ASAE Textbook Number 6
Published by the
American Society of Agricultural Engineers

Pamela DeVore-Hansen, Editor
Books & Journals
June 1993

ENGINEERING PRINCIPLES OF AGRICULTURAL MACHINES

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Generalize by using data from figure 8.37 and equation 6.60 to calculate the slice thickness, δ_s, associated with each feed rate.

8.47 (a) Calculate and plot a torque-displacement curve similar to figure 8.39 for a baler baling alfalfa hay at 13% moisture content to an average bale density of 157 kg/m^3. The chamber is 0.36 m wide by 0.46 m high, the crank radius is 0.38 m, the connecting rod length is 1.12 m and the crank speed is 79 rev/min. Note that equation 8.61 can be used to calculate the plunger displacement, for each crank angle through the full cycle. For each plunger displacement, use the plot made in problem 8.46 (with the maximum slice thickness) to determine the pressure on the plunger face and then calculate the plunger force. Then equations 8.62 and 8.63 can be used to calculate torque at each crank angle. (b) Integrate the torque-displacement curve of part a to find the average torque through the cycle. (c) Calculate the required flywheel inertia to provide 10% speed regulation, i.e., $R_s = 0.2$. (d) Calculate the power required to operate the plunger.

8.48 Same as problem 8.47, except use the minimum slice thickness from problem 8.45 b.

8.49 A large round baler is making alfalfa bales with a width of 1.5 m, diameter of 1.75 m, and average density of 200 kg/m^3. The speed of the baler while making bales is 8 km/h and the windrows contain 0.9 kg of hay per meter of length. The peripheral speed of the chamber belts is 2.75 m/s. The pto power is 3 kW when the baler is running empty, and 30 kW when a bale reaches full size. Calculate (a) the time required to form a full bale, (b) the mass of a full bale, (c) the rotational speed of the bale in the chamber when full size, (d) the torque, and (e) peripheral force that must be supplied by the belts to turn the full bale, (f) the number of rotations of the bale required to wrap twine at 150 mm spacing across the full width of the bale, and (g) the time required to wrap the twine. (h) Calculate the time savings per bale if each bale is wrapped with 1.5 turns of net wrap instead of twine.

8.50 Same as problem 8.49, except that the peripheral speed of the chamber belts is 1.5 m/s.

9

Grain Harvesting

Introduction

The purpose of grain harvesting is to recover grains from the field and separate them from the rest of the crop material in a timely manner with minimum grain loss while maintaining highest grain quality. The methods and equipment used for harvesting depend upon the type of grain crop, planting method, and the climatic conditions. The major grain crops are barley, edible beans, soybeans, corn, oats, rice, sorghum, and wheat. Many other grain crops, such as oil-seed crops, are harvested using the methods and equipment described in this chapter.

9.1 Methods and Equipment

One of the oldest methods of harvesting grains is to cut the grain stocks by means of a hand sickle, transport the cut crop to a central location, thresh the crop to detach the grains, and separate the grains from the rest of the crop material. All of these operations required human and/or animal

Figure 9.1–A modern grain combine (Courtesy of Ford/New-Holland).

power. With the development of technology these operations are now performed by machines. However, in many parts of the world harvesting is still performed by human and/or animal power.

The entire harvesting operation may be divided into cutting, threshing, separation, and cleaning functions. Depending upon the method employed for harvesting, these functions are performed by different machines or they may be combined in a single machine. The methods commonly used in modern mechanized farming are discussed in the following sections.

9.1.1 Direct Harvesting

In the direct harvesting method, all functions, from cutting to cleaning, are performed by one machine called the combine (fig. 9.1). All major crops mentioned above can be harvested directly. The combines may be either a conventional type or a rotary type depending upon the threshing and separating mechanism employed. A combine may be self-propelled or pulled by a tractor and powered by the pto drive as shown in figure 9.2.

Figure 9.3 illustrates a schematic diagram of a conventional combine showing the functional components. During combine operation the uncut standing crop is pushed by the *reel* against the *cutterbar* and onto the *platform*. The cut crop is conveyed towards the center of the platform from either side by the *platform auger* and conveyed to the threshing cylinder by the *feeder conveyer*. The crop is threshed by the *threshing cylinder*. The threshing cylinder rotates at a very high speed (about 30 m/s peripheral speed). A large fraction of threshed grain passes through the *concave* and *grate* (normally about 80%) along with chaff and broken pieces of straw. The rest of the crop is forced through the concave-cylinder gap where the *beater* causes it to slow down. The crop which is primarily straw and some chaff and grain, is delivered to a separator. In a conventional combine the

Figure 9.2–A typical pull-type combine drawn by a tractor (Reproduced by permission of Deere and Co. © 1991).

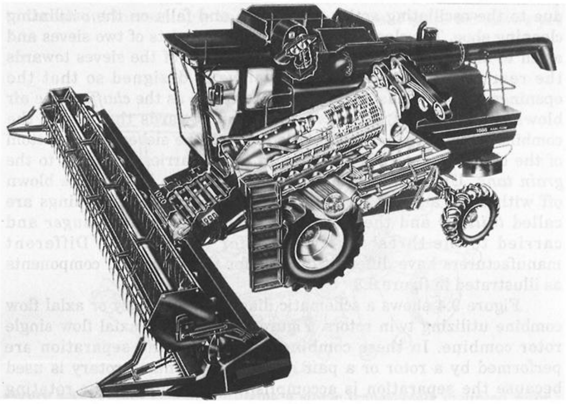

Figure 9.3–Internal construction of a modern self-propelled grain combine (Courtesy of Case-IH Co.).

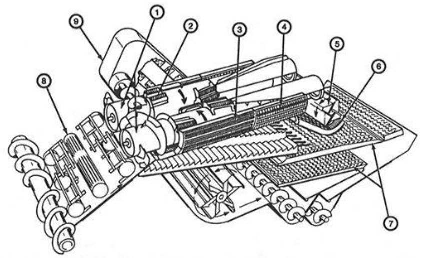

Figure 9.4–A rotary combine utilizing twin rotors: 1 Rotor; 2-Rasp bars; 3-Threshing concave; 4-Separating concave; 5-Discharge beater; 6-Beater grate; 7-Cleaning shoe (Courtesy of Prairie Agricultural Machinery Institute, Canada).

separator is made of oscillating channel sections called the straw walkers. Since early 1970's separator design has changed to a rotary design. These designs are discussed later in the chapter. The separated material falls into the channels and moves towards the front of the combine and is delivered on top of an oscillating *grain pan* where it is combined with the grain/chaff mixture separated at the cylinder/concave. This mixture of chaff and grain moves rearward due to the oscillating action of the pan and falls on the oscillating cleaning shoe. The cleaning shoe generally consists of two sieves and a fan to blow air upwards through the bottom of the sieves towards the rear of the combine. The top sieve is designed so that the openings may be adjusted and it is referred to as the *chaffer*. The air blows the chaff and the straw pieces off towards the rear of the combine while the clean grain falls through the sieves to the bottom of the cleaning shoe. The *clean-grain auger* carries the grain to the *grain tank*. Unthreshed grain heads that are too heavy to be blown off with chaff and too large to escape through sieve openings are called *tailings* and they are collected by the *tailings auger* and carried to the threshing cylinder for rethreshing. Different manufacturers have different designs for the functional components as illustrated in figure 9.3.

Figure 9.4 shows a schematic diagram of a rotary or axial flow combine utilizing twin rotors. Figure 9.5 shows an axial flow single rotor combine. In these combines, threshing and separation are performed by a rotor or a pair of rotors. The name rotary is used because the separation is accomplished by means of the rotating action of the rotor in place of the oscillating action of the straw walker. The name axial flow is used because the axis of the rotor is

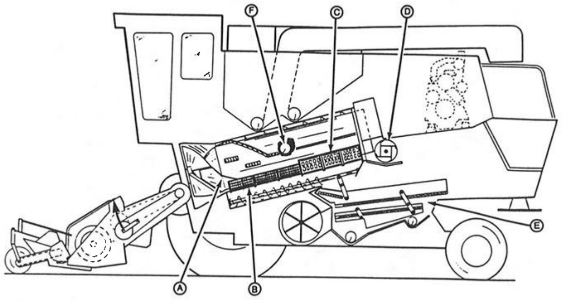

Figure 9.5–An axial flow rotary combine utilizing a single rotor: A-Rotor; B-Threshing concave; C-Separating concave; D-back beater; E-Cleaning shoe; F-Tailings return (Courtesy of Prairie Agricultural Machinery Institute, Canada).

parallel to the line of travel as compared to the transversely located threshing cylinder in a conventional combine. In one rotary combine design, the rotor is mounted transversely as shown in figure 9.6. In some combine designs multiple conventional threshing cylinders are used as shown in figure 9.7. Each cylinder rotates faster successively to thresh out increasingly hard to thresh grains. Figure 9.8 shows yet

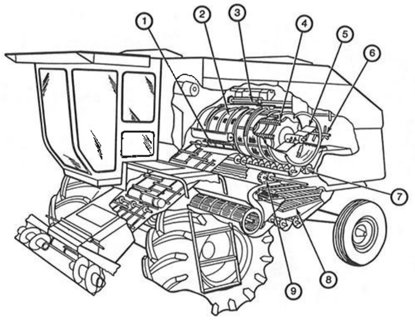

Figure 9.6–A rotary combine utilizing a single transversely mounted rotor : 1-Threshing concave; 2-Cage; 3-Cage sweeps; 4-Rotor; 5-Discharge paddles; 6-Straw choppers; 7-Distribution auger; 8-Cleaning shoe; 9-Accelerator rolls (Courtesy of Prairie Agricultural Machinery Institute, Canada).

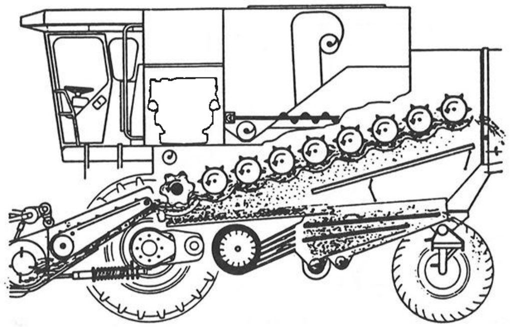

Figure 9.7–A combine design utilizing a conventional threshing cylinder and multiple separation cylinders (Courtesy of Prairie Agricultural Machinery Institute, Canada).

another arrangement. A transversely mounted conventional threshing cylinder is used in conjunction with a rotary tine separator. This design is especially suited for crops with tough straw such as rice.

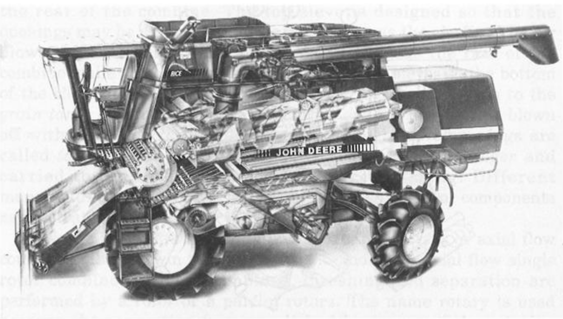

Figure 9.8–A combine configuration utilizing a transversely mounted conventional threshing cylinder and a rotary tine separator (Courtesy of Deere and Co.).

Figure 9.9–A windrow pickup attachment and its operating principle (Reproduced by permission of Deere and Co. © 1991).

9.1.2 Cutting and Windrowing

Some crops that do not lend themselves to direct harvesting are better harvested by cutting and windrowing before threshing, separating, and cleaning. When the crop does not ripen evenly or, in some northern climates, does not mature fully, cutting and windrowing allows for the crop to cure in field before threshing. Some crops, such as edible beans, are cut below ground and windrowed to avoid cutting bean pods.

Equipment for cutting and windrowing is discussed in Chapter 8. Generally, cutting is accomplished by sickle bar and windrowing is done by draper type platform. The crop material in a swath width is placed in a narrow windrow for the purpose of drying. The reel and cutterbar header is replaced by a pickup attachment in the combine as shown in figure 9.9. The windrow is gently picked up by the pickup header and taken into the combine where the subsequent harvesting operations are completed. If the crop was planted in rows, several rows are combined to form a windrow.

9.2 Functional Processes

A modern grain combine performs many functional processes. These are gathering and cutting or picking (in case of windrows), threshing, separation, and cleaning. Figure 9.10 shows a process diagram of a combine.

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