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REVIEW

Study of a Possible Method for Transmitting Knowledge on the Cleaning of Combine Harvester Interiors

Mitsuyoshi SHIMAZU[1]*, Naonobu UMEDA[1], Eiji KURIHARA[1], Masaki UMEMOTO[2], Junko YAMAMOTO[3], Hitoshi OGIWARA[4] and Kazuyoshi NONAMI[5]

[1] Institute of Agricultural Machinery, National Agriculture and Food Research Organization, Saitama, Japan
[2] Central Region Agricultural Research Center, National Agriculture and Food Research Organization, Tsukuba, Japan
[3] Agri-Food Business Innovation Center, National Agriculture and Food Research Organization, Tsukuba, Japan
[4] Institute of Crop Science, National Agriculture and Food Research Organization, Tsukuba, Japan
[5] Faculty of Agriculture, Tottori University, Tottori, Japan

Abstract

With the objective of transmitting high level skills to clean the interior of a combine harvester, a method to create a new cleaning manual based on empirical knowledge was developed. Firstly, in this method, the knowledge of expert workers is extracted from interviews and from watching videos of them performing cleaning works. Secondly, the extracted knowledge is summarized in a table and finally, written in sentences with corresponding figures. To verify its effect, a cleaning manual was created based on the developed method and a cleaning test was conducted. As a result, the amount of residual grain remaining in the machine after cleaning significantly decreased.

Discipline: Agricultural Engineering
Additional key words: contamination, efficiency, residual grain, user's manual

Introduction

The recent increase in the production of rice that is in demand in Japan has created a need for the development of a technology that prevents the mixture contamination of different cultivars in produced rice grains. The main cause of mixture contamination in harvesting work is the grains that remain inside combine harvesters. The best way to solve this problem is to clean the interior of the machine after harvesting. However, because of the complexity of the internal structure of combine harvesters, a highly accurate cleaning process requires knowledge of the structure and the cleaning methods mostly derived from the experience of maintenance and cleaning works of combine harvesters. Since these are not mentioned in the user's manual, the operators need to empirically learn practical technique of cleaning by themselves or from a more experienced colleague. It is, therefore, necessary to develop an effective method of transmitting the knowledge required to clean combine harvester.

In this study, with the objective of establishing a technique to prevent mixture contamination in combine harvesting, a field survey to examine the contamination level inside a combine harvester was conducted, and a method to create the manual that can easily transmit the knowledge and skills for cleaning combine harvester with high accuracy was developed.

Field survey on rice contamination

To determine the level of contamination inside a combine harvester that occurs when switching to another type of rice grain, we calculated the contamination rate. In addition, the contamination rate in the case of cleaning before switching to another type of rice grain was also calculated.

*Corresponding author: e-mail mshimazu@affrc.go.jp
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1. Method

The combine harvester used in the test was a four-cutting-rows head-feeding grain tank type (Model: CA355, Maker: Yanmar). For the survey, non-glutinous rice grains (cultivar: *Koshihikari*) were harvested after sticky rice grains (cultivar: *Ekonomochi*). Then the proportion of sticky rice grains that mixed with the non-glutinous rice collected from the grain port (contamination rate) was calculated every 10 min from the start of each harvest. With regard to sorting, the grains were firstly dyed with iodine and potassium iodide solution. Then, approximately 2 kg of sample rice grains (approximately 100,000 grains) were sorted using a color sorter.

2. Results and discussion

The relationship between the cumulative amount of harvested non-glutinous rice and contamination rate is shown in Figure 1. Generally, the allowable upper limit value of mixture contamination of rice varies depending on uses and areas. As an example, the limit value that the Japanese government regulates for the highest-grade rice used for staple food is 0.3% and for the highest-grade rice used for brewing, 0.1% (Ministry of Agriculture, Forestry and Fisheries of Japan). When the cleaning was performed, contamination rate was less than 0.1% from the beginning of the harvesting, and almost no contamination was detected after a cumulative amount of 100 kg. On the other hand, without the cleaning, contamination rate was approximately 10% at the beginning of harvesting, and contamination was detected even with a cumulative amount of 200 kg. These results indicate that cleaning the combine harvester is highly effective in reducing the contamination rate, confirming that high-precision cleaning can largely prevent contamination when harvesting different product types.

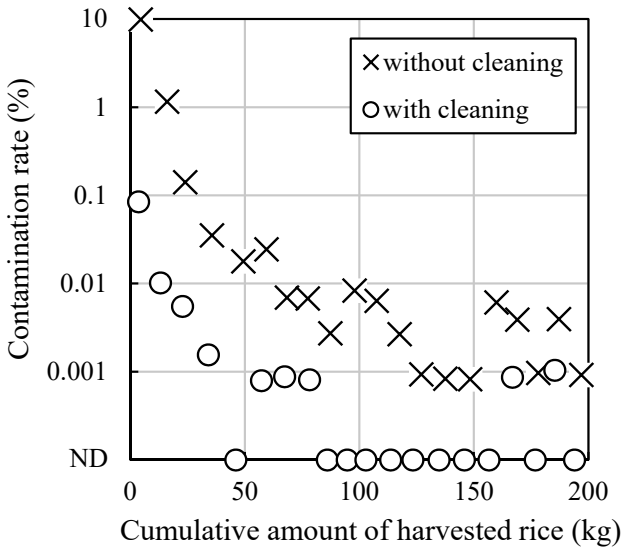

Fig. 1. Cumulative amount of harvested rice and contamination rate
*ND: not detected

Development of a technique to create a high-precision cleaning manual

A method to extract the knowledge and skills needed to perform a high-precision cleaning and turn it into a manual was developed.

1. Knowledge extraction

In a previous study, Umemoto and Yamamoto classified agricultural knowledge into three types: "typical knowledge," which demonstrates the objectives and content of an operation; "sensing and operating skill," the ability to assess working conditions and control the machines as intended; and "intellectual management skill," the ability to plan and modify the procedures and methods of an operation (Umemoto & Yamamoto 2010, Yamamoto & Umemoto 2011). They then proposed a technique that extracts those elements through interviews with and observations of experienced operators. The same technique was applied in this study to create a method of knowledge extraction. The procedure is indicated below:

(1) Recording the operation

Using video cameras, we recorded an expert cleaning the interior of a combine harvester from two different angles. The first angle is a wide image that includes the machine and the expert as he registers the "entire work flow," including his actions and movement path (Fig. 2). When the operator moved, this camera moved along with it. The other angle, filmed through a small camera attached to the expert's head, presents a view of the expert's visual field in an effort to register the expert's "specific actions," such as the performance of manual operations and where the expert directs his attention (Fig. 3).

(2) Interview

We then watched the recorded video with the expert and asked him questions (Fig. 4). The interview was carried out as a three-step process. The first step focuses on typical knowledge, such as the "work outline," which is the objective and the expected effects of the work; the "work conditions," or the necessary tools, environment, and ability requirements of the operator; and "precautions," which are the things the operator should be careful of throughout the operation. The second step consists of asking intellectual management skill while observing the wide image. The operator commented on whether the sequence of the operation was logical, if there were excessive or missing operations, and if the method was adequate and so on. The third step is dedicated to

Fig. 2. Camera for wide image

Fig. 3. Camera for a view of the expert's visual field

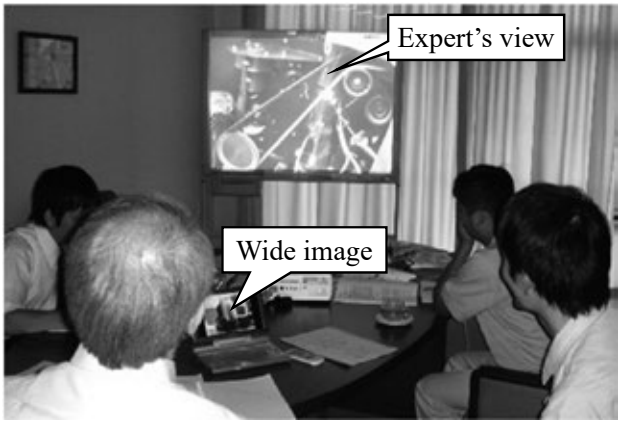

Fig. 4. Interview

sensing and operating skill questions. While observing the expert's visual field, we asked the operator to focus on two things:

1) What the expert is looking at, what kinds of sounds they were trying to listen to, and what kind of decision did they make for what kind of reason, and so on.

2) The working method and the control of cleaning tools, including how the tools such as the air duster were used, when they were started and stopped, the best way to handle them, and so on.

2. Knowledge summarization

The knowledge mentioned in the previous paragraph is summarized by operation process in a table. This table, based on the skills analysis table proposed by Mori & Mori (2007), is composed of a "General Part" and a "Process Part." The General Part summarized the work outline, conditions, and precautions based on the answers of typical knowledge questions. The Process Part summarized the work process and how to best execute the operations based on the results of the intellectual management skills and the sensing and operating skills questions. Lastly, the content of the skills analysis table was checked by the expert and corrected if necessary.

3. Writing knowledge in sentences

After summarizing the knowledge, it needs to be written in sentences. Firstly, based on the General Part of the skills analysis table, the "complete picture of the cleaning operation," the "important aspects of cleaning operation," and the "work environment, ability requirements, and necessary tools and equipment," must be written at the beginning of the manual. Then, based on the Process Part of the skills analysis table, the text of the previous manual is reordered in a sequence that improves work efficiency and accounts for new techniques, such as Work Procedures and Precautions. In addition, figures are added to the sentences. These figures are pictures of working parts and schematic drawings of the internal structure that provides a better visual understanding. The last step is to organize the body in a format that is easy to read and have the content checked by an expert. This concludes the creation process of the cleaning manual.

Effect verification test

To verify the effect of the method developed, a test was carried out wherein an operator cleans the interior of the machine using the cleaning manual (referred to as the "new manual" from hereon) and without using it. We examined the residual grain inside the machine after cleaning and the time required for cleaning. The test was

conducted once to one model of combine harvester, and there was no replication.

1. Method

To create the new manual, a technician of the test machine manufacturer performed the cleaning operation, and his knowledge was extracted and summarized and written with the developed method. The combine harvester used in the test was a two-cutting-rows head-feeding grain tank type (Model: VM217, Maker: Mitsubishi Agricultural Machinery). The crop used in the test was paddy rice (cultivar: *Asanohikari*). In order to examine the differences by the experience of the operators, two operators were selected: one who regularly engages in agricultural operations and has experience with the test machine (referred to as the "experienced operator") and another with little experience both with agricultural operations and the test machine (referred to as the "beginner"). After filling up the test machine tank with harvested rice grain, the cleaning of the machine interior was carried out with an air duster connected to an air compressor (pressure: 0.7 MPa). When the previous manual was used (referred to as "the previous method"), the cleaning process was executed arbitrarily, since the previous method did not contain a work procedure. When the new manual was used (referred to as the "knowledge method"), the procedure described in it was followed. To analyze the amount of grains remaining inside the machine after it was cleaned, the grains were collected according to the classification in Table 1, and its wet weight was measured. To analyze the time required in the cleaning, the operation was classified into three processes indicated in Table 2, and the required time was measured, excluding the time to consult the manual.

2. Results and discussion

Figure 5 shows the part of a new manual and the method of cleaning the interior of the machine in an efficient sequence and with high accuracy equal to a skilled operator. It contains figures and pictures, part names, as well as the internal structure of parts invisible to the viewer so that the work procedure can be easily understood and memorized. Moreover, the important points were marked with attention stickers (Fig. 6) to remind the reader of the most important points indicated in the beginning. The amount of time required to create the new manual is 16h (knowledge extraction process, 4h; knowledge summarization process, 4h; and knowledge writing process, 8h). Since the new manual is created while watching the videos, if the combine harvester is large and demands more time for cleaning, then the time required to create the manual will also be expected to increase. The amount of grains remaining in the machine after it was cleaned and the cleaning time required are shown in Table 3. The amount of grains was reduced from 54.1 g to 4.6 g in the beginner and from 59.9 g to 3.0 g in the experienced operator. This reduction was particularly significant in the grain tank and the grain unloader. Since the machine has many parts whose interior cannot be visually checked, a considerable number of grains would remain when the previous method is used. With the knowledge method, however, it is possible to infer that the operator was able to learn about the internal structure from the new manual, which contributed to the reduction of the grain volume remaining inside the machine. The experienced operator omitted a removal work of selection part components in the previous method, and therefore, a considerable number of grains remained. However, with the knowledge method, the removal work was carried out, and the amount of residual grain largely decreased. The

Table 1. Classification of the cleaning area

Classification	Parts
Threshing area	Threshing unit, Feed chain, Straw discharge unit
Separating area	Grain sieve, Chaff sieve
Grain conveyor area	Cleaning fan, Grain conveyor, Second threshing unit
Grain tank area	Grain tank, Grain unloader

Table 2. Classification of the cleaning process

Classification	Work and Operation
Cover open process	Opening covers, Detaching parts
Grain remove process	Removing residual grain with air duster
Cover close process	Closing cover, Attaching parts

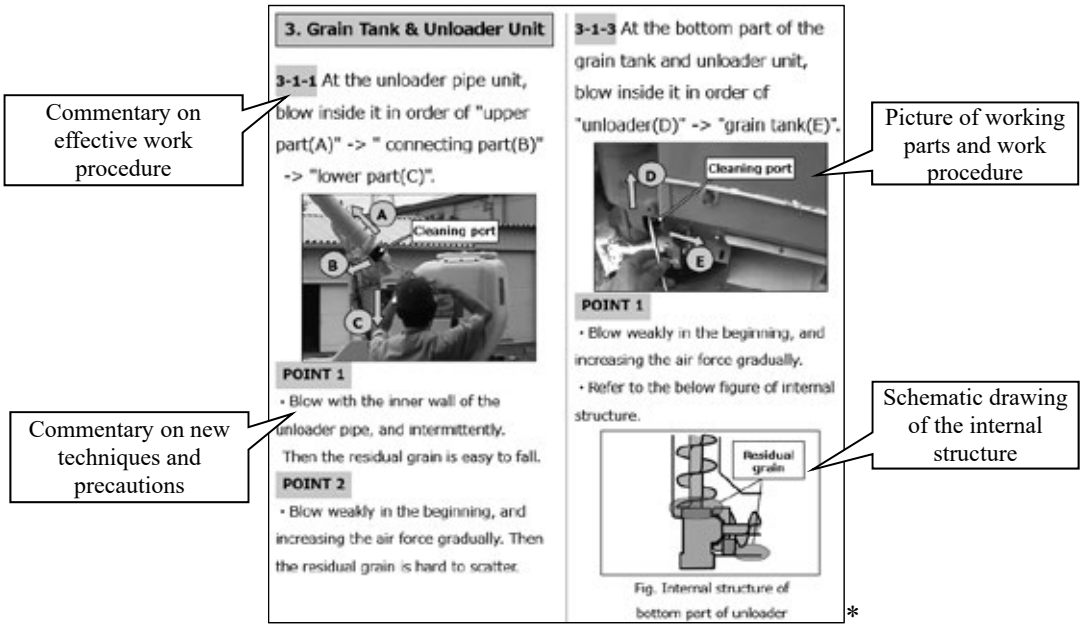

Fig. 5. Example of created knowledge manual

* referred from the website of the Ministry of Agriculture, Forestry and Fisheries of Japan (translated into English)

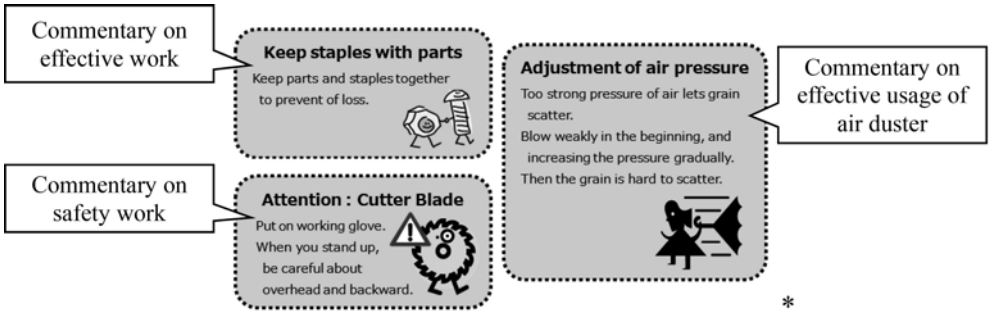

Fig. 6. Attention stickers

* referred from the website of the Ministry of Agriculture, Forestry and Fisheries of Japan (translated into English)

Table 3. Residual grains and required time

Operator:		Beginner		Experienced operator	
Manual:		Previous	Knowledge	Previous	Knowledge
Residual Grain (g)	Threshing area	6.3	2.1	4.4	1.2
	Separating area	1.0	1.1	22.6	0.5
	Grain conveyor area	17.5	1.0	9.4	0.9
	Grain tank area	29.4	0.5	23.5	0.5
	Total	54.1	4.6	59.9	3.0
Required Time (min)	Cover open process	20.8	15.0	11.8	16.8
	Grain remove process	21.6	21.4	24.3	18.0
	Cover close process	25.1	20.4	22.0	28.4
	Total	67.5	56.7	58.0	63.2

new manual enables arousing an attention to the cleaning work of the operator even in the experienced operators. These results indicate that the developed technique to create the knowledge cleaning manual has the potential to reduce the number of grains remaining in a combine harvester. However, this test was conducted only once (no replication) and to only one model of combine harvester. Therefore, more conducts about other models of combine harvester or workers are required for the practical use of the new manual. The beginner's cleaning time was slightly reduced from 68 min to 58 min, which was attributed to the more efficient work sequence. On the other hand, the experienced operator's time slightly increased from 57 min to 63 min, probably because an operation (removal of selection part components) that was omitted in the previous method was executed in the knowledge method. These results indicate that, although in some cases the cleaning time was slightly reduced depending on the operator, not a significant effect could be expected. Based on the fact that the cleaning operation required an equivalent amount of time even when it was performed by an experienced operator, modifying the internal structure of the combine harvester is seen as a more effective solution to reduce the operation time than improving the cleaning technique.

Conclusion

In this study, with the objective of establishing an efficient technique to prevent contamination in combine harvesting, a method to create a manual (knowledge cleaning manual) that incorporates technical and experience-based combine cleaning knowledge was developed. An example of the knowledge cleaning manual is introduced in the website of the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF) as a technique to prevent contamination in the production of feed rice.

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