EFFECT OF CONCAVE DESIGN FACTORS ON CYLINDER-CONCAVE PERFORMANCE IN CORN

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Five concaves with different bar spacing, rod spacing and bar height were used to thresh hand harvested corn, using constant cylinder speed and constant cylinder-concave clearance. Increased concave open area resulted in an increased concave separation efficiency and decreased kernel damage. Amount of non-grain material passing through the concave increased with increasing concave open area.

INTRODUCTION

The modern grain combine is one of the most operationally complex and costly pieces of agricultural equipment on farms today. Although the grain combine is over 150 yr old (Nyberg 1957), a self-propelled combine capable of harvesting corn has been on the market for only 30 yr.

Buckingham (1977) commented that combine design could be described as a series of compromises made to provide a machine capable of harvesting a wide variety of crops (having seeds which vary greatly in shape and size) in conditions ranging from rice paddies to desert and with yields from 1000 kg/ha of wheat to 12 500 kg/ha of corn.

In the harvesting of small grains, the ears of grain and plant stalk material (straw) enter the combine in a continuous mat. This contrasts greatly to the harvesting of corn, where the ear of corn is removed from the plant material and the ears are presented as discrete units to the threshing cylinder.

Threshed small grain kernels must overcome the resistance of the straw mat to migrate to the concave surface before passing through the concave. The threshed kernels of corn do not experience this resistance. Therefore, there are distinct differences between the threshing of small grains and the threshing of corn.

The concave must perform two functions. It must support the crop material passing through the threshing unit so that the cylinder rasp bars can thresh the grain, and it must allow passage of the maximum possible amount of threshed grain. It has been noted, from observation of high-speed movie film of the threshing of corn, that the kernels, once threshed, have difficulty passing through the concave (Wall 1981). Gasparetto et al. (1978) drew the same conclusion from an ultra-high-speed movie film investigation of the movement of wheat kernels in the threshing crescent. Chowdhury and Buchele (1978) estimated that one-half of the corn kernel damage occurring in the threshing cylinder occurred after the kernels had been threshed; that is, the damage occurred whilst the kernels were moving within the threshing crescent prior to passing through the concave or from the threshing crescent. Furthermore, Mahmoud and Buchele (1975) reported that corn kernels passing through the front sections of the concave sustained lower levels of damage than those passing through the rear sections of the concave. Clearly it is desirable to remove the kernels from the threshing crescent as soon as possible after threshing.

A concave which removes the kernels from the threshing crescent soon after threshing would probably pass more grain through the concave; thus decreasing the loading on the separating section of the combine, and decreasing the separating loss.

The objective of this study was to investigate the effect of changes in some of the concave design parameters on threshing efficiency, corn kernel damage and concave separation efficiency. Threshing efficiency is defined as the proportion of corn kernels presented to the threshing cylinder which are detached from the cobs. Concave separation efficiency is defined as the proportion of threshed kernels which pass through the concave rather than over the rear of the concave.

LITERATURE REVIEW

Investigations into the possibility of improving the efficiency of the rasp bar threshing cylinder to permit the implementation of lower cylinder speed during threshing, thereby reducing the risk of grain damage, were conducted by Arnold (1964). Wheat and barley were threshed in a laboratory thresher at different moisture contents and with variations of cylinders and concaves. Arnold (1964) reported that increasing concave length increased concave separation; for unit increase in concave length the proportion of grain separated is equal to $1 - e^{-k}$, where e is the base of the natural logarithms and k is a rate constant. With crops that are easily threshed a longer concave produced little increase in threshing efficiency; however, for crops which were difficult to thresh the increase was more marked. The amount of grain damage increased with concave length, since the grain, which was not separated through the concave, was subjected to a greater number of impacts before leaving the threshing crescent. The spacing of the rasp bars on the cylinder had no significant effect on grain damage, threshing efficiency or concave separation efficiency. The diameter of the cylinder was not inherently important and Arnold recommended that it be chosen primarily to suit the length of concave required.

The effect of concave length when threshing wheat and barley was studied by Cooper (1978). He reported that a 25% increase of arc from 84° to 105° increased grain separation by 17%; but a similar increase of arc from 105° to 135° gave a smaller increase in grain separation; however, the importance of increasing concave separation efficiency was emphasized when a 5% difference of concave separation (between 105 and 135 degrees and at 20 t/h (total feed rate) nearly halved the level of straw walker loss.

Arnold and Lake (1964) demonstrated the importance of removing the threshed grain from the path of the rasp bars if grain damage is to be avoided. Their study utilized an open (normal) concave and a closed (blanking plates fitted between the

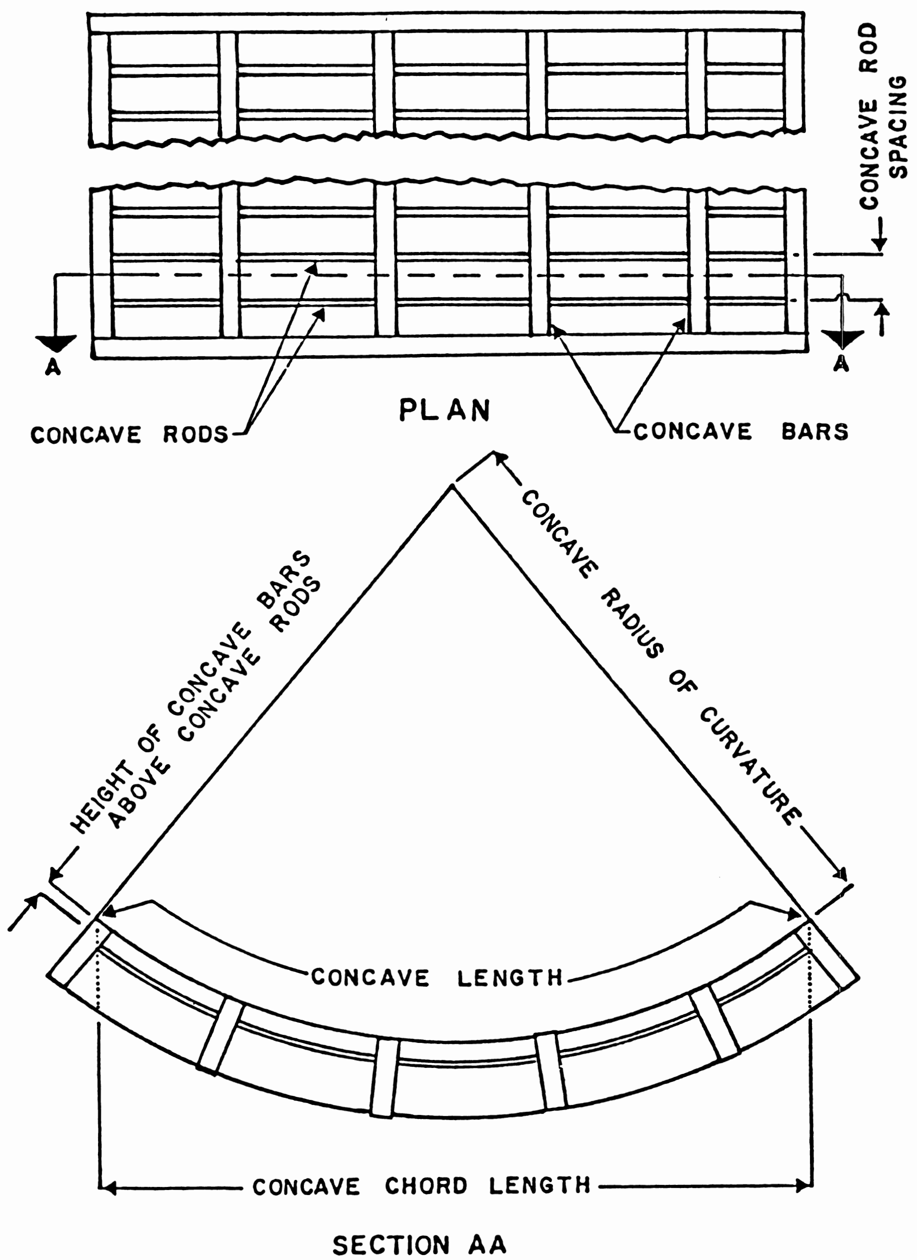

Figure 1. The concave design parameters.

TABLE I. THE VALUES OF THE DESIGN PARAMETERS FOR THE CONCAVES

Design parameter	Number of bars	Concave rod spacing (mm, c-c)	Concave bar height (mm)
Range selected from	6−12	23−37	5−15
Increment	1	1	1
Random selection	10	33	7
	6	30	13
	8	25	12
	12	24	8
Standard concave	9	21	10

Note: For each concave the concave radius of curvature was 280 mm and the concave length was 411 mm.

bars) concave. Wheat was the only crop threshed. They reported that there were four times as many damaged kernels in the samples produced using the closed concave as in those produced by the open version. There was no difference in the threshing efficiency of the two concaves.

The effect of cylinder and concave bar variations on the threshing of corn was investigated by Pickard (1955). He reported that the rasp-type cylinder bar appeared to be superior to the angle cylinder bar in terms of shelling efficiency and kernel damage. Covering the cylinder or concave bars with rubber had little effect on shelling efficiency or kernel damage.

Wrubleski and Reed (1980) conducted a study to investigate the performance of a modified cylinder and concave. The cylinder and concave modifications consisted of shimming the cylinder bars to a 0.75-mm radial tolerance, building up the concave bars so that they were at least 8 mm above the rods and machining the concave to give it a diameter 3 mm larger than the cylinder diameter. The front one-third of the concave was blanked and the rear two-thirds had every second concave rod removed. The cylinder-concave clearance was set to 0 at the rear and 8 mm at the front for all the small grain crops. Tests were conducted both in the field and in the laboratory with barley, canola and wheat. In general the modifications to the threshing unit did not increase combine capacity; in many cases combine capacity was reduced and grain damage was increased.

CONSTRUCTION AND OPERATION OF THE MODIFIED CONCAVE DESIGNS

Five concave design parameters were identified. These were (with reference to Fig. 1):

1. The concave radius of curvature.
2. The number of concave bars (assuming equal spacing between bars).
3. The interior peripheral length of the concave.
4. The concave rod spacing (assuming constant concave rod size).
5. The height of the top of the concave bar above the top of the concave rod.

Four new concaves were built and, along with the standard concave for a Massey-Ferguson 300 combine, were used to thresh corn in a laboratory threshing unit. The laboratory threshing unit was constructed from Massey-Ferguson 300 combine parts (Wall 1981). Of the five concave design parameters, the number of bars, the concave rod spacing and the height of the concave bars above the concave rods could be easily varied. The values of these three design parameters were selected at random for each concave (Table I). The concave radius of curvature and concave length for the four new concaves were the same as for the standard concave (Table I).

The four new concaves and the standard concave were each used to thresh corn. A cylinder-concave clearance of 25 mm front, 16 mm rear was used for each concave; the cylinder peripheral speed was 14.7 m/s. The experiment was conducted in the form of a randomized complete block design. Measurements were made of concave separation efficiency, shelling efficiency, kernel damage (using the colorimetric technique developed by Chowdhury (1978)), weight of husks and silks passing through the concave and weight of cob pieces passing through the concave. The kernel moisture content was 23.3%, wet basis.

TABLE II. RESULTS OF THE COMPARISON OF THE FIVE CONCAVES DATE

Number of concave bars	Concave rod spacing (mm)	Percent open area	Foreign material under concave: Cobs† (g)	Foreign material under concave: Husks/silks† (g)	Kernel damage†‡	Concave separation efficiency† (%)	Shelling efficiency† (%)
12	24	41	10*a*	0.2*a*	50.0*a*	53.1*a*	94.1*a*
9§	21	44	9*a*	0.0*a*	43.7*a*	60.2*b*	92.3*a*
10	33	51	36*ab*	1.1*ab*	44.0*b*	66.7*c*	94.9*ab*
8	25	51	74*b*	1.6*b*	55.3*b*	74.9*d*	96.8*b*
6	30	60	221*c*	5.4*c*	38.0*c*	82.8*e*	96.1*b*

†Each value is the mean of three determinations.
‡The kernel damage reading for hand-shelled kernels (i.e., no machine damage) was approximately 18.0. This is due to tip caps remaining on the cob.
§The standard Massey Ferguson 300 concave.
a–c Means in the same column with the same letters adjacent are not significantly different at the 5% level.

RESULTS

Table II shows the results of the tests conducted on the five concaves. The order of presentation is according to increasing concave open area. The dependent variables (foreign material under concave, kernel damage, concave separation efficiency and shelling efficiency) have each been subjected to Duncan's multiple range test to detect any significant differences among the concave designs.

From the data, a limited comparison of the performance of the concaves may be made. The amount of foreign material which passes through the concave is of concern, because it passes directly to the cleaning section of the combine and adversely affects the performance of the cleaning section. The weight of foreign material passing through the concaves generally increased as the percent open area of the concave increased (Table II).

The level of kernel damage was least for the six-bar concave and greatest for the twelve-bar concave. Kernel damage for the eight-, nine- and ten-bar concaves was not significantly different amongst these concaves but was significantly different from that of both the six- and twelve-bar concaves (Table II). The correlation coefficient for kernel damage versus concave separation efficiency was −0.79 (significant at the 1% level). Thus, some foundation was given to the hypothesis that decreased kernel damage would be achieved with increased concave separation efficiency. The six-bar concave caused 24% less damage than the standard Massey-Ferguson 300 concave.

The concave separation efficiency of each concave was significantly different from that of the other concaves (Table II). The six-bar concave had a concave separation efficiency which was 38% greater than the concave separation efficiency of the standard Massey-Ferguson 300 concave. Clearly then, reduced kernel damage and increased concave separation efficiency can be achieved through changes in some of the concave design parameters. Furthermore, the six-bar concave passed 50% fewer threshed kernels to the straw walkers than did the standard Massey-Ferguson 300 concave. It is expected that this would result in a significant reduction in separation losses.

SUMMARY AND CONCLUSIONS

The prospect of reducing the corn kernel damage occurring in a "conventional" combine cylinder, and increasing the concave separation efficiency of a conventional combine cylinder has been investigated. Five different concaves were used to thresh corn in a laboratory thresher. It is concluded that corn kernel damage may be decreased and concave separation efficiency increased by changes in some of the concave design parameters. Experimental results show that corn kernel damage can be decreased by at least 24% and concave separation efficiency can be increased by at least 38%; however, these improvements were accompanied by a significant increase in the quantity of foreign (non-grain) material passing through the concave. This result was achieved by decreasing the number of concave bars from nine to six, by increasing the concave rod spacing from 21 mm to 30 mm, and by increasing the height of the concave bars above the concave rods from 10 to 13 mm. It must be stressed, however, that the data presented here are not sufficient to specify an optimum concave design for threshing corn.

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