SIMULATION AND AUTOMATION OF A RICE MILL PLANT
- DEVELOPMENT OF SIMULATION MODEL -

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ABSTRACT

A rice mill plant with a capacity of 2.5 ton/hr was constructed with automated facilities at Chonnam National University. A simulation model was developed with SLAMSYSTEM for evaluating and improving the rice mill plant. The developed model was validated in the views of hulling efficiency, milling efficiency, milled rice recovery, other materials produced, and bottlenecks in the processes. The results of hulling efficiency, milling efficiency, milled rice recovery in the simulation were, respectively, 81.1%, 89.5%, and 73.1%, while those of the actual mill plant were 81.5%, 90.2%, and 73.5%. The simulation results including the productivity of other materials(chaff, bran, broken rice, stone, etc) produced in the processes were almost similar with those of the actual process. In the simulation the bottlenecks were found out in the processes of separating brown rice and of sorting colored rice. These phenomenon also appeared in the actual process. It needed to increase the hourly capacity of the brown rice separator and the rice color sorter. As the developed model could well express the automated rice mill plant, it could be used for designing and improving rice mill plants. In addition, an alternative model needed to be developed for the system control more accurately and for increasing the rice quality.

Key words: simulation, rice mill plant, improvement, evaluation

INTRODUCTION

Rice processing complex more than three hundreds have been constructed to produce rice with high quality in Korea since 1991. The rice processing complex(RPC) consists of a rice mill plant and a facility for drying and storage of rice. However, many problems have been caused in RPC because RPC have been built without enough consideration technically. Especially, improvement of a rice mill plant was needed in its performance and automation. To solve some problems in constructing and operating a rice mill plant, a theoretical analysis on the process of a rice mill was necessary using a simulation with SLAMSYSTEM. So, development of a simulation model was required to analyze and to improve a rice mill plant constructed at Chonnam National University. Namely, bottlenecks of materials, utilization of unit machine, productivity, and so on in the rice mill were needed to be analyzed through the simulation model.

Chung and Kim (1995) applied a simulation technique to the design of a small rice mill and developed a simulation model to analyze the effect of the performance of a brown rice separator on the flow of materials. Chung and Rhee(1997) developed a simulation model of a rice-taffy plant to evaluate the plant and to improve its process. They suggested some ways for automation to remove bottlenecks and for improving the productivity.

In this study, the main objectives were to develop a simulation model of a rice mill plant and to suggest an improving method in views of performance efficiency and automation of the process.

MATERIALS AND METHOD

System Description of Rice Mill Plant

The milling capacity of a rice mill plant constructed at CNU is 3ton/h in basis of paddy. A block diagram on the main process of the rice mill plant is Fig. 1, and the specifications of the milling machinery are shown in Table 1. The rice mill process consisted of a paddy cleaner, a destoner, an automatic huller, a screen sorter for brown rice, a brown rice separator of tray type, a thickness grader, a brown rice destoner, a horizontal frictional whitener, a vertical abrasive-frictional whitener, a rotary sifter, a color sorter, a polisher, an impact feeder for measuring flow rate of polished rice, an auto vinyl packer sequentially.

Table 1. Machinery of a rice mill plant at Chonnam Natioanal University(CNU)

Machinery	Model	Maximum Capacity	Capacity used
Paddy Cleaner	Book Sung,Batch type	20 t/h	3.0 t/h
General De-stoner	Kook Gwang	6.0 t/h	3.0 t/h
Huller	MyungJin MJH-SBCA	4.5 t/h	3.0 t/h
Screen Sorter	Book Sung	4.0 t/h	3.0 t/h
Brown Rice Separator	DaeRyuk Tray type	4.0 t/h	3.0 t/h
Thickness Grader	Two Rotary Screeners	4.0 t/h	3.0 t/h
Brown Rice De-Stoner	Kookgwang	4.0 t/h	3.0 t/h
Complex Whitener	Complex, Book Sung	4.0 t/h	2.1 t/h
Vertical Whitener	HRW-4	4.0 t/h	2.0 t/h
Rotary Sifter	HRS-400	4.0 t/h	2.0 t/h
Color Sorter	DCS-98S40	2.7 t/h	1.2 t/h
Hi-Brilliant Polisher	Bo Chun BCPWJ-2400	3.0 t/h	2.0 t/h
Impact Feeder	SI-20F, Se Jin Tech.	20 t/h	2.0 t/h
Auto Vinyl Packer	Se Jin Tech.	1.8 t/h	1.8 t/h

Process Automation

The milling machineries are manually and automatically controlled in a central control panel. And a huller, a whitener, a color sorter, a packer can be also controlled locally. All the machineries are sequentially operated, while the machinery are conversely stopped if an overload is even detected. The main tanks such as a paddy tank, brown rice tank, polished rice tank are so big compared with auxiliary tanks for each machine that these can be used as buffer tanks. A independent control block is set up among the main tanks. As proximity switches are attached to the main and auxiliary tanks, the level of each tank can be detected. So, the exit gates of tanks are automatically controlled by the signals of the proximity switches. The amount of materials in the main tanks is automatically measured by the load cells(CAS LS-5 and BS-5) installed at the bottom of the main tank legs. The Fig 2 shows the sensors of proximity switches of load cells and air cylinder gates attached to main and auxiliary tanks.

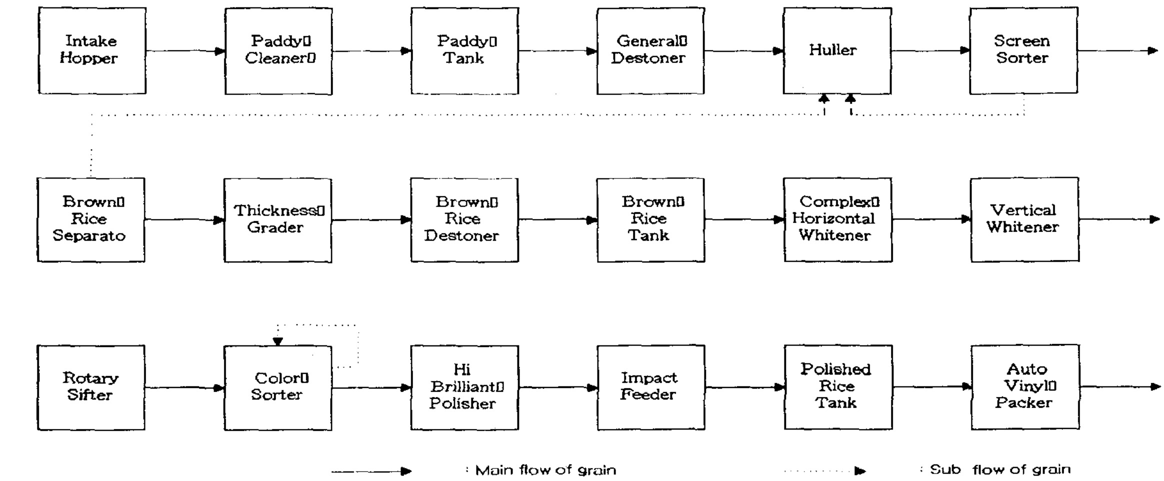

Fig. 1 The block diagram of the rice milling plant at CNU

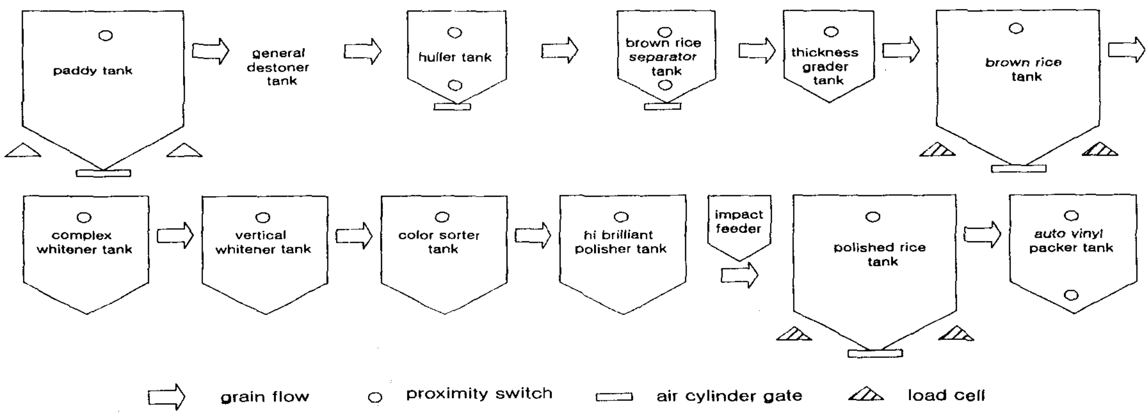

Fig. 2 The sensors and air cylinder gates attached to main and auxiliary tanks

Milling Experiment

Milling experiments were conducted for obtaining data such as the capacity of each unit machine and the rates of foreign materials (stones, straws, foreign grain, etc) and by-products(chaff and bran). The capacity of tanks was also measured. The current capacity of the machinery determined by adjusting the exit gate of tanks was measured through the preliminary tests of each machine.

Model Validation

The simulation results were compared with experimental results to validate the developed model. The main items analyzed were 1) hulling efficiency, milling efficiency, milled rice recovery, 2) the amount of foreign material at each machine, 3) bottlenecks of process, 4) stopping of unit machine, 5) capacity of unit machine, etc. The developed model was validated in views of these items.

DEVELOPMENT OF SIMULATION MODEL

Assumption

A simulation model of a rice mill plant was developed with SLAMSYSTEM. The assumptions used in the model were followings: 1) The intaking period of materials was 4 hours in the morning and 4 hours in the afternoon except the lunch time of 1 hour. But the milling operation was continuously carried out irrespective of the lunchtime. The unit of simulation time in the model was minute. 2) The weight of a entity was assumed to be 5 kg. 3) The conveying time at shuts was included in the conveying time of bucket elevators. 4) No breakdown happened in the machinery. 5) The duration time of each process was assumed to be normal distribution with standard deviation of 5%. 6) The materials separated from each machine did not include other foreign materials. 7) The capacity of intake process was assumed to be 2.5 t/h, and the hulling process with capacity of 2.5 t/h, the milling process with capacity of 2.0 t/h, the packing process with capacity of 1.7 t/h.

Model Characteristics

The model developed was shown in Fig. 3 and consisted of a network model and an user insert model. The main milling process controlled with PLC was expressed with the network model, while the duration time of each process and the control on the intaking process of materials were expressed with an user insert model.

The automatic operation of each machine and the tank exit gates was modeled with nodes of SLAMSYSTEM. The developed network model consisted of the main network of the process (Fig, 3(1)), sub-network (Fig. 3(2)), and control network (Fig. 3(3)). The automated basic milling process was modeled in the main network, and the creation of entities according to time was modeled in the sub-network. It was modeled in the sub-network that the daily intaking time of materials was 8 hours and the certain amount of materials was only taken into the system. The intaking time of materials was modeled with GATE, OPEN and CLOSE nodes. The signals for the control of each machine and exit gates of tanks was expressed in the control network. The levels of tanks were expressed with a DETECT node, and exit gates of tanks were automatically operated with OPEN and CLOSE nodes and ALTER node according to the signals of DETECT nodes. The duration time of each process was modeled in the user insert model. Also, the amount of intake materials was controlled in the user insert model using SUBROUTINE EVENT.

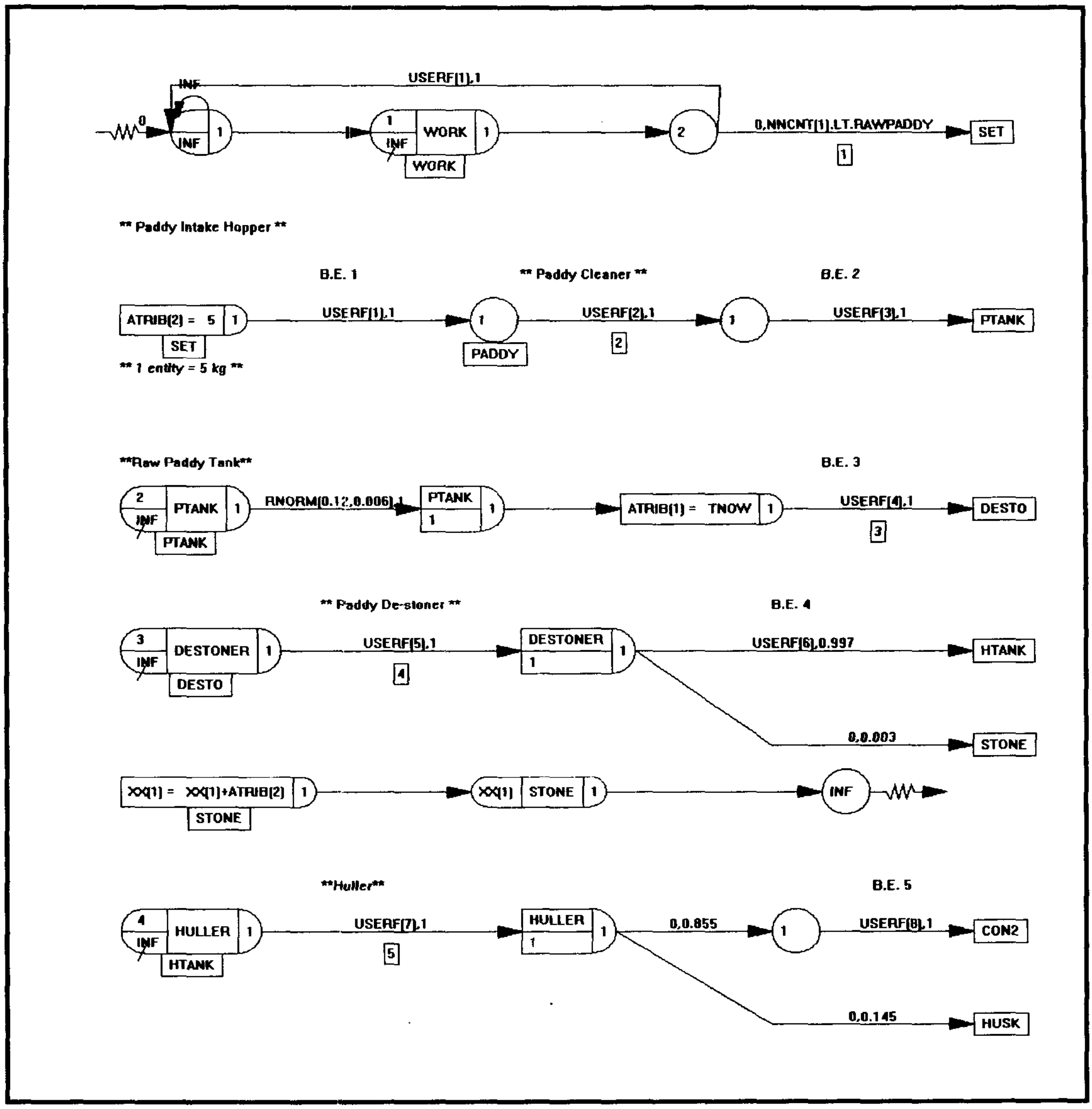

Fig. 3(1) A part of the main network in a basic model

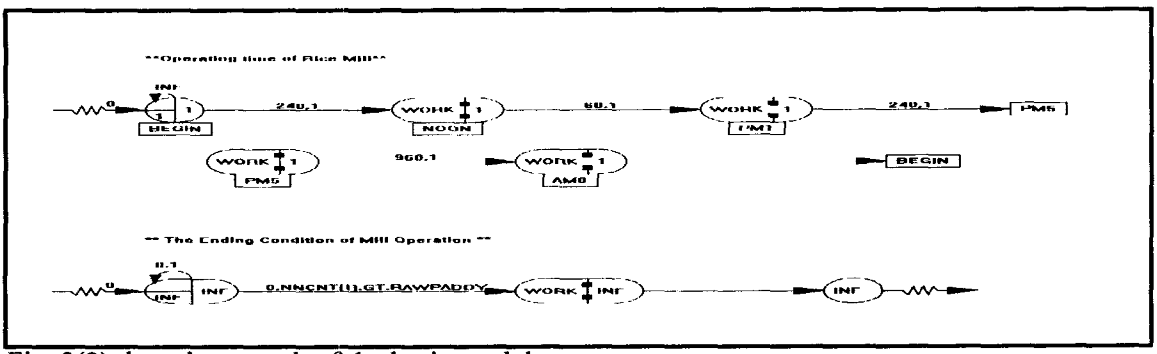

Fig. 3(2) the sub-network of the basic model

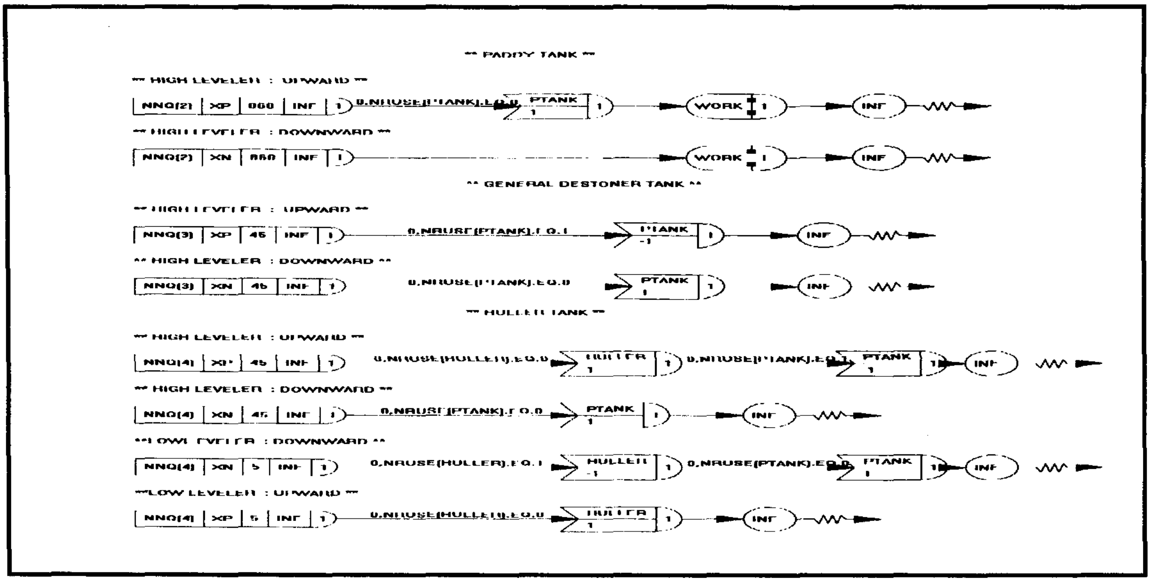

Fig. 3(3) the control network of the basic model

RESULTS AND DISCUSSION

Simulation Results

The amount of outputs produced in each process was analyzed through the simulation. The hulling efficiency was about 81.4%, milling efficiency about 90.1%, and the milled rice recovery was about 73,2% in the simulation. The average utilization of each machine except a color sorter was 0.33, so it was known that all the machinery were operated for 9 hours during the simulation time of 24 hours. The average utilization of the color sorter was 0.6. This meant that the color sorter was operated for about 14 hours longer than the normal operation time of other machines because of less capacity of the color sorter. Namely, a severe bottleneck of materials happened in the process of the color sorter.

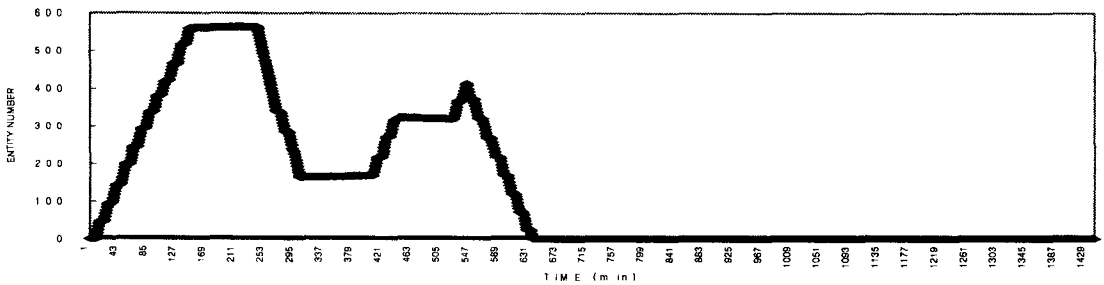

Fig. 4 The entity change of the paddy tank in the basic model

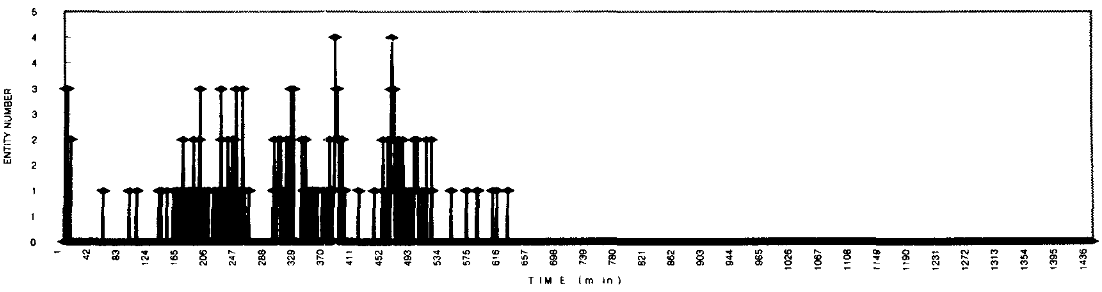

Fig. 5 The entity change of the huller auxiliary tank in the basic model

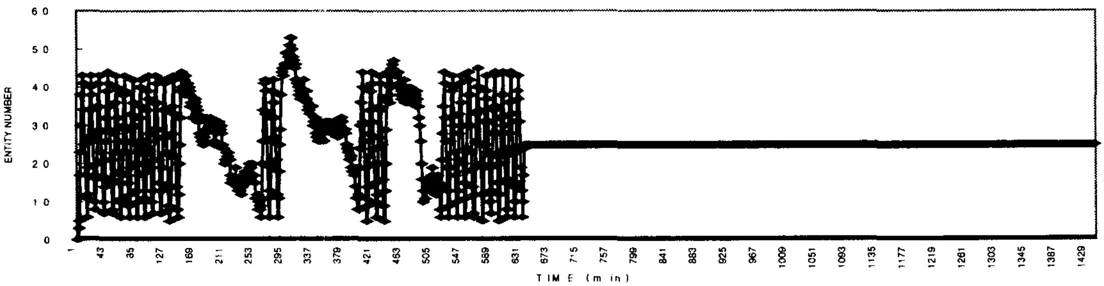

Fig. 6 The entity change of the brown rice separator auxiliary tank in the basic model

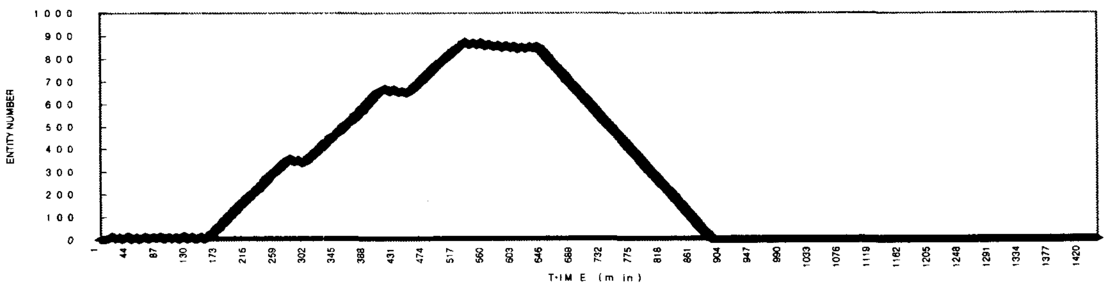

Fig. 7 The entity change of the color sorter auxiliary tank in the basic model

The change of materials in the paddy tank was shown in the Fig. 4. In the beginning of the operation, the amount of the paddy tank increased gradually up to about 2800kg. After the initial 2 hours, the level of the paddy tank was constant, and it decreased during the lunchtime. After the lunchtime, though the level increased a little, it was stable and decreased as materials were not taken in the paddy tank. Anyway there was no problem in the paddy tank because the maximum capacity of the paddy tank was more than 5,000 kg.

Fig. 5 shows the entity change of the huller auxiliary tank in the basic simulation model. There was no bottleneck in the auxiliary tank of a huller as the capacity of the huller was enough. The high leveler and the low leveler of the auxiliary tank of a huller were often detected because the capacity of the tank was not enough. The upward detection of the high leveler of the auxiliary tank let the exit gate of the paddy tank close, and the downward detection of the low leveler let the brown rice separator stop. The screen sorter and the brown rice separator should be efficiently operated with the separator set in the proper angle to solve such a problem. Fig 7. shows the entity change of the auxiliary tank of the color sorter in the basic simulation model.

There was a severe bottleneck in the process of a color sorter. The capacity of the color sorter should be increased with adjusting the feed rate of materials.

Model Validation

Efficiency and Productivity of Mill

Hulling efficiency, milling efficiency, milled rice recovery are indexes indicating the efficiency of a rice mill plant. The comparison of milling efficiency factors between experimental results and simulation results is shown in Table 2. The differences of hulling efficiency, milling efficiency, milled rice recovery between experiment and simulation were 0.4%, 0.7%, 0.4%, respectively. Though the simulation results were a little lower than experimental ones, the simulation results were almost similar with those. The materials produced in the processes of simulation were compared with those in experiment like Table 3.

As the hulling and milling capacity was 2.2 t/h and 1.8 t/h in the simulation, these results were also similar with actual results. From these results, the developed simulation model could be used for analyzing the rice mill plant and for predicting the outputs produced in the processes.

Process Bottleneck

There were no bottlenecks in the processes of destoning, hulling, milling, polishing, but there was a severe bottleneck in the color sorting process due to high sensitivity and low feeding rate of a color sorter in the simulation. This phenomenon happened in the actual process of the mill. Also, there was a bottleneck in the process of the brown rice separator with a tray type due to less capacity of brown rice separator and its auxiliary tank. The bottleneck in the brown rice separating process often closed the gates of the auxiliary tank of a huller and of the paddy tank, while the brown rice separator often stopped if the low leveler of the auxiliary tank for the brown rice separator was off. This stopping of the brown rice separator also happened in the actual process. Namely, the process bottlenecks were well found out through the simulation.

Table 2 The comparison of milling efficiency factors between experimental results and simulation results

Milling Efficiency Factors	Experimental Results (%)	Simulation Results (%)	Difference (%)
Hulling Efficiency	81.5	81.1	-0.4
Milling Efficiency	90.2	89.5	-0.7
Milled Rice Recovery	73.5	73.1	-0.4

Table 3 The comparison of quantity of materials between experimental results and simulation results

Machine/(Materials)	Experimental results		Simulation results		Difference (%)
	Total weight 2195 kg	Percent (%)	Total weight 20000 kg	Percent (%)	
General De-Stoner/(Stone)	0.649	0.03	50	0.025	-0.05
Huller/(Husk)	390.9	17.8	3490	17.45	-0.35
Thickness Grader/(Unripe Grain)	12.379	0.58	90	0.45	-0.13
De-Stoner/(Stone)	1.54	0.07	25	0.13	0.06
Whitener/(Bran)	98.78	4.5	915	4.58	0.08
Rotary Sifter/(Broken Rice)	54.9	2.5	535	2.68	0.18
Color Sorter/(Colored Rice)	15.37	0.7	240	1.20	0.5
Polisher/(Bran)	3.70	0.169	40	0.20	0.031
Polisher/(Polished Rice)	1598	73.5	14495	73.1	-0.4

CONCLUSIONS

A rice mill plant with a capacity of 2.5 ton/hr was constructed with automated facilities of a programmable logic controller, load cells, proximity sensors at Chonnam National University. A simulation model was developed with SLAMSYSTEM for evaluating and improving the rice mill plant and its automation. The developed model was validated in the views of hulling efficiency, milling efficiency, milled rice recovery, Productivity of materials produced, and bottlenecks in the processes. The results of hulling efficiency, milling efficiency, milled rice recovery in the simulation were, respectively, 81.1%, 89.5%, and 73.1%, while those of the actual mill plant were 81.5%, 90.2%, and 73.5%. The simulation results including the rates of other materials (chaff, bran, broken rice, stone, etc) produced in the processes were almost similar with those of the actual process. In the simulation the bottlenecks were found out in the processes of separating brown rice and of sorting colored rice. These phenomenon also appeared in the actual process. It needed to increase the hourly capacity of the brown rice separator and the rice color sorter. As the developed model could well express the automated rice mill plant, it could be used for designing and improving rice mill plants. In addition, an alternative model needed to be developed for the system control more accurately and for increasing the rice quality.

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