INSTRUMENTED SPHERE EVALUATION OF POTATO HARVESTING AND HANDLING SYSTEMS [1,2]

by
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Abstract

We measured both impact severity and character in several potato harvesters and pilers in 1990, using the Instrumented Sphere (I.S.) developed at Michigan State University. The I.S. measured effects of drop height and potato loading levels. In two instances, increasing the tuber loading to full capacity in a piling system reduced the severity of the impacts at the drops by 45 and 50 percent. Harvester experiments showed the rear cross conveyor to be a continuing problem area. Need for simple cushioning in other areas was also apparent.

The Problem

Potato tuber mechanical damage is the problem, especially blackspot and shatter bruise. The latter two are caused by impact. If the tubers are turgid, they tend to shatter; if soft, they blackspot. However, temperature, cultivar, cropping practices and other factors affect the kind of bruise, the bruise threshold, and the bruise resistance.

Solutions

The three basic ways to solve the bruise problem are to:

1. Improve tuber resistance to bruise damage,
2. Reduce, modify or eliminate impacts,
3. Reduce or eliminate tuber damage symptoms (i.e., if the tuber didn't crack, turn black or rot as a result of the damage, then bruising wouldn't be of so much concern. This solution is not part of this report).

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[1] Presented at the Washington State Potato Conference & Trade Fair, Moses Lake, Wa., Feb., 1991.

[2] This research is funded in part by the Washington State Potato Commission.

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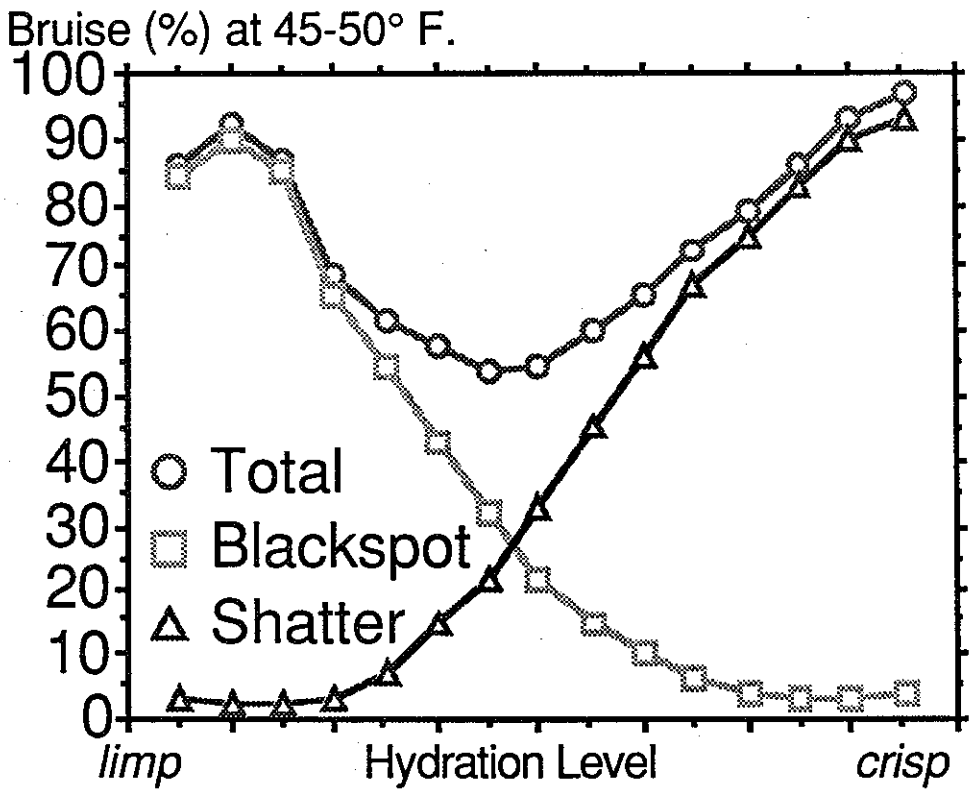
1. Bruise Resistance

Tuber bruise resistance varies with temperature, turgor, cultivar, fertility and bruise type. Figure 1[1] shows how black spot, shatter bruise and the total bruise resistances vary with tuber hydration level or turgor at one temperature. Total bruise resistance is best at about a middle hydration level if the tubers are at 45-50°F. These curves all shift downward and to the right as temperatures increase, so bruise resistance is better at higher temperatures if hydration level is higher.

Figure 1. Bruise type and hydration level (turgor).



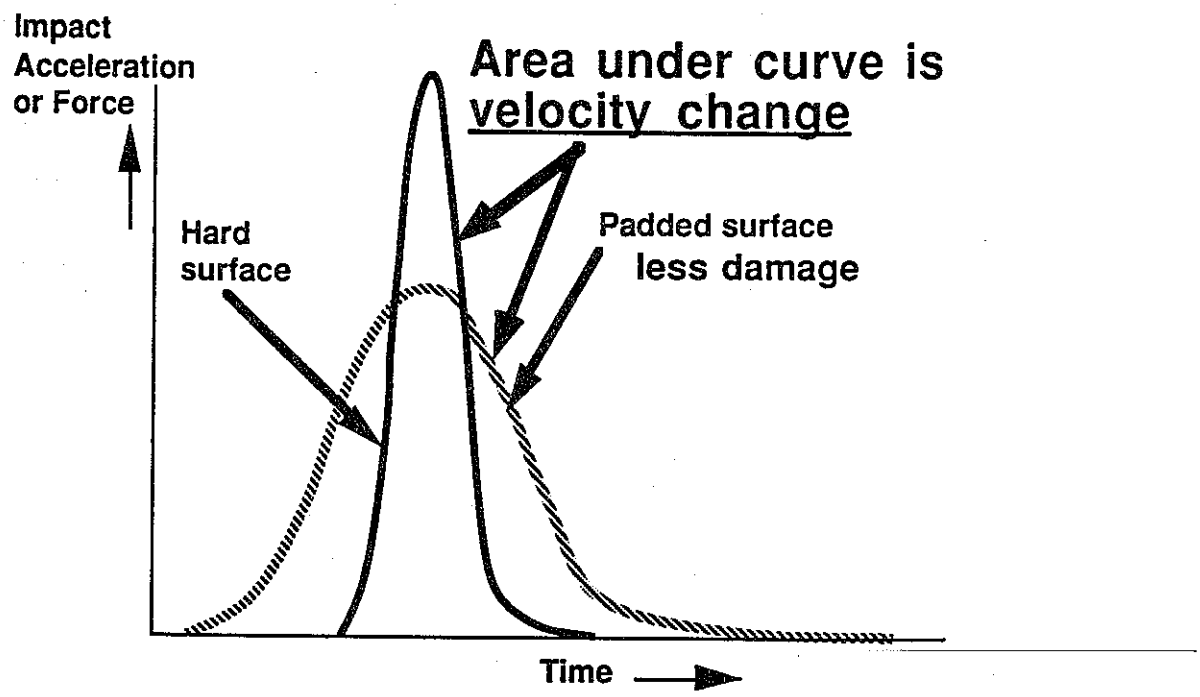
[1] Thornton, R.E., D.A. Smittle, and C. L. Peterson. 1974. Reducing Potato Damage During Harvest. Extension Bulletin 0646, Coop. Extension Service, College of Agriculture and Home Economics, Washington State Univerity, Pullman, Wa. 99164.

2. Reducing Impacts

The Instrumented Sphere (I.S.) tells us the character of the impacts that it experiences as it travels through the harvesting and handling equipment. However, the link that is not yet firmly established is how impact severity and character translate into tuber damage. Bruise resistance is the ratio of impact energy to bruise volume resulting from the impact. Bruise resistance varies with temperature, turgidity, potato variety, season, and fertility practices. However, initial estimates are that impacts on hard surfaces of more than 50 g's may begin to cause blackspot or shatter bruise. Impacts on hard surfaces exceeding 80 g's are clearly damaging[1]. We are currently using the I.S. in the laboratory to establish more definitely the impact levels that begin to cause bruise, that will bruise half the tubers, and that will bruise all of the tubers under known tuber conditions.

The number of impacts, the severity of each impact, and how well an impact is cushioned all affect tuber damage. The instrumented sphere provides information on all three of these factors (Figure 2).

Figure 2. Impact curve that can be produced by the I.S.

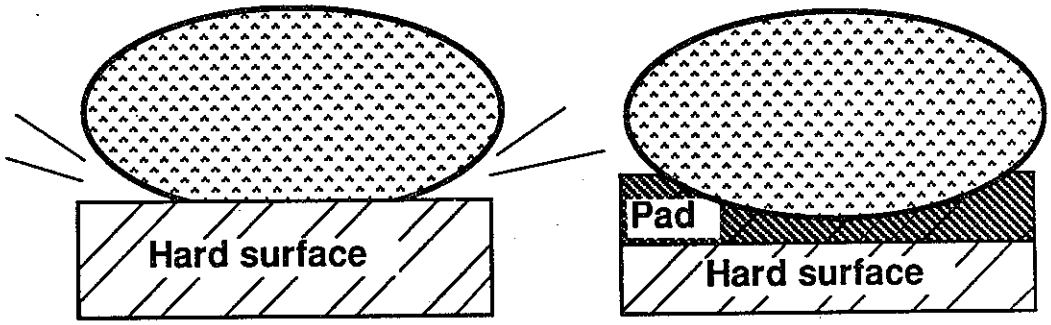


[1] Brown, Galen K., 1989. Personal correspondence.

The height of the curve tells the severity of impact (number of g's of acceleration), the area under the curve tells whether the impact was on a hard or cushioned surface, and the clock in the I.S. tells when the impact occurred. By tracking with a stop watch or video, we can tell where the impact happened.

Cushioning does two things to reduce impact damage: it reduces the severity of the impact, and it spreads the force over a larger area of the tuber (Figure 3). The energy of the impact is absorbed either by the tuber or the cushion; if by the tuber, damage may result.

Figure 3. Hard and cushioned impacts.



Results

Harvesters

Figure 4 shows impacts during 12 passes of the I.S. from the secondary to the boom on a two-row potato harvester with a star-roller rear cross conveyor. The largest impacts occurred at the drop onto the rear cross and in hitting the uncushioned sides of the elevator and boom.

Figure 5 shows the character of these same impacts by location on the harvester. The same three rear-cross impacts are circles and indicate velocity changes in the range of 1.5 to 2.1 m/s. Note that the higher the velocity change, the better the cushioning. The two least-cushioned hard impacts were on the elevator and boom, near the steel line on the graph. Note also the large number of smaller impacts that occurred on the star rollers (the squares on the graph).

Figure 4. Two-row harvester, secondary to top of side elevator.

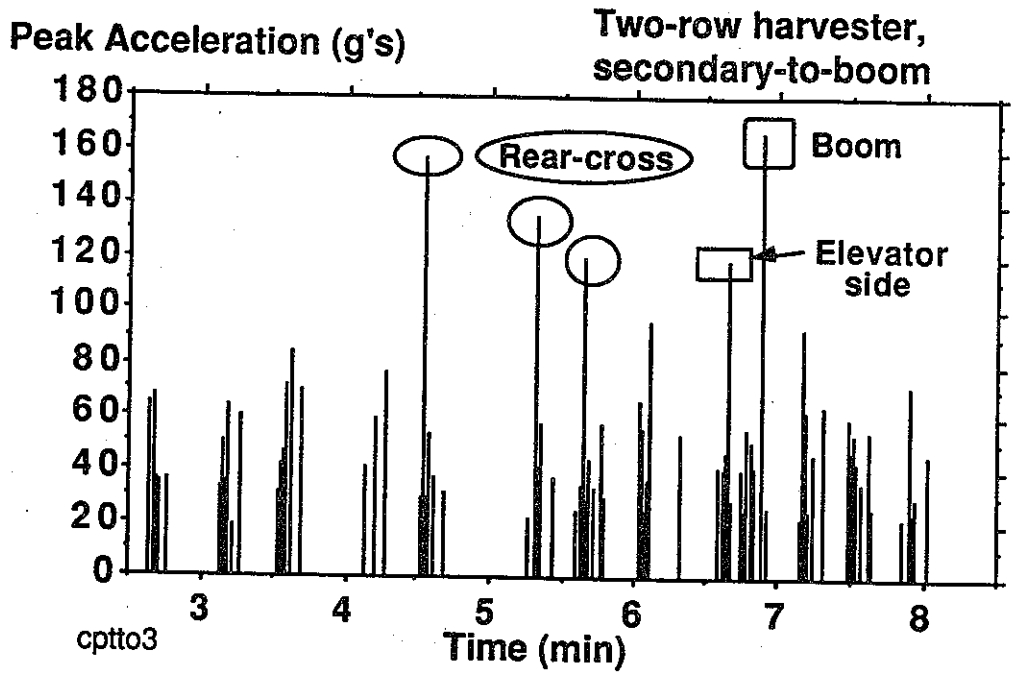


Figure 5. Impact character on the 2-row harvester with star-roller rear cross.

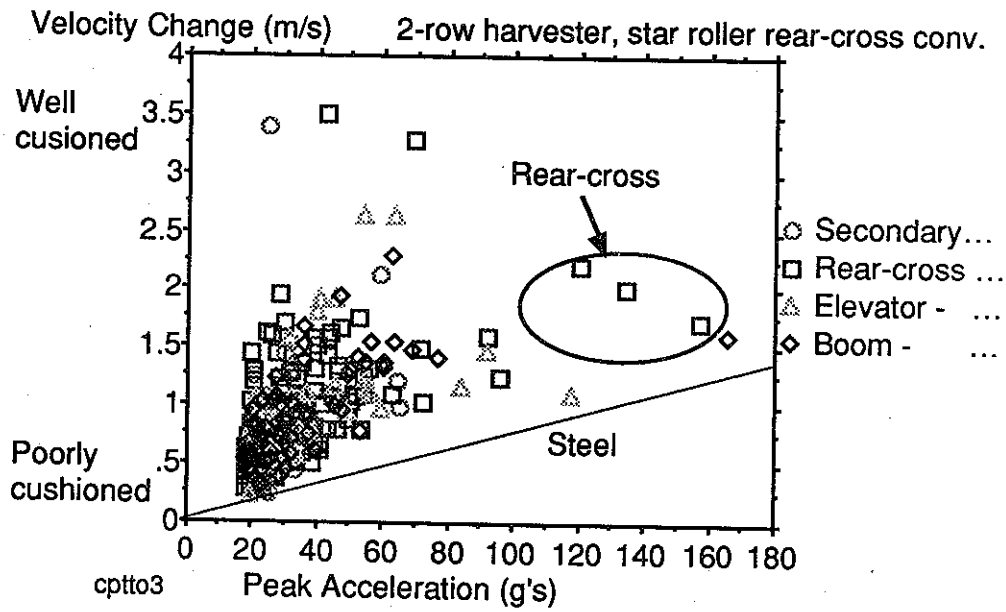


Figure 6 shows impact characteristics for a new 3-row harvester with a conventional rear-cross chain, new cushioning, and reduced drop heights. In addition to the fact that there were fewer impacts on the chain rear cross than on the star rollers of the 2-row machine, overall severity of impacts on the three row machine were less due to the new cushioning material and the reduced drop heights.

Figure 6. Impact character on new 3-row harvester with conventional rear cross chain.

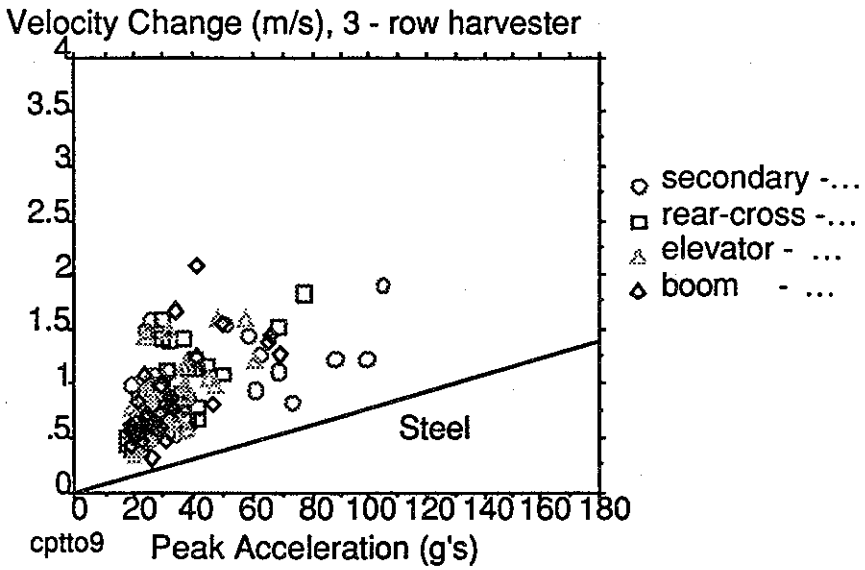


Figure 7. Star roller rear-cross conveyor (left) on 2-row, conventional rear-cross (right) on 3-row harvester.

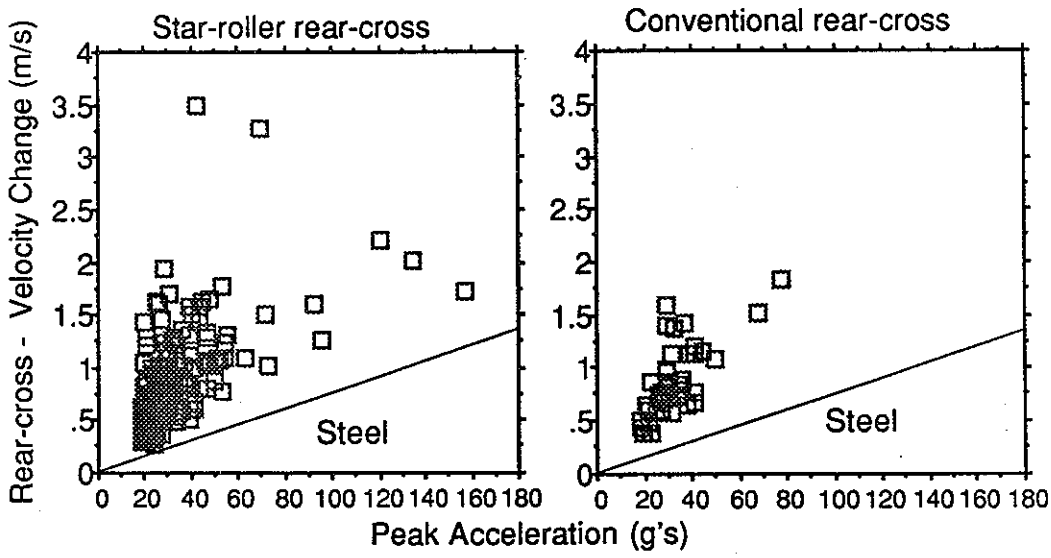


Figure 7 compares rear cross impacts for the star-roller and conventional rear-cross conveyors. Note fewer impacts on the conventional conveyor. Larger impacts on the star-roller conveyor are drops onto it and probably mean that the drop is greater than on the 3-row machine with the conventional rear-cross.

Piler Results

Figures 8 and 9 show correctly- and under-loaded piler elevator bowls. Full loading reduced the peak impacts occurring at this drop by 45% (Figure 10). At a similar drop in the same system, maintaining full load reduced impact severity by 50%.

Figure 8. Correctly-loaded piler bowl.

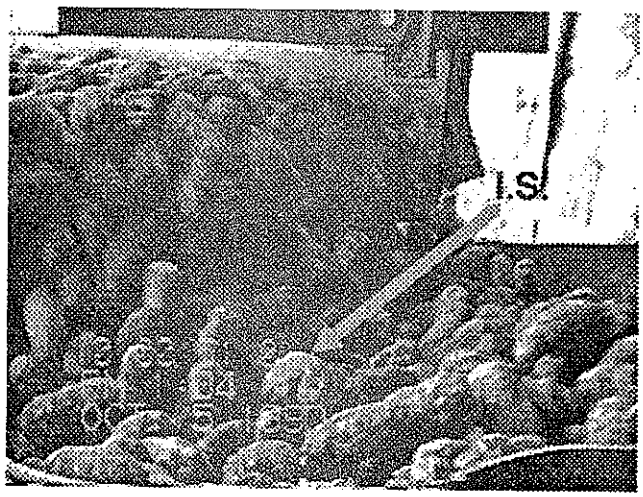


Figure 9. Under-loaded piler bowl.

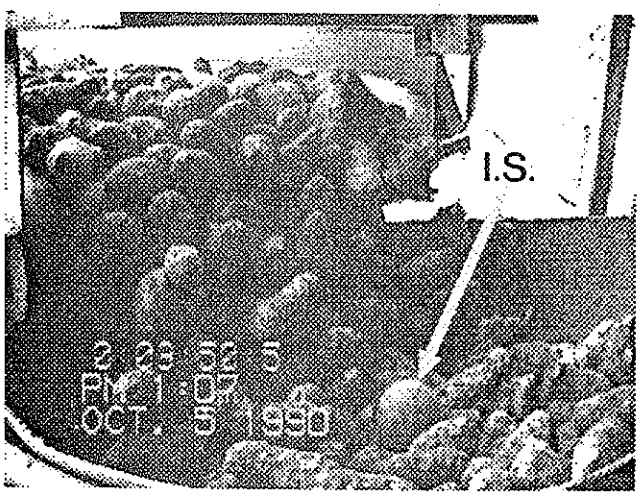
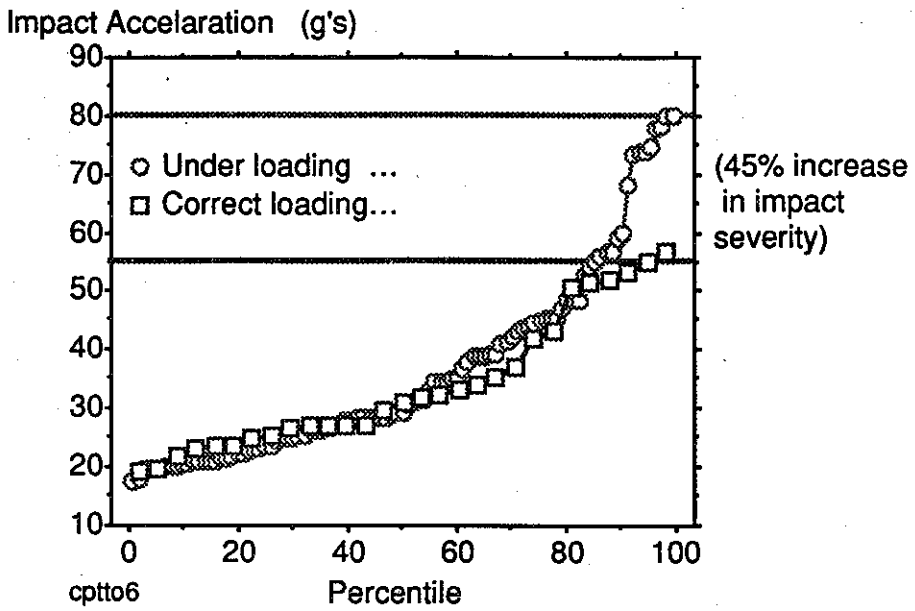


Figure 10. Peak accelerations at full load and under-loaded. Note the 45% increase in impact severity when underloaded.



Conclusions

1. We can successfully measure impact levels in potato harvesters. Results so far show that:

   a. Many low level impacts occur on star roller rear-cross conveyors with peak accelerations up to 60 g's. (Average for the rear -cross was 32 g's.)
   b. Some larger impacts also occur on the rear cross, but involve the drop onto it.
   c. Occasional hard, large impacts occur in elevators and booms with uncushioned sides.
   d. The new harvester with reduced drop heights and good cushioning had had less severe impacts.

2. Keeping piler conveyors fully-loaded can reduce impact severity at drops by as much as 50% compared with even moderate underloading.