling and sorting process for the conceptual design.

II. Mechanical Parts and Functions

To understand mechanism and functions of the small rice milling machine was disassembled and observed. The rice milling and sorting processes were demonstrated. When a user loads paddy into the funnel (the right-hand side funnel of Fig. 1), the paddy was fed and milled into the milling chamber via a screw conveyer as shown in Fig. 2(a). After the mill process, rice and broken rice are fallen on the sorting mechanism then mixing rice was sorted as shown in Fig. 2(b).



(a)

(b)

Fig. 2. (a) Demonstration of the milling process (b) Demonstration of the sorting process

Finally, there are 3 main parts that need to modify following the customer's requests.

A. Milling Chamber

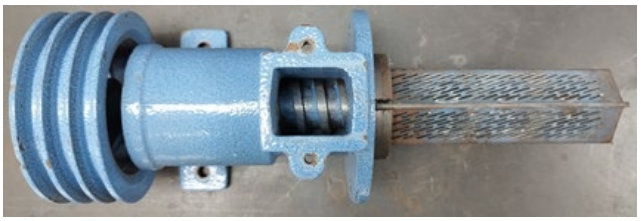
The milling chamber is separated into two parts. The first part is the screw conveyer, which is used for conveying paddy to the hollow hexagonal prism (the second part). The shaft inside the prism is rotated and husked paddy to rice. The screw conveyer and the hollow hexagonal prism are shown in Fig. 3(a).

B. Rice and Broken Rice Sorting

The sorting mechanism is installed as the last process of the rice milling machine. When paddy is husked, they became rice and broken rice mixing together. The sorting mechanism will let broken rice separating out from rice. The sorting mechanism is shown in Fig. 3(b).

C. Paddy Funnel

A 40 cm. diameter funnel, shown in Fig. 3(c), is installed on top of the machine for loading paddy to the milling chamber. A user has to continuous fill paddy into it when the machine is operated.



(a)

(b) (c)

Fig. 3. (a) Screw conveyer and milling chamber (b) Paddy loading funnel (c) Rice and broken rice sorting

Other parts of the small rice milling machine are a 220 V single phase 3 hp AC motor, pulley set transmitting motor power and the crusher (There is no concerned). By the observation, these are three main parts that have to be modified.

Next session will show a conceptual design to modify each part and simulate the result.

III. Modification and Simulation Result

The conceptual idea for the machine modification is to reach the customer's requests with the same manufacturer technique. The customer's requests are 1) Increasing the milling rate is more over than 100 kg/hr. 2) Sorting rice and broken rice and 3) remove the waste (weed) from rice.

A. Increasing the milling rate

The modification process to increase the milling rate with the same manufacturer technique are to boost up the rotation speed of the screw conveyer shaft and build up the screw conveyer size. However, boosting up the rotation speed make more broken rice, this research chooses to build up the screw conveyer size to maintain the milling condition as much as possible. The detail of the screw conveyer is shown in Fig. 4.

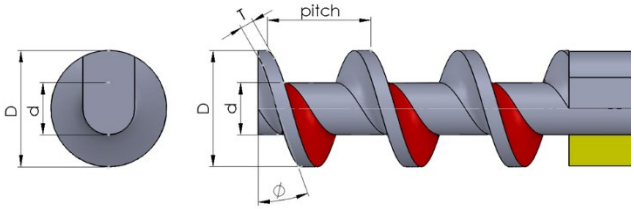


Fig. 4. Screw conveyer dimension for the small rice milling machine

Where,

D is an outside diameter of the screw conveyer. (mm)
d is a shaft diameter of the screw conveyer. (mm)
ϕ is a teeth angle of the screw conveyer. (degree)
T is a teeth thickness of the screw conveyer. (mm)
Pitch (Pit) is a distance between the teeth. (mm)
N is the rotation speed of the screw conveyer. (r/min)

GR is a gear ratio between the motor and the screw conveyer shaft.

ρ_r is paddy density. (kg/mm^3)

Because of the fixed housing size of the screw conveyer, the shaft dimension of the screw conveyer (d) is chosen to modify. The approximation of milling rate (Q) is calculated base on the screw conveyer geometry with the rotation speed of the screw conveyer (N) showing in (1).

$$Q = \left[\left(\frac{\pi(D^2 - d^2)}{4}\right) - \left(\frac{4DT\csc\emptyset - \pi d^2}{8}\right)\right] \cdot \sqrt{(\pi D)^2 - pit^2} \cdot N \cdot 60 \cdot GR \cdot \rho_r \quad (1)$$

The milling rate is depended on many variables but only the shaft diameter of the screw conveyer (d) can modify with the same manufacturer protocol. The simulation result between the milling rate (Q) and the shaft diameter of the screw conveyer (d) by (1) is shown in Fig. 5

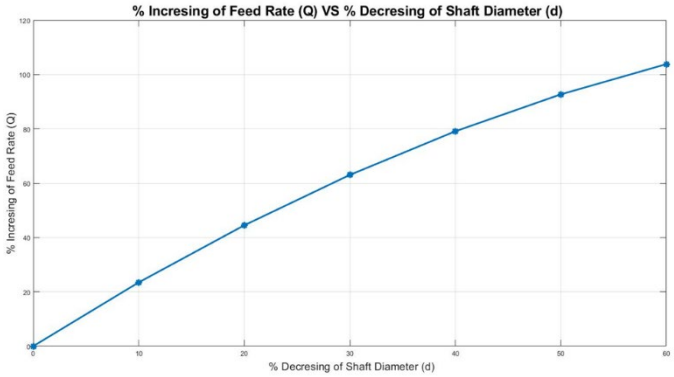


Fig. 5. The simulation result between the percentage of increasing milling rate (Q) and the percentage of decreasing shaft diameter of the screw conveyer (d).

The result is shown the relation between the milling rate (Q) and the shaft diameter (d) are inverse variation. To response the request for improving the milling rate from 100 kg/hr. (the current version) to 120 kg/hr. (the modify version). The company will modify their screw conveyer shaft by reducing the shaft diameter 10 percentage to increase approximately 20 percentage of the milling rate.

B. Sorting rice and broken rice

After milling, paddy become rice and broken rice mixing together and flowing by gravity along the sorting mechanism. However, the current mechanism is not working well. Broken rice remaining is more over than 90 percentage. Mixing rice from the current small milling machine is shown in Fig. 6(a).

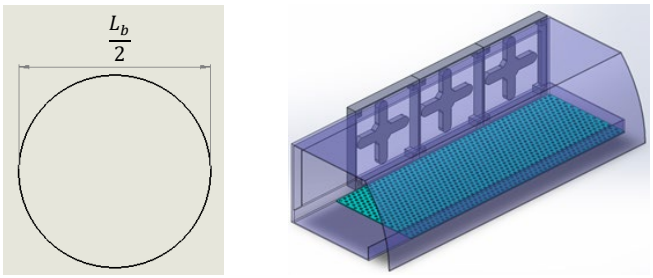
The sorting mechanism is remaining the same function but it is modified a hole size on the sorting plate. Moreover, a length of the sorting path is also increased and added a vibration source for shaking a new sorting mechanism. The suitable hole size and vibration with long sorting path will reduce the quantity of broken rice that mixing at the end of the milling process.

To modify a hole size, rice geometry shown in Fig. 6(b) is considered. The modified hole is designed for broken rice (its length is no longer than 75 percentage of the full length of rice). The approximated diameter and length of rice is 2 mm. and 9 mm., respectively.

(a) (b)

Fig. 6. (a) Rice fron the current small rice milling machine (b) Example of rice geometry [6]

A diameter of the modified Hole is a half of a maximum of broken rice length. Center of gravity and unbalance object with the suitable vibration will let broken rice go through the modified hole. Finally, broken rice remaining in milled rice is less than 10 percentage as the customer's request. The modified hole with the extended sorting path are shown in Fig. 7 (a) and (b), respectively.



(a) (b)

Fig. 7. (a) The modified hole (b) The extended sorting path with fan units

Because of variety of rice in Thailand, a hole diameter is determined following (2) and a length of the sorting path and suitable frequency of vibration will come from experiments.

$$\emptyset = \frac{L_b}{2} \quad (2)$$

Where,

ϕ is the diameter of the modified hole. (mm)

L_b is the third quarter of interested rice length. (mm)

C. Remove the waste

A normal harvest process, paddy will mix up with the waste such as soil, sand and weed. Because a user does not treat paddy before loading to the milling machine, thus quality of rice from the current machine dose not satisfy the user.

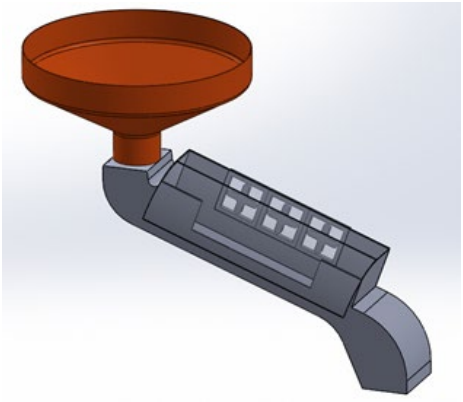


Fig. 8. Paddy funnel and a modified path with fan units

To satisfy the user request, the paddy funnel and the sorting mechanism are modified by installing fan units at both of them as shown in Fig. 8 and Fig. 7(b), respectively. Fan units apply for blowing lightweight wastes which are mixed with paddy and rice. The fan speed is selected based on experiment results. For other wastes (soil and sand), they are removed with the milling and sorting process.

However, all customer requirements are fulfilled with the conceptual modified design, but experiments are still needed.

Next session, the expect specification of the modified small rice milling machine is shown. Suggestions and comments, related to manufacturer techniques and processes from the company, are discussed.

IV. Concludsion and Discussion

The expect specification of the modified small rice milling machine is shown in Table II. By the relation of the milling rate and the diameter of the screw conveyer shaft, the shaft diameter is reduced to 27 mm (from 30 mm) to increase the milling rate to 120 kg/hr. (from 100 kg/hr.). The broken rice and wastes remaining in milled rice are 10 percentage of the current machine.

TABLE II. Specification of Modified Small Rice Milling Machine

	Goal	Specification
1. Milling rate	More than 100 kg/hr.	120 kg/hr.
2. Broken rice remaining	Less than 10%	10% (by weight)
3. Waste remaining	0% (Remove)	10% (by weight)

The expected result and the modified concept were discussed with A R C Global Co., Ltd. The company was satisfied with the modified process to improve the milling rate, however for the rice sorting and the waste removing, experiment results are requested.

Next step of the research is developed the modified parts and do experiments. After that, the modified parts will be assembled and testing through the small rice milling machine standard of Thai Industrial Standards Institute. (TIS NO. 888-2532) [1].

Acknowledgment

This research is a part of an ongoing project the "Development of a small rice milling machine of A R C Global Co., Ltd. for commercial production and distribution" funding by the Talent Resource Managements (TRM), Rajamangala University of Technology.

Authors would like to thank you to A R C Global Co., Ltd. for their customer survey, technical supports (manufacturer knowledge) and comments.

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