17. TECHNICAL PROBLEMS OF SMALL HARVESTERS

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Harvesting mechanization in Japan

A small binder and a small combine are popular harvesting machines and have come into wide use in Japan. The former cuts crops and makes them into a small bundle while the latter both harvests and threshes crops simultaneously.

In Europe and the United States, harvester, binder and combine of a large size have been widely used for the past 100 years and have shown a high performance in a vast stretch of upland.

A bundle made by a large binder is rather big, i.e. 1.5 to 2.0 m in circumference. However, a large binder does not give a high efficiency to the lodged plants or at the paddy field where soil pan is not hard enough to support this heavy machine. Due to the impracticability on paddy field, it is not widely suitable for use in Japan.

The self-propelled large combine was put into the production line about 40 years ago and has been introduced to give a better performance. More than 2 million units of large combine were distributed throughout the world, and about 600 units were imported and about 150 sets were made in Japan (Fig. 1) from 1962 to 1969. These large combines are called Direct-Flow Type Combines to distinguish them from the small ones made in Japan. Its cutter bar ranges from 2 to 5 meters in width.

Anyway, it is a huge machine for small Japanese paddy field. Table 1 shows the

Fig. 1. Direct-flow type combine.

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Table 1. Number of farm households by size of cultivated land under management

Unit 1,000

Area / year	Total	under 1 ha	1~2 ha	above 2 ha
1950	6177	4504	1340	333
1955	6076	4334	1390	352
1960	6057	4243	1431	383
1965	5665	3905	1375	385
1968	5350	3563	1335	452

number of farm households by the size of cultivated land under management. Researchers and others concerned have exerted their utmost efforts to scrutinize suitability of this giant machine to the field condition of planting area for paddy rice totalled 3 million ha in Japan and to utilize it at small Japanese paddy fields. However, farmers are not willing to use a large combine because it causes the grain losses and the damage to crops. In addition, another obstacle is that they themselves do not like their field to be destroyed by this giant machine unsuitable for use in a small plot. That is why, direct-flow type combines are shunned by farmers.

The economy of Japan has been greatly expanding so there has been a noticeable population drain from the rural to the urban areas as shown in Fig. 2 and Fig. 3. Consequently, the labor shortage in rural districts has become acute. To break such a serious situation, mechanized farming is an urgent problem facing the farmers.

The acute depletion of rural population was unavoidable. However the decrease in number of farmhands was only fractional. Consequently, what farmers want most or

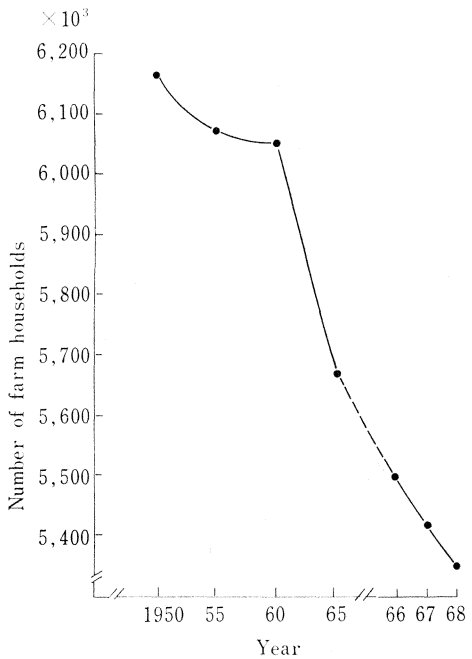

Fig. 2. Decreasing farm households in number.

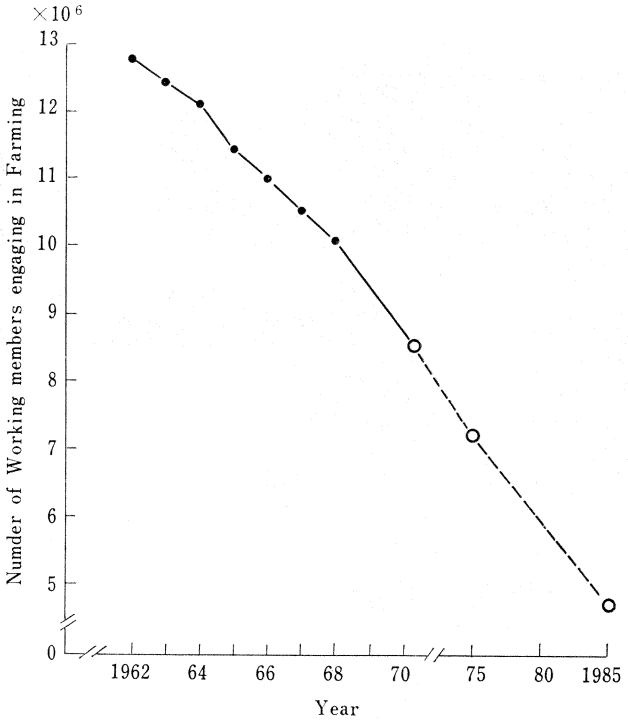

Fig. 3. Decreasing number of working members engaging in farming

the aim of mechanization lies not in a higher capacity of machines but in a quality of work. The majority of the harvesting machines they need is therefore the small type such as mini-combine or small binder with the length of the cutter bar ranging from 0.5 m to 1.0 m.

Small bundle binder

Harvesting of paddy rice and after-harvesting work traditionally consist of harvesting rice plants with sickle, making smaller rice bundles and drying them under the sun, as shown in Fig. 4. This is followed by threshing and drying the threshed grains by the grain driers. The dried grains are fed to the huller and the hulled rice or brown rice is sold to the Government.

More than 80 per cent of farmers in Japan harvest rice, following this process. So Japanese farmers most need to see that the conventional process is maintained. The binder is used for smaller size of bundle and its circumference is from 20 to 30 cm.

Regarding the knotting of twine, we have different ways of twisting and knotting string. We considered and tried various ways but could not find out an easy way to knot in spite of our efforts to improve the already completed and more complicated apparatus. Principally, we adopted the binding method of the Knotter Bill system, which was invented around 1880. This mechanism was miniaturized by one-tenth, compared with a foreign-made one. The binder adopting this knotting system was highly acclaimed on the market recently.

It is estimated that more than 600,000 sets of binder will be put on paddy field this year. They were sold so increasingly and rapidly during short years that 200 sets were sold in 1966, 10,000 in 1967, and 90,000 in 1968, 210,000 in 1969, and this year 295,000

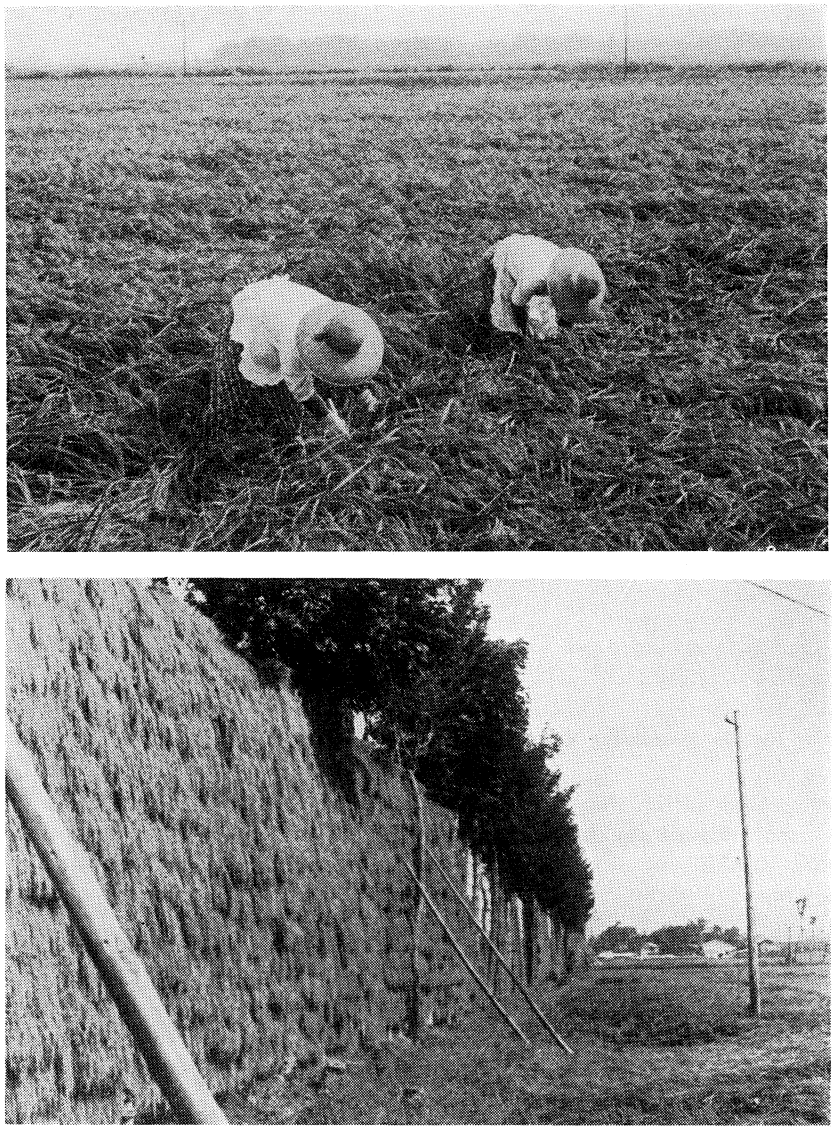

Fig. 4. Traditional harvesting operation in Japan upper; harvesting by sickle lower; drying on racks.

sets will be sold. The number of small bundle binders is shown in Fig. 5. We call this type of binder a small bundle binder against the large foreign-made ones.

Construction of a small bundle binder

The construction of a small binder is made up of a pick-up device with fingered chain for the lodged plants, 50 mm pitched cutter bar ranging from 30 cm to 75 cm in width, cut-stem conveying apparatus binding mechanism, travelling parts, engine and transmission.

The binder is drived by gasoline or kerosene engine with 3–5 ps. Fig. 6 shows the

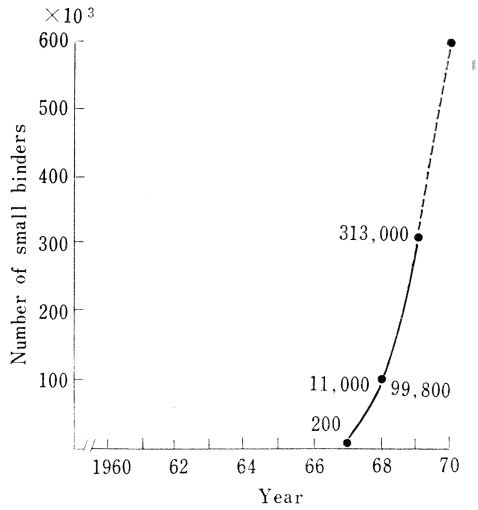

Fig. 5. Number of small binders on farms.

construction of small bundle binder and the size is shown in Fig. 7 and Fig. 8.

The specification of binder is as follows: the length ranges 200–230 cm, the width 90–150 cm, the height 100–130 cm, and the weight 200–270 kg.

A pair of pneumatic tyres, which are travelling parts, are installed at a rear portion of cutting device. The binder is a walking-type machine travelling within a range of 0.3–0.8 m/s. Travelling speed on the road becomes a little faster and is 1.3–1.8 m/s.

The knife bar has knife sections of 50 mm in width and most stroke is 50 mm wide.

Dividers are set in front of the cutter bar every 20 or 30 cm of the cutter width. The frontal processing apparatus has two functions to pick up the lodged plants and to support the upper portion of plants when they are cut, and it is fixed behind the divider with a certain angle. This apparatus is a pick-up device with a chain fingered by nylon twines.

Plants, being lifted by pick-up device, are cut by the cutter bar and sent to a side or rear portion of binder by conveyor. In case of conveying plant stems sideward, they

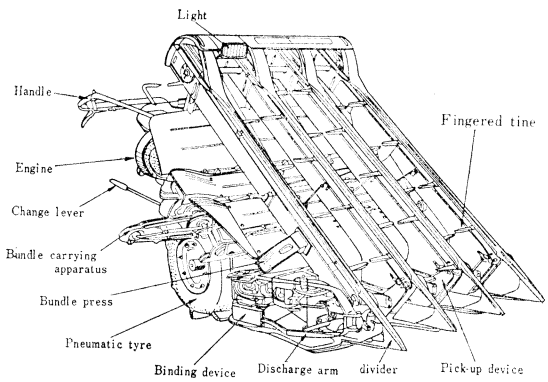

Fig. 6. Small bundle binder.

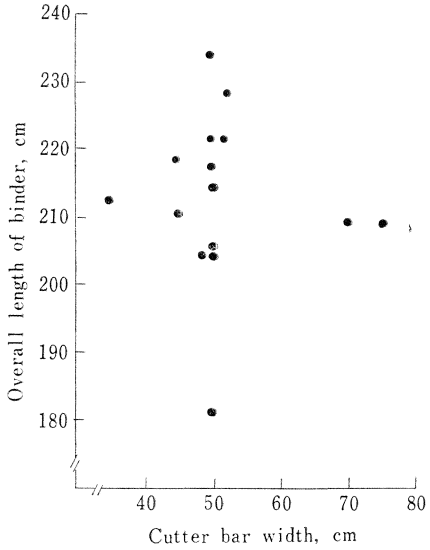

Fig. 7. The relation between cutter bar width and overall length of binder.

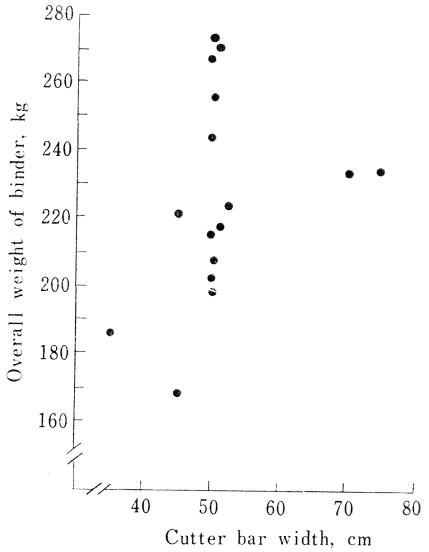

Fig. 8. The relation between cutter bar width and overall weight of binder.

are shot as far as a binding apparatus by star-wheel installed behind a pick-up device and a fingered chain or a belt for conveying stems sideward. In the latter case, plants are also carried to the binding apparatus of the machine by the star-wheel or a crank wheel and chain.

When plants conveyed and gathered in a pocket reach a given volume enough to be made into a small bundle and to press the clutch door with the aid of a packer arm, then the binding mechanism is put in motion which requires 0.2–0.3 seconds, and the discharge arms throw out the bundle to either side of the binder.

Jute, sisal and polypropylene are selected, as twine materials, and their tensile strength is over 40 kg/cm^2. Fig. 9 shows the construction of the cutter bar and the binding apparatus.

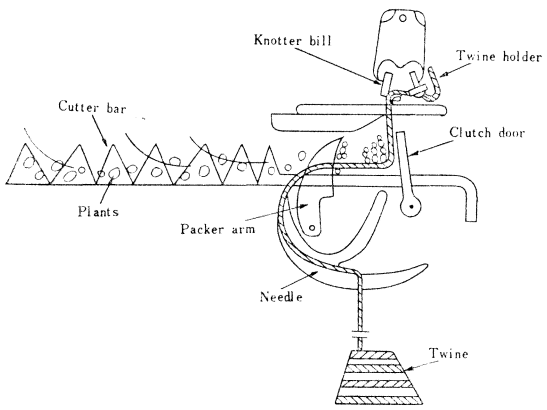

Fig. 9. Binding apparatus.

Fig. 10. Operation by binder.

Among the binders of this type, those equipped with a 50 cm cutter bar are distributed most popularly.

Operation of the binder

Operation of the binder is shown in Fig. 10. The small bundle binder also gives a good performance even in harvesting lodged rice or wheat whose standing angle is 20–30 degrees. The grain losses are minimized below 2 per cent. However a work is done less accurately when the standing angle drops as low as 20 degrees or below, and in proportion to the worse condition of lodging, the grain losses increase as shown in Fig. 11.

However, the binder is not available for harvesting wheat if fields are ridged.

The size of the bundle is adjustable within 1.2–1.6 kg. 1,500 to 1,800 bundles are made up per 10 a.

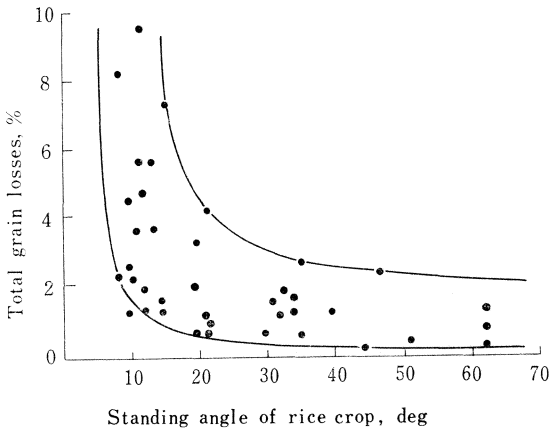

Fig. 11. The relation between standing angle of rich crop and grain losses.

When one cuts the plants along the levee as well as at the space where the binder is turned beforehand by the sickles, a highly efficient work of 6–13 a/hr is expected.

21 binders were put to test for 518 days selected in the harvesting season, the result of which shows that the proper harvesting days vary according to the varieties of rice and the regions. In the south area such as Kumamoto prefecture, they are 99 days, and in the north area such as Akita prefecture, they are 20 days. The average days required are 35 days in this season and binder can work for 25 days.

The harvesting area per day is 18 a to 55 a, and the average is 32.5 a. The average efficiency of work is 6.4 a/hr.

Binder starts to work at 7–9 o'clock am, and finishes at 4–6 o'clock pm, and the working hours are 5–10 hrs. per day and the average is 8.5 hrs. 7% of them is assigned for travelling field to field, 12% for adjusting and repairing, 21% for resting, including lunch time, and 60% for harvesting.

The mean horsepower required for the binding apparatus is about 0.7–0.9 ps, and 1.0–1.2 ps is also required for cutting and picking up units and 1.0–1.5 ps for travelling section. Thus, the total horsepower required for a binder with a 50 cm cutter bar ranges from 2.5–3.5 ps.

The fuel consumption is about 1.5 for harvesting 10 a.

Techhical problems of the biner

A small bundle binder works in a rice field of small size with high efficiency and causes few troubles as shown in Fig. 12, so Japanese farmers are content with it, but it has some problems.

Fig. 12. Frequencies of binder troubles.

The first problem is that the mechanization of binder needs much labor after mechanical binding. Farmers have to hang small bundles on racks and gather and transport them to threshers. This work requires 15 man-hrs for 10 a. A binder must take 6–8 laborers to harvest 32.5 a in one day.

The second is a weight of a binder. As a binder is heavy in weight, it can not work effectively in harvesting season when the paddy field is wet and soft. Our binder is equipped with low-pressured and wide tires, and yet it can not travel on soft field. We are promoting a study to lighten a binder and to simplify its mechanisms, especially, the knotting one.

The third is the characteristics of crops. When crops lodge down, and are shorter than 70 cm or longer than 140 cm, our binder can not cut and bind them perfectly.

Japanese-type combine, Jidatsu combine

Combine is a harvesting machine with two kinds of operation, that is, harvesting and threshing. The combine which is now developing in Japan is equipped with an axial-type threshing drum functionally different from a foreign-made one. In case of the latter all the harvested crops are fed to the threshing drum. On the other hand, a Japanese combine feeds not all the plants but the panicles to a threshing chamber in the rotating direction of a threshing drum while the whole plant are being conveyed in parallel with the axis of a rotating threshing drum.

We call this Japanese combine Jidatsu Combine, or a so-called head-feeding thresher type combine.

100,000 sets of Japanese combine will have been distributed on farms this year. 1,000 sets were sold in 1967, 15,000 in 1968, 40,000 in 1969 and 55,000 are expected to be sold

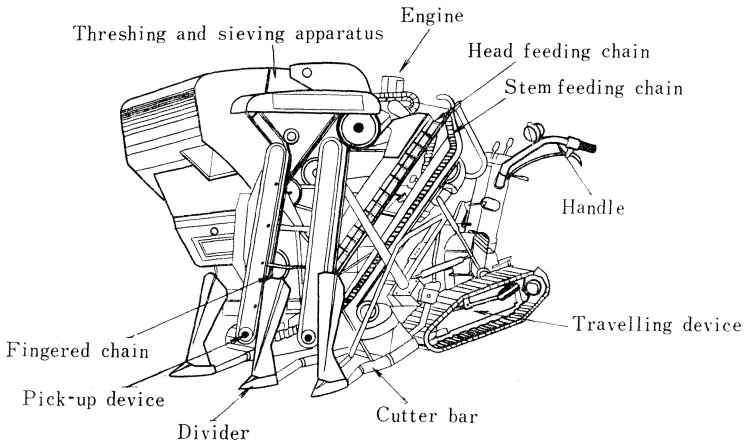

Fig. 13. Walking type 2 rows Jidatsu combine.

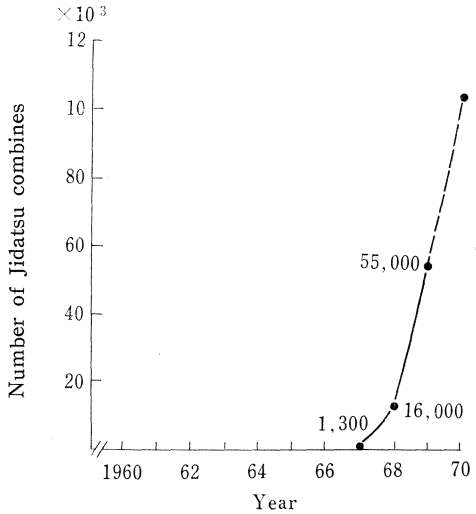

Fig. 14. Number of Jidatsu combines on farms.

this year, and this type of machine will also be rapidly distributed in the near future. Fig. 13 shows one of the Jidatsu combine and Fig. 14 the number of this machine on farms.

Construction of the Jidatsu combine

Jidatsu combine, a unique Japanese model, consists of engine, travelling device, cutting apparatus, pick-up apparatus, threshing and sieving section, and straw disposing section.

Almost all these combines are equipped with a crawler at their travelling device or trafficability and adaptability in paddy field, except such operations as crossing over levee or field work on the upland condition. Ground contact pressure of travelling device ranges 0.1–0.3 kg/cm^2.

The net weight of a 50 cm combine ranges from 500 to 900 kg, and it neither destroys the soil structure of paddy plot nor have any effect on land tillage work which is usually put into practice after harvesting rice.

The specification of a 50 cm combine is as follows: The length ranges 220–330 cm, width 160–240 cm, as shown in Fig. 15 and Fig. 16.

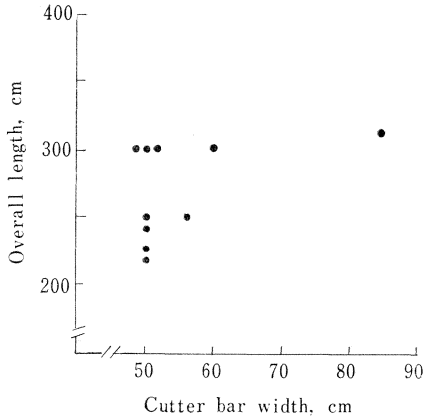

Fig. 15. The relation between cutter bar width and overall length of Jidatsu combine.

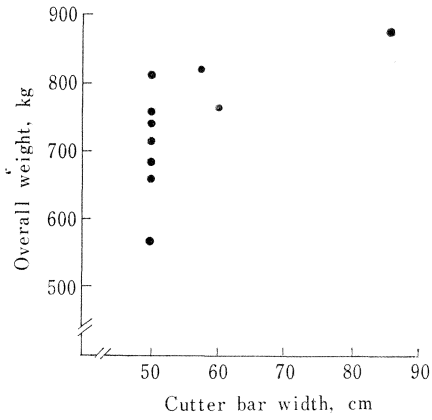

Fig. 16. The relation between cutter bar width and weight of Jidatsu combine.

Plants sometimes lodge due to the various kinds of natural or cultural condition. Therefore these plants have to be set right beforehand to cut efficiently. This sorting operation is performed by a divider and a pick-up apparatus. The pick-up device consists of rotating chains with nylon fingers. By selecting a proper titling angle of pick-up device and a proper rotating speed of chain, we can accurately not only rise up or cut the lodged plants but also convey them to a threshing machine, and besides grains are not shredded.

The cutter bar is made up of 50 mm wide knife sections, the wedge angle is around 20 degrees and the cutting angle is more or less 30 degrees. This cutter is a reciprocating type with a range of 1.0–1.5 cutting velocity ratio (cutting speed per travelling speed).

Cut and neatly arranged plants are ready to be threshed by a thresher mounted on a combine.

Cut plants are held at a basal portion by a feeding chain running in front of a

Fig. 17. Harvesting by the Jidatsu combine.

threshing drum at a speed of 0.2–2.4 m/s, while it takes 1 or 2 seconds to thresh them completely.

Threshing device of a combine consists of a threshing drum, wire teeth planted spirally on it with 12–14 m/s peripheral speed and a concave sieve with an 8–9 mm mesh. In addition, a small rethreshing drum is installed to some models.

Such a blower is a functional element in a cleaning section of a combine. Some new models have cleaning sieves with 1–2 m^2.

Operation of the combine

A cutter bar of a combine widely put on the market is about 50 cm wide, far smaller than its overall width. Thus, a small stretch along the levee has to be harvested by hand or any other means before combining, and in the paddy plot of 10 a (20×50 m), 1.0–1.5 a is the minimum space to be disposed of before combining. So we are developing a cutter bar as wide as the combine in order to dispense with hand reaping.

In Fig. 17, the operation of a Jidatsu Combine is shown.

Still Japanese farmers have shown a keen interest in this machine. This is because grain losses are under 3 per cent and grain damages are 0.1–0.5 per cent even when plants are harvested while stems are still pale green and contain moisture of high percent, or when they are hard to thresh, as is in the most rice planting areas in Japan. When the foreign-made combine is used under the same conditions, grain losses are estimated as much as 6 percent or more and grain damages 5 percent or more.

Those combines show a good performance in harvesting lodged rice whose standing angle is over 30 degrees, as in harvesting by small binder.

In the practical test of 28 sets of combine for over 1,028 days, the average operating hours for combine were 8 hours, from 9 a.m. to 5 p.m. Out of 8 hours, 3.8 hours are spent for harvesting and threshing, 1.2 hours for threshing only (stationary operation), thereby actual working hours for combine account for 63 percents. The other are spent for travelling (8%), for rest including lunch time (18%) and for repair and maintenance (14%).

Field capacity of the combine with cutter bar of 50 cm in width varies according to the

conditions. However, the mean daily capacity is estimated 15 to 35 ares per day. The average mean capacity for total operating hours is found 24 a per day. The capacity per hour shows only 4.8 a.

The mean required horsepower of the combine of this class to a certain extent depends on travelling speed of machine and harvesting capacity. When travelling speed of machine is 0.35 m/s and throughput of grain is 350 kg/hr., it will be around 4 ps, and travelling speed 0.6 m/s, and throughput 800 kg/hr and nearly 8 ps. The input allocation of horsepower of the combine is approximately 50 percent for travelling device, 10 per cent for harvesting device and 40 percent for threshing device, respectively.

Technical problems of the small combine

Today, the average land holdings per farm are merely 60 ares in the standard paddy cultivation regions. Nearly one million farms are estimated to hold more than 1 hectare, and they show a keen interest in mechanization of harvesting operation. Farms of above average holdings tend to call for more precision and a greater field capacity for small combines.

Because of its surplus production, the selling price of rice is expected not to increase at a high rate as that of the other commodities. In addition, labor shortage in agriculture is becoming more serious, while the size of land under management is increasing.

The first problem of small combine is that it requires preparatory hand reaping along the edge of field, as cutter bar width is smaller than the overall width of combine. The hand portion or headland for hand reaping is generally 10 to 15 percent of the total plot, and requires more or less labor. The reason of this disadvantage is that 50 cm wide cutter bar is of a greater capacity than thresher of the same width. Hand reaping would be omitted, if the capacity of 50 cm wide thresher would become double or triple.

The second problem is that small combine can work almost perfectly only when standing angle of stalk is over 30 deg. and height is 70 to 140 cm.

The third is the trafficability on wet paddy field, although ground contact pressure of crawler tractor is 0.1–0.3 kg/cm^2. Reduction in contact pressure will be our future task.