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REVIEW

Development of Rotary-type High Speed Puddling Harrow

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Abstract

In order to improve the work rate of puddling, we developed rotary-type high speed puddling harrows. The stubble burying performance and the soil pulverizing performance of the developed puddling harrows were nearly the same as those of conventional puddling harrows working at 20 to 30% slower travel speeds. Power requirement of the developed puddling harrows were similar to those of conventional harrows. When the developed puddling harrows worked at 24 to 30% higher travel speeds than the conventional harrows, work rates of the developed puddling harrows were 21 to 22% larger, and the fuel consumption of the developed puddling harrows was 13 to 15% less than that of the conventional harrows.

Discipline: Agricultural machinery
Additional key words: power requirement, soil pulverizing, stubble burying, work rate

Introduction

In Japan, rotary harrows are a major equipment for puddling in paddy fields. Although the folding type puddling harrow which has wide working width has been developed, the work rate of puddling is still low[5] because two or three repeated passes are necessary for accurate puddling. High speed puddling is also difficult because work accuracy such as stubble burying performance and soil pulverizing performance is reduced.

Based on this background, we developed rotary-type puddling harrows that had high performance on stubble burying and soil pulverizing, by installing new rakes in front of the rear cover and improving the arrangement of the blades. The developed puddling harrows have been commercialized and are widely utilized.

Results of the fundamental tests

We discussed the problems to be solved and the factors related to high-speed puddling and then conducted fundamental tests on non-holding type puddling harrows. The following results were obtained[1,2]. (1) The stubble burying performance was improved by installing a large rake. The good average lateral clearance of the large rake teeth was 37 to 45 mm. (2) It was better to adjust the mounting positions of the large rake according to the soil conditions. (3) The blade arrangement in which a pair of blades was installed 15 mm apart laterally yielded higher stubble burying and soil pulverizing performance than the conventional blade arrangement. (4) The PTO specific power of the harrow with rotary blades at a cutting angle of 95° was 5 to 10% less than that of the harrow having 105° cutting angle blades. However, the stubble burying performance of the 95° cutting angle blades was worse than that of the 105° cutting angle blades. (5) Increasing the blade rotating speed 8% improved the soil pulverizing performance slightly but degraded the stubble burying performance and increased the PTO specific power by 14%.

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Outline of the prototype puddling harrows

Two prototypes of rotary-type high speed puddling harrows (Fig. 1) were manufactured[2] based on the fundamental test results. The working widths of these machines were 2.4 m for the non-folding type and 3.0 m for the folding type. The rotary blades were the same as those of conventional harrows, the cutting angles of which were 105° for the non-folding type and 88° for the folding type (Table 1).

These puddling harrows had the following features. (1) New large rakes were installed in front of the rear cover (Fig. 2). The lateral clearance of large rakes was 37 mm for the non-folding type and 42 mm for the folding type. The mounting position of the large rakes could be adjusted according to the soil conditions. (2) The lateral arrangement of the blades was changed (a pair of blades was installed 15 mm apart laterally) in the non-folding type (Fig. 3). (3) The inner volume of the rear cover was larger than that of conventional harrows.

Working performance

1. Work accuracy and power requirement

Two prototypes of rotary-type high speed puddling harrows and two conventional rotary-type puddling harrows were employed to investigate the accuracy of puddling in six paddy fields (soil texture: LS, L and SiC) and

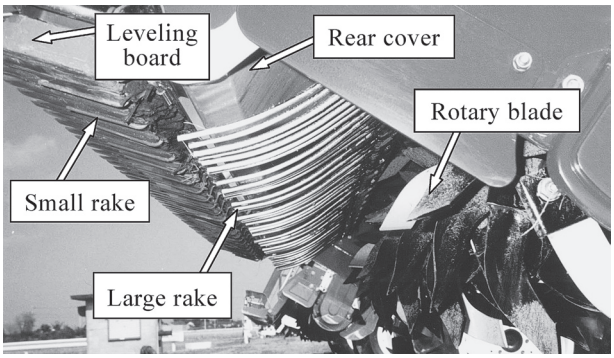

Fig. 2. Construction of high speed puddling harrow

a) Non-folding type b) Folding type

Fig. 1. Prototype of high speed puddling harrows

Table 1. Specifications of developed and conventional paddling harrows

Kind of machines		Non-folding type		Folding type	
		Developed	Conventional	Developed	Conventional
Working width (m)		2.4	2.4	3.0	3.0
Total mass (kg)		309	293	410	425
Adaptable tractor (kW)		18–34	18–34	24–46	24–46
Blade	Number of blades	64	64	80	80
	Lateral installing interval (mm)	60 or 15	75.5	72	72
	Rotational radius (mm)	185	185	180	180
	Cutting width (mm)	46	46	55	55
Large rake	Diameter of rods (mm)	6	–	8	–
	Average pitch (mm)	42	–	50	–
	Average lateral clearance (mm)	37	–	42	–
Small rake	Diameter of rods (mm)	4	4	4	4
	Average pitch (mm)	100	100	60	60

power requirement in four paddy fields (soil texture: LS and SiC)[3]. The following results were obtained. (1) The stubble burying performance and the soil pulverizing performance of the developed puddling harrows exceeded that of the conventional harrows at the same travel speed as the developed puddling harrows (Figs. 4 and 5). (2) The stubble burying performance and the soil pulverizing performance of the developed puddling harrows were nearly the same as those of conventional harrows working at 20 to 30% slower travel speeds (Figs. 4 and 5). (3) The stubble burying performance and the soil pulverizing performance of the developed puddling harrows after two passes were almost equal to those of the conventional harrows at the same travel speed after three passes. (4) The average PTO specific power of the developed puddling harrows was almost equal to that of the conventional harrows in the primary puddling and the final puddling.

2. Work rate and fuel consumption

Two prototypes of rotary-type high speed puddling harrows and two conventional rotary-type puddling harrows were employed to investigate the work rate and the fuel consumption in a SiC paddy field[4]. When the developed puddling harrows worked at 24 to 30% higher travel speeds than the conventional harrows, work rates of the developed puddling harrows were 21 to 22% larger, and the fuel consumption of the developed puddling harrows were 13 to 15% less than that of the conventional harrows (Table 2).

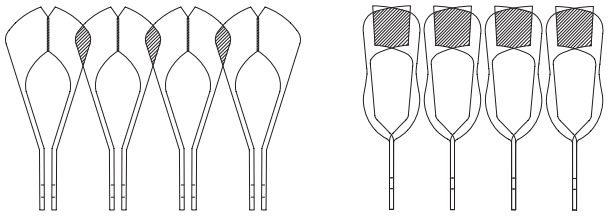

Fig. 3. Lateral disposition of rotary blades

Influence of high speed puddling on rice transplanting

Two prototypes of rotary-type high speed puddling harrows and two conventional rotary-type puddling harrows were employed to investigate the accuracy of rice transplanting after puddling in two paddy fields (soil texture: SL and SiC)[4], and the following results were obtained (Table 3). (1) The amount of exposed stubble after puddling and the rate of surfaced- and buried-seedlings after rice transplanting produced by the developed puddling harrows operating at the same travel speed as the conventional harrows were fewer than those produced by the conventional harrows. (2) The accuracy of puddling and rice transplanting that was produced by the developed puddling harrows operating at 20 to 30% higher travel speeds, and at one less pass than the conventional harrows was nearly the same as that produced by the conventional harrows.

Conclusion

The developed rotary-type high speed puddling harrows were more accurate for stubble burying and soil pul-

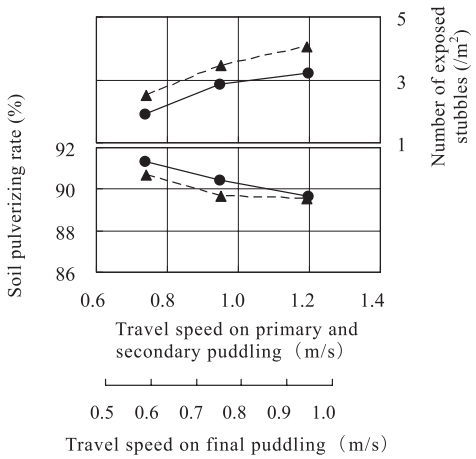

Fig. 4. Work accuracy of non-folding type paddling harrow (mean value of the tests in four fields)
● : Developed harrow, ▲ : Conventional harrow.

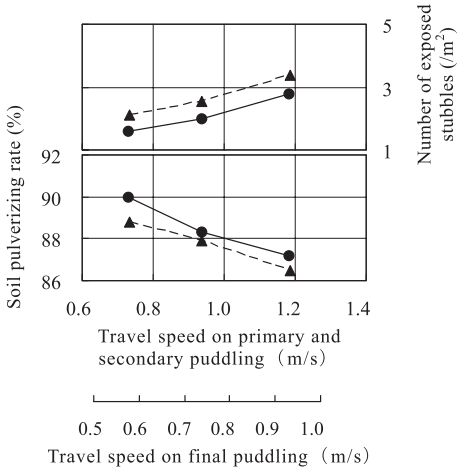

Fig. 5. Work accuracy of folding type paddling harrow (mean value of the tests in four fields)
● : Developed harrow, ▲ : Conventional harrow.

Table 2. Work rate and fuel consumption

Experimental plot		Non-folding type		Folding type	
		Developed	Conventional	Developed	Conventional
Travel speed (m/s)	Primary puddling	0.79	0.65	0.81	0.65
	Secondary puddling	0.79	0.66	0.82	0.66
	Final puddling	0.66	0.51	0.66	0.47
Work rate (a/h)		16.3	13.5	20.3	16.6
Fuel consumption (L/ha)		33	39	26	30

Table 3. Work accuracy of rice transplanting (mean value of the tests in two fields)

Experimental plot		Developed harrow			Conventional harrow 2 or 3 passes
		High speed 2 or 3 passes	Same speed 2 or 3 passes	Same speed 1 or 2 passes	
Travel speed of harrows (m/s)	Primary puddling	0.89	0.70	0.62[1)]	0.70
	Secondary puddling	0.78[1)]	0.62[1)]	–	0.63[1)]
	Final puddling	0.72	0.57	0.56	0.56
Number of exposed stubbles[2)] ($/m^2$)		4.1[a]	3.2[b]	4.7[a]	4.4[a]
Soil pulverizing rate (%)		88[a]	89[a]	87[a]	90[a]
Travel speed of rice transplanter (m/s)		0.8~1.0			
Planting depth[2)] (cm)		3.1[a]	3.1[a]	2.8[b]	2.8[b]
Surfaced seedling rates (%)		0.24[a]	0.19[a]	0.21[a]	0.26[a]
Buried seedling rates[2)] (%)		0.16[ab]	0.07[a]	0.08[a]	0.20[b]
Inclined seedling rates (%)		0.91[a]	0.76[a]	0.75[a]	0.76[a]

1): Data in one field.
2): 5% significant difference between a and b.

verizing than conventional models. Power requirements of the developed puddling harrows were similar to those of conventional models. As a result, even when the travel speed was increased, the performance of the developed puddling harrows was still similar to that of conventional models with a higher work rate and less fuel consumption.

We now expect to manage larger work areas more timely, reduce energy consumption and provide comfortable work by using the developed rotary-type puddling harrows. Rotary-type high speed puddling harrows have been sold since 2002, and three companies had manufactured 63,000 machines by Mar. 2010. The development of these machines has promoted highly efficient puddling work in paddy fields.

Acknowledgments

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