Threshing Performance of Japanese Type Combine

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Harvesters made in Japan have been typically developed resulting in peculiar shape and size since rice stalk in Japan is almost of the same height (0.8 to 1.2 m), the threshability at harvesting time is not so easy and the planting pattern is in line.

Moreover, a small and light type harvester has been generally used as the average land under management per farmhouse is small.

About 1,000,000 binders with a weight of 100–150 kg and about 100,000 combines weighing 600–800 kg have been popularized, the cutter bar width of which is about 0.5 m.

In this report, attention is focused on the performances of the Japanese type combine which is one of the topics for harvesting. The combine developed in Japan which is called Jidatsu-combine—so-called "head feeding type combine"—, as described before in JARQ Vol. 4, No. 1, 1969, shows a favorable quality of work at the time of harvesting Japanese rice varieties, with the grain loss below three per cent and damage grain under 0.5 per cent.

In contrast with such features, most of the combines have the main structure of the cutter bar and threshing mechanism in parallel and crosswise to the movement of the combine.

Thus, the threshing capacity is somewhat lower compared with the feeding capacity of the cutter bar, thereby the width of a 50 cm cutter bar is most suitable to which cylinder is 50 cm in width.

Consequently, it is necessary to clear the space along the levee and at the corner of the plot for combine turning in advance with a sickle before combining is started.

Owing to such causes, the harvesting capacity of the combine with a cylinder of width of 50 cm per day is low (25 to 30 a).

The results of the study on developed combine which has a width of cylinder narrower than 50 cm is small and light with a weight of below 150 kg, and has the threshing capacity two to three times larger than that of the conventional one with the same size as the present machine described in this report whose research was conducted during 1965–1971. The HT-711 type of the Jidatsu-combine with high performance which has been built on a trial basis following the results of the study is shown in Fig. 1.

Fig. 1. Prototype high capacity combine, manufactured for trial in IAM —IAM HT-711—

Improvement of the threshing mechanism efficiency

1) Threshability tester for rice

In order to make a tester with high measuring accuracy and easy to operate indicating the number of threshability of rice as numerical value, vibrating type, roll type, friction type which could be moved in front and back, shaking type and automatic threshing type testers have been built as a trial for further study of the threshing and separating mechanism and the comparative experiments of these testers have been accomplished.

As a result, it was proved that the automatic threshing type tester could indicate the threshability at the highest accuracy so the thershability of rice can safely be indicated as numerical value by using the tester.

2) Circulation of grains in threshing mechanism

Assuming that the materials flow to be threshed is 100 per cent in the case of a general combine, 110–120 per cent of grains are constantly circulated in the threshing mechanism.

In case of the poor adjustments of threshing parts and the worse condition of materials, it sometimes happens that too much load puts is applied on the amount of the work given, since the circulating rate reaches 150 per cent. About 90 per cent of grains in the threshing chamber fall down through the concave and about 10 per cent are discharged from the threshing chamber to a separating device. About 50 per cent of the chaff produced in the threshing chamber fall down through the concave and 20 to 50 per cent in weight of the tailings returned for rethreshing are chaff which is one of the causes decreasing the capacity.

3) Threshing process in threshing chamber

The process in which rice is threshed through the section and the concave of threshing mechanism has been studied by means of high-speed photography (800–3,000 coma/sec).

The heads of rice are threshed by V-shaped wire teeth as they are fed by the feeder-chain to the side way at a speed of 0.2 to 0.3 m/s for chain interval of about 50 cm.

In the course of threshing a rice head is to be stricken by the wire teeth 30 to 40 times in the threshing chamber. But practically, the rice head is almost shattered at the beginning of circulations, stricken two to three times.

Meanwhile, much tailings appear and the tailed grains are pulverized while they continue to circulate with the chaff in the threshing chamber.

There are many cases whereby grains are scattered to the feeding side of the threshing chamber on the concave for which the radial direction type one is used, and the falling speed of grains is mostly below 5 m/s. (See Fig. 2).

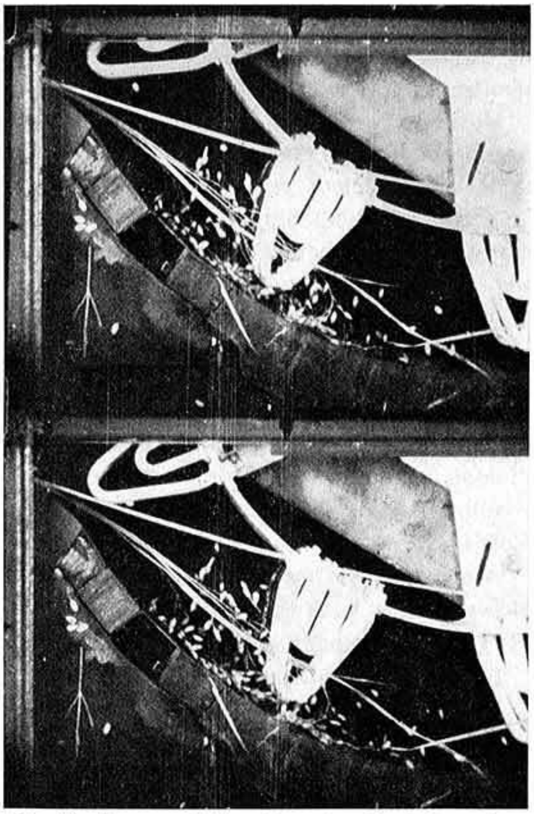

Fig. 2. Process of threshing rice head by wire teeth in the threshing chamber

4) Relation between grain throughput and threshability

Materials flow and grain throughput augment with an increase in the speed and the cutter width of the combine. While within a

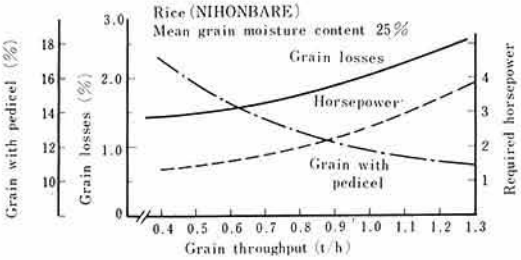

Fig. 3. Relationship between grain throughput and grain losses, required horsepower, grain with pedicels. (grain damage, under 0.5%)

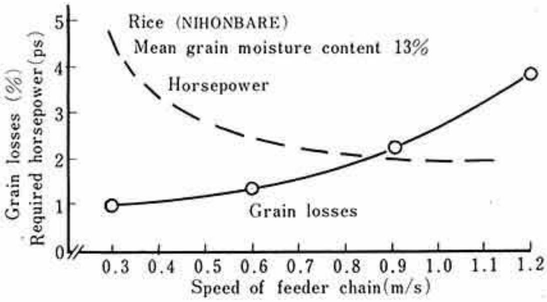

Fig. 4. Relationship between speed of feeder chain and grain losses or required horsepower in Jidatsu-combine

range of 0.4 to 1.6 t/h of grain throughput, the losses of grain such as unthreshed grains, scattered grains from the feeding outlet, etc. and the required power increase a little, and the grains through the concave and the grains with pedicels decrease. (See Fig. 3).

5) Relationship of feeder chain speed to threshing performance

The speed of the feeder chain of the general combine is in the range of 0.2 to 0.3 m/s. The limitation of the speeds and the corresponding threshing performance changes with the increase in speeds have been studied.

The loss of grain and grain with pedicels augment slightly with an increase of the feeder chain speed.

However, the grain loss can be reduced with an increase in wire teeth or with appropriate arrangements of wire teeth corresponding with the feeder chain speeds.

With an increase of the feeder chain speed, the production of chaff in the threshing chamber decreases and the required power is remarkably reduced.

Threshability could be greatly augmented with an increase of the feeder chain speed up to about 0.6 m/s on a cylinder which is 0.5 m in width. (See Fig. 4).

6) Relation between cylinder speed and threshing performance

The required power increases and the falling rate of grain from the concave increases to some extent as the peripheral cylinder speed at the outer end of the wire teeth increases in a range of 11 to 19 m/s.

When the speed gets above 15 m/s, few unthreshed grains appear while damaged grains increase inversely. The producing rate of chaff in the threshing chamber also increases with an increase in the cylinder speed.

7) Relation between number of teeth, their inclination and threshing performance

When the feeder chain speed is about 0.3 m/s, about 45 wire teeth would be sufficient on a cylinder 0.5 m wide, but when it is about 0.6 m/s, about 65 wire teeth would be required to obtain satisfactory threshing.

It is possible to decrease the production of unthreshed grains and grains with pedicels due to inclining the angle of three to four teeth on a row of the threshing cylinder.

8) Relation between cylinder size and threshing performance

According to the results of comparing the threshing performance for three kinds of large, medium and small diameters of the cylinder (about 600 mm, 520 mm and 400 mm respectively) when speed of the cylinder is constant (15 m/s), there are few differences in the required power, the quality of work and the falling rate through the concave, but the small cylinder is not so practical as it is hard to feed due to serious loss from the feeding outlet while in the case of the large cylinder much grains with pedicels appear. Consequently, the cylinder with a medium diameter of about 520 mm would be proper.

9) Relation between the number of limiting arch plate of concave and threshing performance

The limiting arch plate which is attached to the concave has an effect on separating unthreshed grains and tailings to single grains and also on grains falling down through the concave since the movements of heads and stalks are regulated in the threshing chamber by the plate. However, the appropriate number of the plates has not yet been clearly known.

10) Relation between concave shape and threshing performance

The crimp type concave woven with 2 mm steel wire is used in the Japanese combine. In order to develop the concave which, compared with the crimp type concave, (1) has more grain falling rate through the concave, (2) has more favorable condition of falling down and scattering of grains, (3) has higher capacity of treatment for tailings and grains with pedicels in the threshing chamber, (4) has no grains blocking in interstice of the concave when high moisture rice is threshed, (5) has less chaff produced by chopping straws in the threshing chamber, (6) requires less power, and (7) has more wear-resistant quality, five types of the concave have been built on a trial basis and experimented, changing the speed of the combine, materials flow, etc. and using as the sample dried or raw materials of rice or wheat.

First, the longitudinal plate type concave producing grain blockings show a low falling rate and an unfavorable process of making single grain.

Second, the parallel horizontal plate type concave, though it produces blockings, shows a favorable falling rate, scattering conditions of falling grains and process of making grains fine.

Third, the double parallel type concave which does not produce any blocking shows a favorable process of making grains fine and scattering condition of falling grains but shows a low falling rate of grains.

Fourth, the radial direction type concave shows a favorable falling rate of grains and an excellent performance for wheat, while the process of making rice grains fine and the scattering direction of falling down of grains are not favorable.

Fifth, the angle type concave which produces no blocking shows an excellent wear-resistant quality, a favorable process of making grains fine, and an excellent scattering condition of falling grains. By use of this type of concave, the Jidatsu-combine is expected to increase its efficiency. (See Fig. 5).

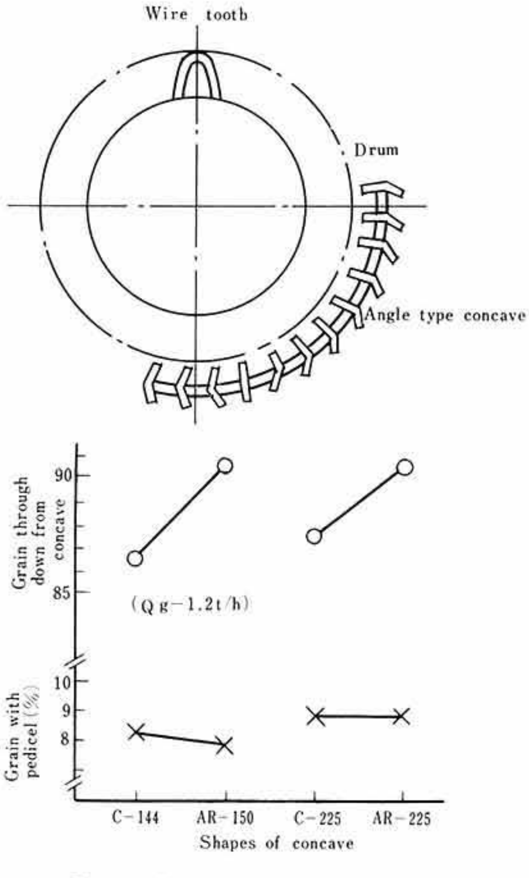

Fig. 5. Performance of the concave

Improving the performance of separating device (separating grains from chaff)

1) Utilization of tangential flow fan

Generally, the Jidatsu-combine is equipped with a centrifugal plate fan with a diameter of about 300 mm. However, it is necessary to make the winnower smaller in order to make the combine smaller. To achieve this object, a tangential flow fan producing parallel velosity of the wind was trially adopted.

It has been clarified that the tangential flow fan with a diameter of 150 to 200 mm could be used to obtain an average wind velocity of 9 to 11 m/s. (See Fig. 6).

2) Shaking grain pan and sieve under concave

A sieve is used to transfer the grains and the chaff fallen through the concave and separate the grains from the chaff.

Following is a description of the performance of the sieve with a small area.

When the rice grains are transferred by the feeder chain with a width of 400 mm, a length of grain pan of 450 mm and a length of sieve of 180 mm, there is no problem up to a grain throughput of 2.5 t/h, if the amplitude is 30 mm, the direction of vibration is 30° to 45°, the angle of the face of the sieve is below 5° and the number of vibration is above 300 cpm.

But when the grain throughput is more than 2.5 t/h, the amount of grain falling through from the end of the sieve is more than that of throughing down from the sieve. Consequently, the length of the sieve should be made longer from the structural point of view.

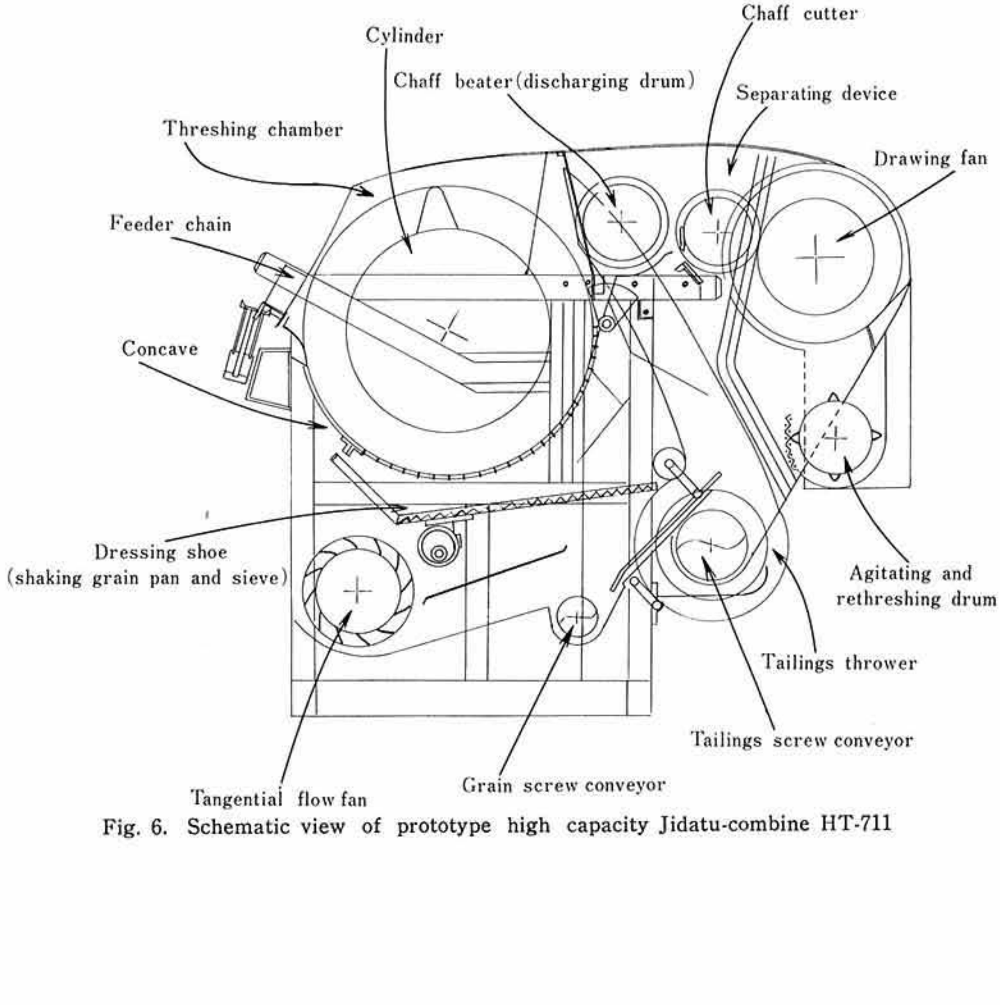

Fig. 6. Schematic view of prototype high capacity Jidatu-combine HT-711

3) Air flow in separating chamber with drawing fan

Most of the Jidatsu-combines are so designed as to separate the chaff and the grains which are discharged from the threshing chamber by means of shaking the grain pan and the sieve but separate them using the drawing fan for which a sealed separating chamber is equipped with the combine.

According to the result of investigation on the air flow in the separating chamber, most of the fans produce a swirl above the central line of the drawing fan.

The separating chamber has such a mechanism that the chaff floats in the swirl air flow, resulting the grains separating and falling down into the returned outlet for refreshing.

But since the heavy chaff with a high moisture content and the long chaff are not drawn into the drawing fan, they are returned to the threshing chamber, resulting in worsening the threshability.

4) Cutter and agitating, rethreshing drum equipped with drawing fan and separating chamber

A small cutter is equipped between the threshing and the separating chambers in order to cut the long chaff since the separating capacity is lowered when the long chaff is discharged from the threshing chamber to the separating chamber with the drawing fan. Due to this effect, it is possible to increase the capacity of the general Jidatsu-combine up to 1 t/h of grain throughput from 600 kg/h when high-moisture rice is harvested.

When the chaff is moist, even if it is short, it possibly piles up on the side wall of the separating chamber, and moreover the deposits (mass of piles) fall down on the tailings' screw conveyor and there is danger of the mass becoming plugged in the tailings thrower.

In order to avoid such a phenomenon and to make grains fine, an agitating and rethreshing drum is attached over the tailings' screw conveyor.

Due to the remarkable effect of this small revolving drum, it is possible that the amount of chaff returned for rethreshing is decreased, the tailed grains are made fine and the capacity of the combine is increased to a grain throughput of 1.2 to 1.8 t/h.

5) Shaking and separating performance of discharged material from threshing chamber

According to the experimental result of separating the discharged material from the threshing chamber under the condition that the strawrack has a length of 800 mm, a width of 50 mm and a number of vibrations of 300 to 400 cpm, plugging of the tailings' thrower is decreased by a shaking and separating process rather than by the drawing fan process, while grain loss is possibly increased when high-moisture rice or hard-to-thresh rice is harvested. It is possible to increase the capacity of the combine by the strawrack process if the quality of work is decreased to some degree.

Prototype combine

On the basis of designing the data obtained from the results of fundamental study on threshing mechanism and the separating device, the IAM-HT70 and HT71 combines, etc. have been built as a trial and they were put to test for harvesting of rice and wheat. As a result, it has been proved that it is possible to construct a combine with a small and light threshing mechanism, and with a constant grain throughput of 1 to 1.5 t/h.