The Nature of Corn Kernel Damage Inflicted in the Shelling Crescent of Grain Combines

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The Nature of Corn Kernel Damage Inflicted in the Shelling Crescent of Grain Combines

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ABSTRACT

THIS study investigated what percentage of the corn kernel damage was caused by the cylinder and the concave before and after the kernels were shelled from the cob and the effects of kernel moisture contents, cylinder speeds, and the different concave zones on these two categories of damage.

INTRODUCTION

In the conventional combine, the corn kernels are subjected to mechanical damage while passing through the shelling crescent (between the cylinder and the concave). Subsequent operations inside the combine, such as sieving and cleaning action, separation over the straw walker and transportation by the augers, also contribute mechanical damage to the corn kernels. It is well documented that deterioration in the quality of corn kernels begins with the mechanical process of harvesting and that practically every subsequent operation in the drying, transporting and handling further decreases the quality of the grain. The rate of deterioration of quality of corn kernels is dependent upon the type and magnitude of the initial injury and sustained during such mechanical processes, particularly the harvesting operation.

While the corn is being shelled by a combine cylinder, the ears are subjected to impacts (both low and high) and compressive loading between the rasp bar and the filler plates of the cylinder and the steel bars of the concave. High-speed photography of conventional corn shelling operation, used by Fox (1969) revealed that an ear of corn sustains about seven to nine impacts of the rasp bars of the combine cylinder before the kernels are shelled off the cob. With each of these impacts, the teeth of the rasp bars and the steel bars of the concave cause some kind of mechanical damage to the crown of the kernels. The high speed photography also revealed that after the kernels are shelled off the cob, they do not all pass immediately through the concave. The detached kernels keep bouncing back and forth between the combine cylinder and the concave bars until they pass through the concave openings. During this bouncing period, the shelled kernels are subjected to high and low impacts from the rotating cylinder and the steel bars of the concave. The shelled kernels also are subjected to compressive loads applied by the incoming ears and cobs when they roll over these shelled kernels, while moving through the shelling crescent. Thus, the corn kernels, while they are in the shelling crescent are subjected to mechanical damage both when they are attached to the cob and also after they are shelled from the cobs.

OBJECTIVES

The objective of this study was to determine the percentage of corn kernel damage caused by the cylinder and the concave before and after the kernels were shelled from the cob and to investigate the effect of kernel moisture contents, cylinder speeds and the different concave zones on these two categories of damage.

REVIEW OF LITERATURE

Ayres et al. (1972) found that the mechanical damage of combined corn kernels ranged between 16.4 and 79.4 percent in typical field harvesting systems in Iowa. The major portion of the mechanical damage done to corn kernels in combines is caused by the shelling operation, in particular when the ears and the shelled kernels pass through the shelling crescent. Mahmoud (1972) found that the mechanical damage caused by the shelling operation in the crescent ranges between 12.0 and 60.0 percent. He also reported that the percentage separation of shelled kernels per unit length of concave was higher towards the front of the concave and lower towards the end; but the magnitude of percentage mechanical damage was lower towards the front of the concave and increased linearly with an increase of the concave length. His study also revealed that more damage occurs as the ears and the shelled kernels progress along the concave towards the rear. Although most of the kernels are shelled from the cob in the front portion of the concave, they don't pass through the concave immediately. Hence, the longer these shelled kernels keep bouncing back and forth between the cylinder and the concave, the more damage is sustained by these kernels and consequently the more mechanical damage.

Brass (1970) developed a low damage corn shelling cylinder. His high-speed photography study revealed one similarity between his roller sheller and the traditional cylinder-type sheller. He noticed that, in both machines, the detached kernels had considerable difficulty in passing through the concave opening. This was further verified by his study of types of damage and their percentages of the total damage caused by both shells. Around 44 percent of the total damage was classified as crown and severe damage, and 56.0 percent embryo and pericarp damage.
FIG. 1 The stationary laboratory shelter with the conveyor belt and the five compartments collection pan for the five zones.

for both machines.

Koehler (1957) studied the pericarp injuries in seed corn caused by the 2-hole sheller and the cylinder sheller and their effects on germination and seedling growth. He reported that damage caused by a cylinder sheller was 14.3 percent crown injury, and 29.8 percent injury over or around the embryo and 13.4 percent other pericarp injuries.

EQUIPMENT AND PROCEDURE

A stationary laboratory sheller (Fig. 1), constructed from John Deere Model 95 combine parts, was used in this study. The relative position of the cylinder, beater and concave are identical to manufacturer's specifications. A detailed description of the laboratory shelter and its power supply was provided by Mahmoud (1972). The cylinder diameter was 55.88 cm (22 in.) and the concave clearances were fixed at 2.54 cm (1 in.) in the front and 1.59 cm (5/8 in.) in the rear. Three levels of cylinder speed were used: 440, 540 and 640 rpm. The concave and its extension were divided into four zones (Fig. 2), and the samples were collected from these compartments to investigate the nature of kernel damage along the concave. The 5th zone was used for the collection of cobs and unshelled kernels.

The stationary sheller was fed by a belt conveyor for uniform feeding as shown in Fig. 1. The feed rate of 10.57 m$^3$/h (300 bu/h) was used in the study for each run.

One commercial variety of corn, Black B73 x MO 17 was used in the experiment. The corn was hand picked and husked from the fields of Agronomy-Agricultural Engineering Research Center of Iowa State University. The levels of kernel moisture content used were approximately 27, 22, 19, and 16 percent (wet basis).

After each run, the shelled kernels with fines were collected from each compartment (each of the four zones). The samples were then weighed and sieved through a 4.76 mm (12/64 in. round-hole sieve.) The portion of the sample that passed through the sieve was weighed and converted to percentage weight. The rest of the samples were then dried in a small drier at room temperature without any supplemental heat, to avoid any additional damage to the kernels.

The dried samples were then passed through a Boerner grain divider to obtain a 100-g sample for damage evaluation. The 100-g sample was soaked in 0.5-percent Fast Green FCF dye solution to aid in visual inspection (Chowdhury and Buchele, 1975).

The dyed samples were then sorted by visual inspection with naked eyes for the following categories.

1 Severe damage: This portion of the sample was made up of broken, chipped and crushed kernels, None of the kernels were intact in this category. That is, at least, one-third of the whole kernel was missing (Fig. 3).

2 Crown damage: This category of damage consisted of kernels of which any portion of the crown was bruised, chipped, cracked or completely missing. Both severe and slight crown injuries (Fig. 4) were included in this category.

3 Embryo damage: This category included kernels of which any portion of the embryo was either bruised, chipped, cracked or contained any hairline cracks. This included injury over the plumule, injury over the radicle, and injury around the edge of the
FIG. 6 Pericarp damage of different magnitudes.

FIG. 7 Sound kernels.

FIG. 8 Kernels with more than one type of injury.

germin (Fig. 5). This sample also included kernels with major or minor embryo damage.

4 Pericarp damage: If the damaged kernel was intact and the most dominant damage was neither on the embryo nor crown, then it was classified as pericarp damage. This included open cracks, chipped, severe damage, major or minor injuries, hairline cracks in the pericarp or spots of missing pericarp. (Fig. 6).

5 Sound kernels: This category consisted of whole kernels without any of the injuries described. In this category, the kernels did not absorb dye on any part of the kernel except the root tip. (Fig. 7).

When the kernels were analyzed, in the different categories of damage, one kernel occasionally had more than type of injury (Fig. 8). For example, a kernel may have had injuries over both the embryo and the crown. In such instances, it was possible to place the kernel in either category. But in this study, the injury causing a higher degree of damage was used as basis for classification. For example, if a kernel had both slight injury over the embryo and severe injury over the crown, then it was treated as having a crown injury. The same procedure was applied to other categories as well. Thus, only the most serious or prominent damage was considered for classification, but this situation did not occur very often.

Once the 100-g samples had been visually inspected and weighed for the different categories of damage, then the weights of those categories also were recorded as the percentage damage. Later the damage categories also were recorded as percentage of total damage.

In this particular study, to obtain three levels of cylinder speeds, four levels of moisture content, and three replications of each treatment, we were required to make 36 runs of the cylinder sheller. Each run produced four samples at the four zones, a total of 144 samples.

THE USE OF DAMAGE CLASSIFICATION

The purpose of this classification of damage was to find out what percentage of the corn kernel damage was caused by the cylinder and the concave before and after the kernels were shelled from the cob. The damage categories that we used could be divided into two major groups: on-the-cob damage and off-the-cob damage.

The on-the-cob damage group consists of damage categories that include the kernels damaged while being shelled from the cob. When a kernel is attached to the cob and hit by the rasp bars of the cylinder or abraded by the filler plates or the concave bars, the most probable part of the kernel which will be injured is the crown, as shown in Fig. 9. This shelling action will cause either major or minor crown damage or may remove the crown completely. Because the other sides of the kernel are protected by the adjacent rows of kernels, it is not very likely that kernels would be damaged either on the embryo or on the pericarp. The crown is the only part of the kernel which is exposed to mechanical damage in this particular situation. Thus, shelling damage (on-the-cob damage) basically consists of crown damage.

Part of the severe damage could be classified in the on-the-cob damage group. This is because when a kernel is struck hard by the rasp bars, the whole crown may be removed, causing more than one-third of the kernel to be lost, or the teeth of the rasp bars may break the kernel into two or more pieces, while still attached to the cob. The remaining severely damaged kernels could be classified in the off-the-cob damage group. This may occur when the shelled kernels are run over the ears or the cobs which may smash the kernel or break the kernels to pieces. In either on-the-cob or off-the-cob case, the damage will result in fines (that is, the portion that passes through the 4.76 mm (12/64) round hole sieve.). Thus, fines could also be classified in either category.

The off-the-cob damage group consists of those damage categories, where the kernels are damaged after being shelled off the cob. In this particular group, the kernels are mainly damaged either on the embryo or on the pericarp. Neither the embryo nor the pericarp is exposed to mechanical damage until the kernels are free (shelled) from the cob.

When the kernels are freed from the cob and begin floating inside the shelling crescent, all sides of the kernels are exposed to mechanical damage. When the loose kernels bounce inside the shelling crescent, they

FIG. 9 Pieces of cob with attached kernels, showing the crown damage and severe damage [inside the circles] as they came out of the cylinder and the concave, and were collected in zone No. 5.
may be hit by the rasp bar and concave, which could cause damage to either the embryo or pericarp, or both. Again, when the kernels are run over by an ear or cob, they will be subject to embryo or pericarp damage. In addition, there is a possibility of embryo or pericarp damage while the kernels pass through the concave.

To make the analysis simple, we have assumed that the sieved group, severe damage and crown damage, fall under the on-the-cob damage group. The embryo and pericarp damage fall under the off-the-cob damage group.

RESULTS AND DISCUSSION

Fig. 10 shows the effect of cylinder speed on different kinds of kernel damage. The total damage increases with increases in cylinder speed. The total kernel damage increased from 26.30 percent for 450 rpm to 42.0 percent for 650 rpm. Each damage category also increased as cylinder speed increased. Crown and pericarp damage each contributed around 10.0 to 12.0 percent of total damage.

Fig. 11 shows the effect of the zone concave (and distance from front of concave) on different types of kernel damage and especially on the total damage. The kernels, while free or attached to the cob, receive additional impacts as they move down the shelling crescent. Though most of the shelling takes place in the forward part of the concave, the kernels continue to move towards the rear of the concave seeking a passage way through the concave screen. There is a steady increase of the crown damage as the kernels move down the shelling crescent. Fig. 12 shows the effect of kernel moisture content on different kinds of kernel damage.
CALCULATION OF DAMAGE
ON A WEIGHT BASIS

The categories of kernel damage were converted from percent of total weight to percent of total damage (weight-basis). This permits a more intensive study of damage. Fig. 13 shows the effect of cylinder speed on different categories of damage as a percent of total damage. The pericarp damage decreased with increase in cylinder speed. Severe and embryo damage however increased with increase in cylinder speed. Fig. 14 shows different categories of damage passing through the zones of the concave. Fig. 15 shows the effect of kernel moisture content on different categories of damage, as a percentage of total damage. The pericarp damage increased and the crown decreased with increase in kernel moisture content, while the other damage categories remained fairly constant.

Figs. 16, 17 and 18 show that about 50 percent of the damaged kernels fall under the on-the-cob damage group while the other 50 percent fall into the off-the-cob damage. Fig. 16 shows the effect of cylinder speed on the two groups of damage. The off-the-cob damage group slightly decreased with increase in cylinder speed while the on-the-cob damage group increased. Fig 17 shows the effect of zone on the two groups of damage. Fig. 18 shows the effect of kernel moisture content on the two groups of damage. The off-the-cob damage increases, while the on-the-cob damage decreases with increase in kernel moisture content.

It is apparent from this study that about 50 percent of the mechanical (off-the-cob) damage inflicted in the shelling crescent could be reduced, if the kernels could be immediately removed from the shelling crescent after they were shelled from the cob.

CONCLUSION

While corn is being shelled by the conventional combine, most of the mechanical damage to the kernels is inflicted in the shelling crescent. About 50 percent of the mechanically damaged corn kernel consists of sieved (through 4.76 mm (12/64 in.) round hole sieve) material, severe, and crown damage; which can be classified as on-the-cob damage. While the other 50 percent of the mechanically damaged kernels consists of embryo and pericarp damage; which can be classified as off-the-cob damage. The second category of damage can possibly be reduced by redesigning the shelling mechanism, which includes both the cylinder and the concave, so that the shelled kernels can leave the shelling crescent immediately after shelling.

References