Performance Evaluation of Rice Mill Plant By a Computer Simulation

J. H. Chung

Abstract: A rice mill plant with a capacity of 3 t/h was constructed with automated facilities at Chonnam National University. A simulation model was developed with SLAMSYSTEM for evaluating and improving the rice mill process. 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 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 process for separating brown rice and sorting colored rice. These phenomena also appeared in the actual process. It needed to increase the hourly capacities 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.
Keywords: Simulation, Rice mill plant, Evaluation, Validation

Introduction

Rice processing complex (RPC) more than three hundreds have been constructed to produce rice with high quality in Korea since 1991. 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 technical consideration. It is too time-consuming to analyze an incomplete rice mill plant because its process consists of many system and operation parameters. 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 required using a simulation language like as SLAMSYSTEM (Pritsker, 1986). So, a simulation model was developed to analyze and to improve the system of a rice mill plant constructed at Chonnam National University (CNU) (Chung and Youm, 2000). 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. They recommended an increase to 60%~70% in the separating efficiency of brown rice separator was necessary to remove the bottleneck of materials in the separating process of brown rice. Chung et al. (1995) developed a rice mill pilot plant based on the simulation and evaluated its performances in views of bottleneck, efficiency and productivity.

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

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Materials and Methods

1. System Description of Rice Mill Plant

The milling capacity of a rice mill plant constructed at CNU is 3 t/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

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

Machinery	Model/Specification	Maximum Capacity (t/h)	Capacity used (t/h)
Paddy cleaner	PPC-300, Booksung	20	3.0
General de-stoner	Kookgwang, 6t/h	6.0	3.0
Huller	MJH-SBCA, Myungjin	4.5	3.0
Screen sorter	Screen type, Booksung	4.0	3.0
Brown rice separator	C2, 5 trays, Daeryuk	4.0	3.0
Thickness grader	Twin rotary type, B.S.	4.0	3.0
Brown rice de-stoner	Kookgwang, 4t/h	4.0	3.0
Complex whitener	Complex, Booksung	4.0	2.1
Vertical whitener	HRW-4, Hyundai	4.0	2.0
Rotary sifter	HRS-400, Hyundai	4.0	2.0
Color sorter	DCS-98S40, Daewon Co.	2.7	1.2
Polisher	BCPWJ-2400, Bochun	3.0	2.0
Impact feeder	SI-20F, Sejin Tech. Co.	20	2.0
Auto vinyl packer	SP-10, Sejin T. Co.	1.8	1.8

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 flowrate of polished rice, an automated vinyl packer, sequentially.

2. Process Automation

The milling machinery are manually or automatically controlled in a central control panel. And a huller, a whitener, a color sorter, and a packer can be also controlled locally. All the machinery are sequentially operated, while the machinery are conversely stopped if an overload is detected. The main tanks such as a paddy tank, brown rice tank, polished rice tank are so big compared with the auxiliary tanks for each machine that these can be used as buffer tanks. An independent control block is set up among the main tanks. The level of each tank can be detected with proximity sensors(switches) attached to the main and auxiliary tanks. So, the exit gates of tanks are automatically controlled by the signals from the proximity sensors. The amount of materials in the

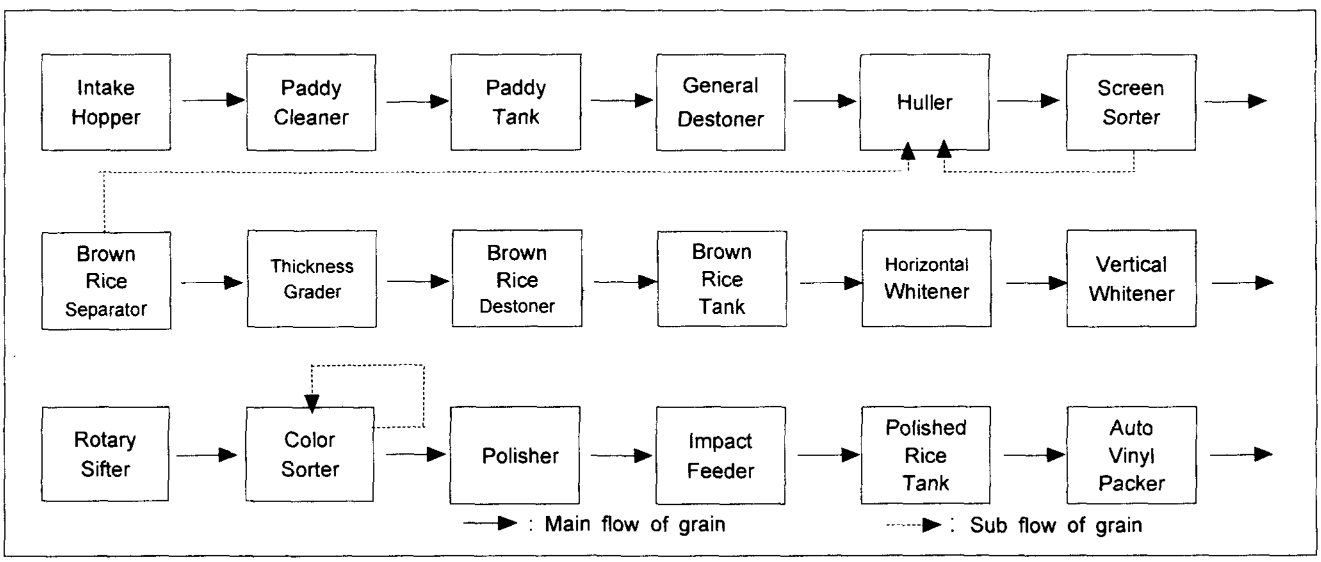

Fig. 1 The block diagram of the rice milling plant at CNU.

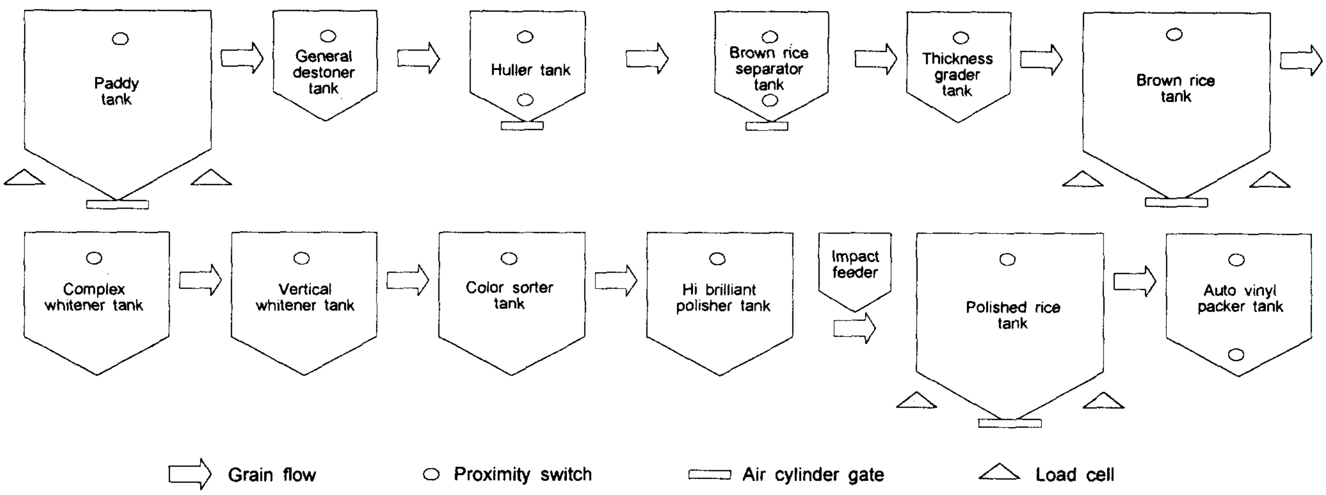

Fig. 2 The sensors and air cylinder gates attached to main and auxiliary tanks.

main tanks is automatically measured by the load cells(LS-5 and BS-5, CAS) installed at the bottom of the main tank legs. The Fig. 2 shows proximity sensors, load cells and air cylinder gates attached to main and auxiliary tanks.

3. Milling Experiment

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

4. Model Validation

The simulation results were compared with the 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 materials at each machine, 3) bottlenecks of process, 4) stopping of unit machine, 5) capacity of unit machine, etc.

Development of Simulation Model

1. Assumption

A simulation model for system evaluation 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 lunch time. 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 shutes 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 included 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.

2. 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 a programmable logic controller 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 modelled 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 modelled in the main network and the creation of entities according to time was modelled in the sub-network. It was modelled in the sub-network that the daily intaking time of materials was 8 hours and

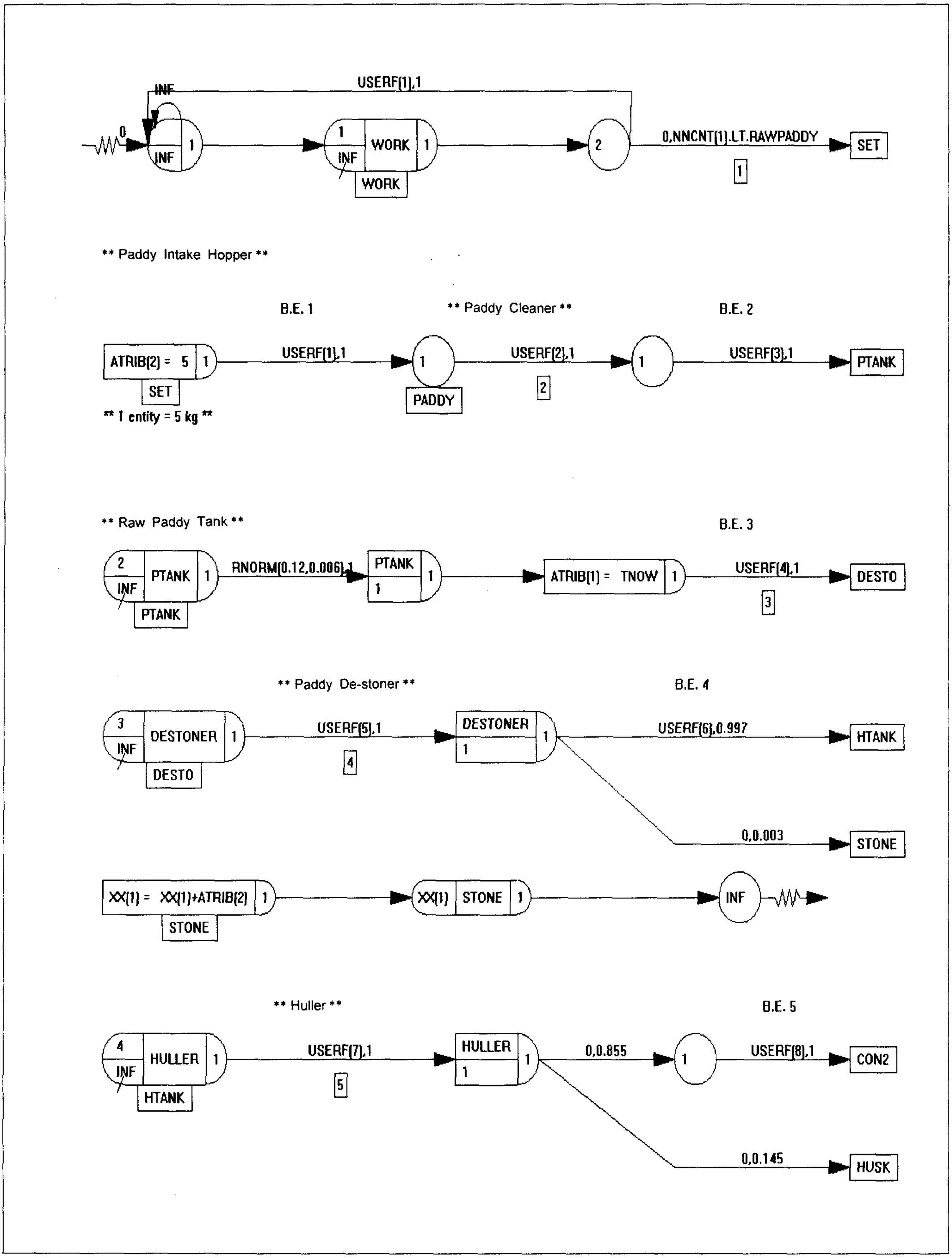

Fig. 3(1) A part of the main network in a basic model.

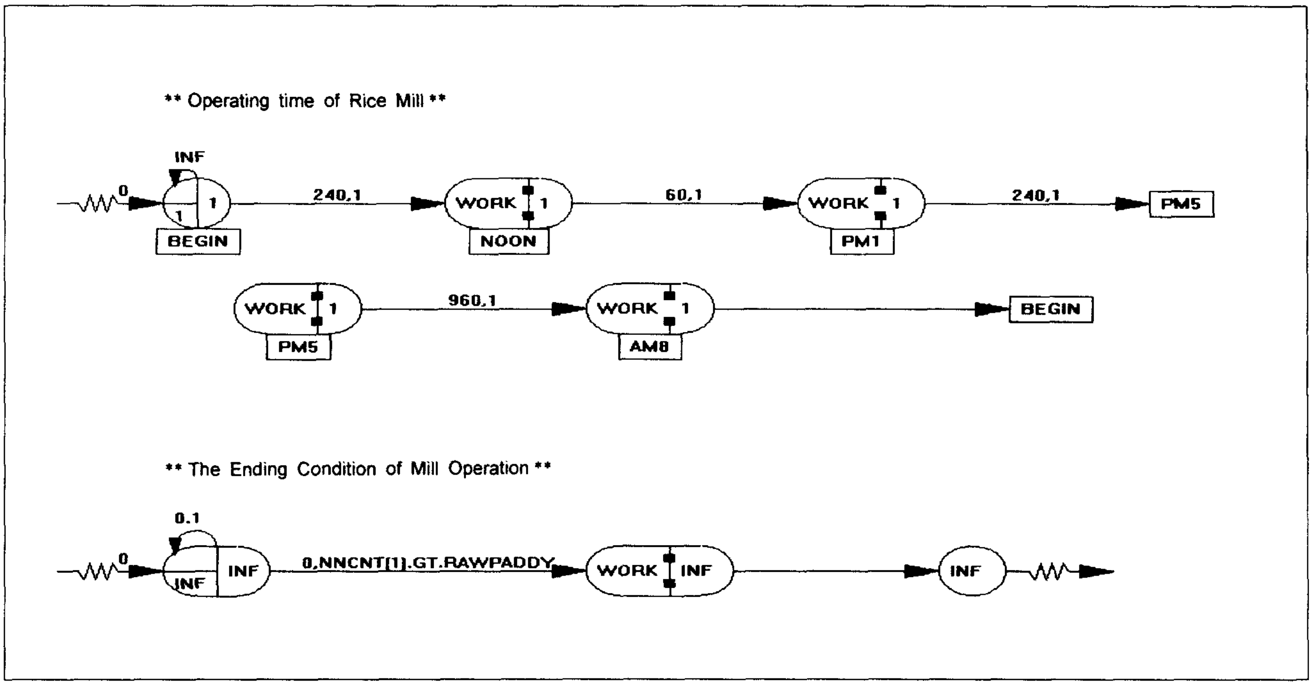

Fig. 3(2) The sub-network of the basic model.

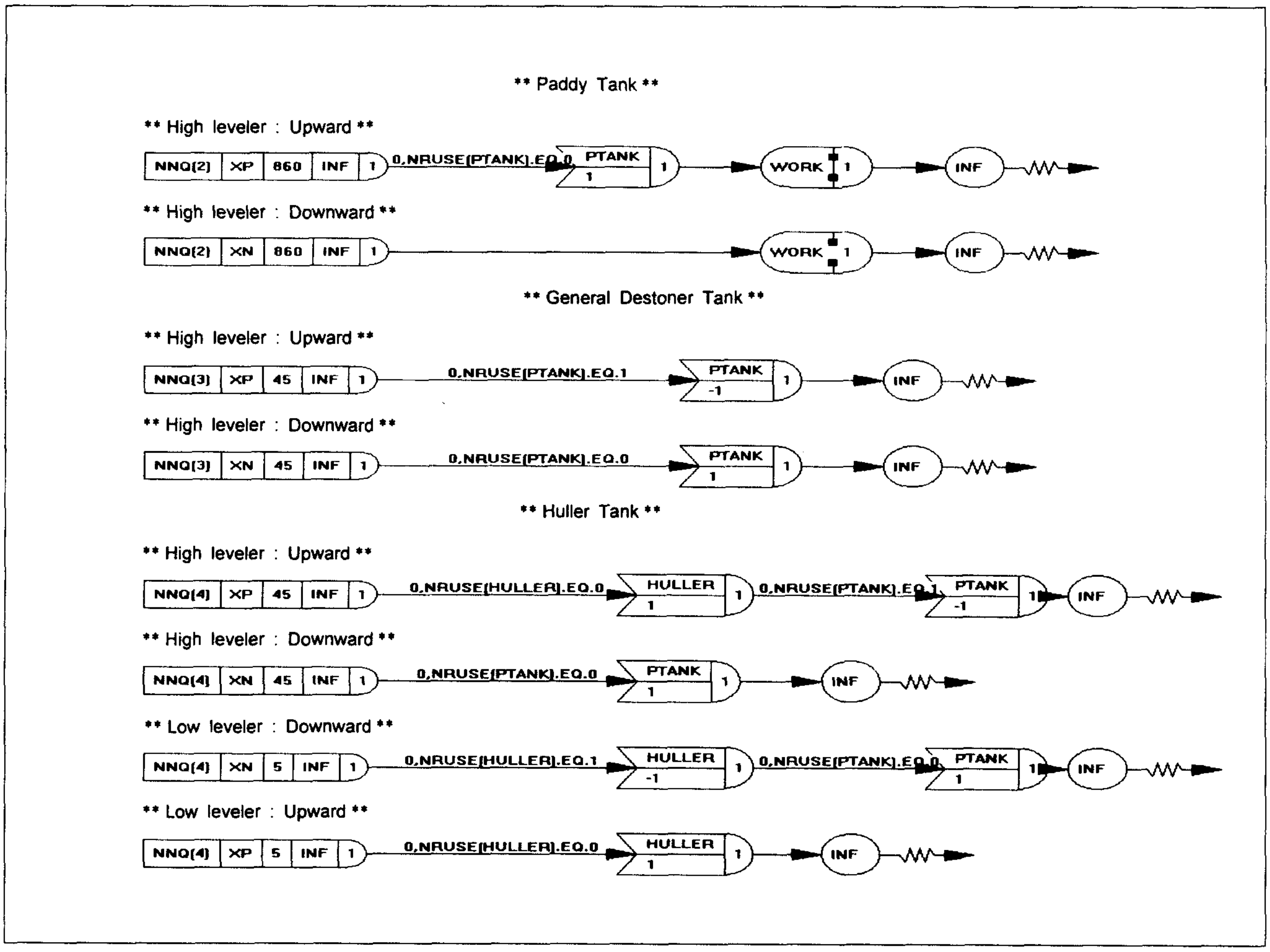

Fig. 3(3) The control network of the basic model.

the certain amount of materials was only taken into the system. The intaking time of materials was modelled 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 modelled in the user insert model. Also, the amount of intake materials was controlled in the user insert model using SUBROUTINE EVENT.

Results and Discussion

1. Simulation Results

The amount of outputs produced in each process was analyzed through the simulation. The hulling efficiency, milling efficiency, and the milled rice recovery were approximately 81.4%, 90.1%, and 73.2%, respectively 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 about 8 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.

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 upto about 2,800 kg. After the initial 2 hours, the level of the paddy tank was constant, and it decreased during

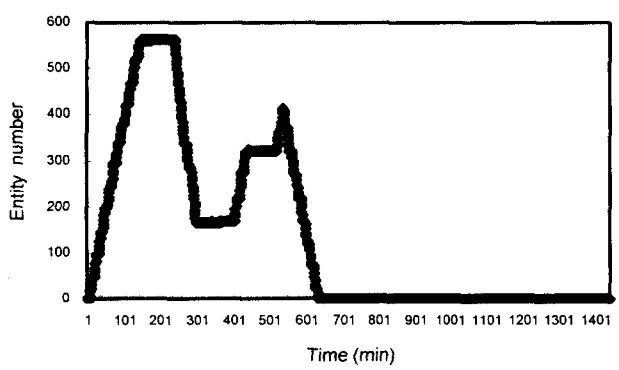

Fig. 4 The entity change of the paddy tank in the basic model.

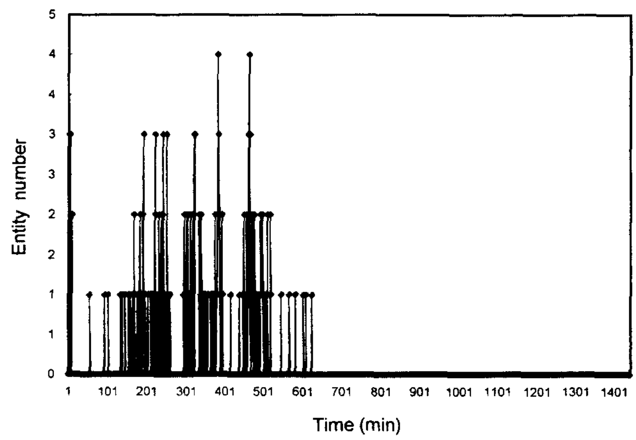

Fig. 5 The entity change of the huller auxiliary tank in the basic model.

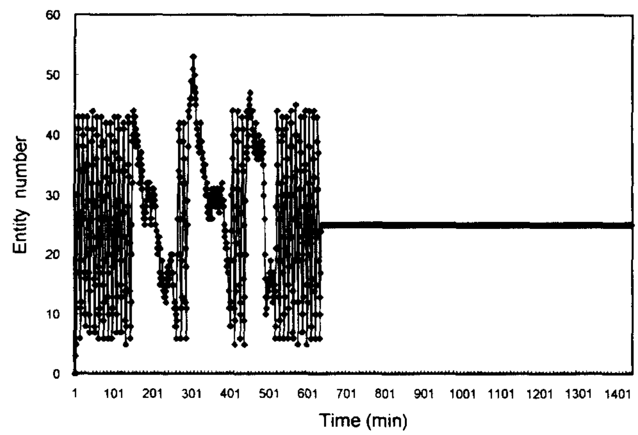

Fig. 6 The entity change of the brown rice separator auxiliary tank in the basic model.

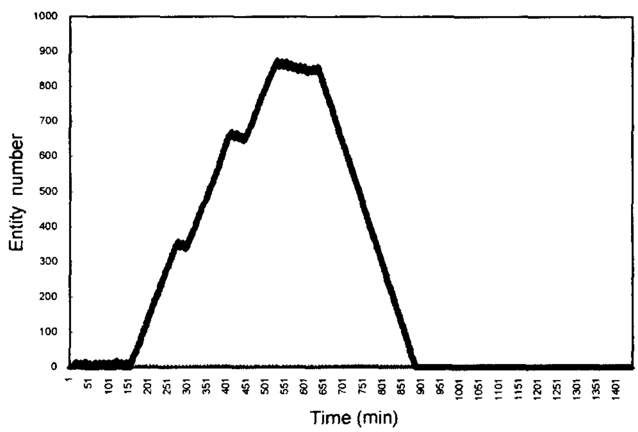

Fig. 7 The entity change of the color sorter auxiliary tank in the basic model.

the lunch time. After the lunch time, 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 leveller or the low leveller of the auxiliary tank of a huller was often detected because the capacity of the tank was not enough. The upward detection of the high leveller of the auxiliary tank let the exit gate of the paddy tank close, and the downward detection of the low leveller 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.

2. Model Validation

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 the these results, the developed simulation model could be used for analyzing the rice mill plant and for predicting the outputs produced in the processes.

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 (%)
	Weight (kg)	Percent (%)	Weight (kg)	Percent (%)	
General De-Stoner/(Stone)	0.649	0.03	50	0.025	-0.05
Huller/(Husk)	390.9	17.8	3,490	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)	1,598	73.5	14,495	73.1	-0.4
Total	2,195	100	20,000	100	

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 feed-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 leveller 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.

Conclusions

A rice mill plant with a capacity of 3 ton/hr in paddy 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, other materials produced, and bottlenecks in the processes. The results of hulling efficiency, milling efficiency, milled rice recovery in the simulation were 81.1%, 89.5%, and 73.1%, respectively, 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 phenomena 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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