A GREEN SECTION SUPPORTED RESEARCH PROJECT

A Machine for Cleaning Sand Bunkers

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REMOVAL OF TRASH or foreign materials from sand bunkers is an essential maintenance chore for golf course superintendents. A machine that quickly and efficiently removes trash from bunkers has been developed. It effects a small degree of separation by using narrow belts spaced a preset distance apart and driven by rotating circular pulleys. With this arrangement, material on the bed of moving belts that is smaller than the space between the belts should fall through and the remaining material will be carried to the end of the bed. There are two major problems with this arrangement.

(1) When small particles are on the top of the larger particles, they are carried on to the end of the belt without being separated, and

(2) At certain moisture contents, sand particles will adhere to each other and not be separated.

This problem can be solved if vibration is provided so that the position of the particles on the belt is changed and the force of adhesion is overcome to disperse sand particles.

A pulley-belt mechanism was developed in which pulleys of non-circular cross-section were successfully used to transmit vibration to the belts. Pulleys of any constant width closed curve* can be used, provided that the two pulleys are of the same shape and size and that the two pulleys are in time. Figure 1 shows the pulley cross-section and Figure 2 illustrates the positions when the two pulleys are in- and out-of-time.

CONSTRUCTION OF THE TEST CLEANING BED

Two pulleys of constant width triangular cross-section (Figure 1) were constructed by the following procedure:

Start with an equilateral triangle ABC, where AB=BC=CA=1 inch and extend the three sides in both directions so that AD=AE=BF=BG=CH=CI=0.375 inch. Then construct three arcs FI, EH, and GD with the compass point at A, B, and C, respectively. Similarly, draw three arcs DE, GF, and HI with centers at A, B, and C, respectively. The resulting closed figure is a constant width triangle and is the desired cross-section for the two pulleys.

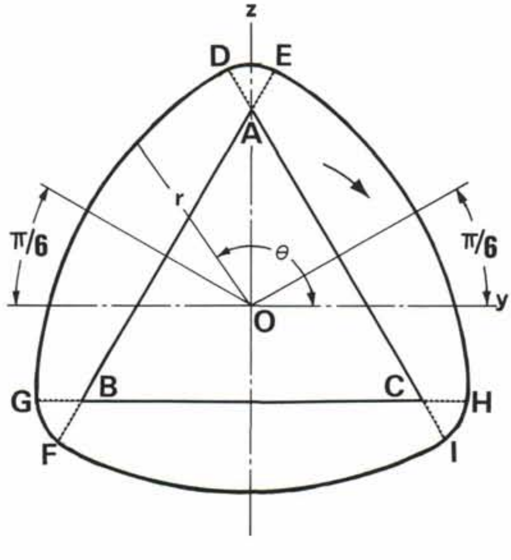
To construct these pulleys in a practical manner, make nine punch marks on four 2 x 2 x ½ inch flat metal pieces outlining the periphery of the constant width triangle. Drill ¼ inch diameter holes at the punch marks on the four metal pieces. Then insert ¼ inch diameter steel rods 13 inches long into the holes of a pair of the metal pieces using them as end caps. Welding the rods to the caps forms a 12-inch wide pulley of the desired configuration (Figure 3).

A 12-inch wide by 18-inch long cleaning bed was made by using the two pulleys and 26 3/16-inch diameter round nylon belts. The belts were spaced 3/8 inch apart, center-to-center. Chain and sprockets of the same size, on each pulley shaft, were used to keep the pulleys in time during operation.

EXPERIMENTAL DESIGN AND PROCEDURE

A laboratory experiment was designed to test the separating efficiency of the curved triangular pulley-belt system. The cleaning bed was mounted

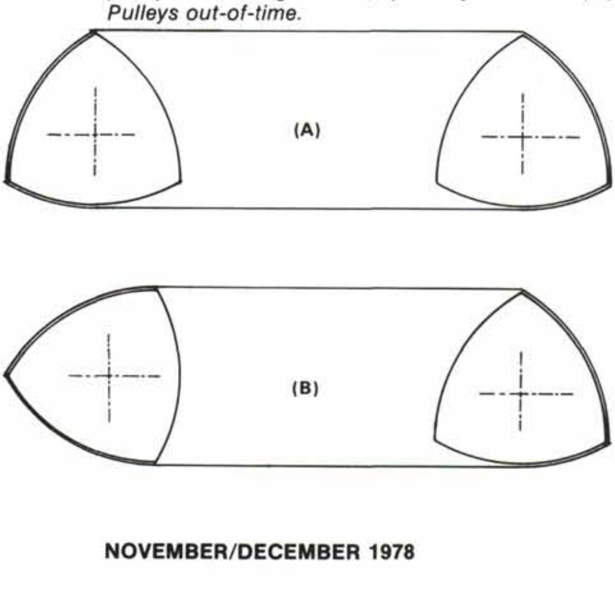
Figure 1. Cross-section of constant width triangular pulley.



*Constant width closed curves possess the property in which the distance of any two parallel tangents are always at the same. Circle is only one such shape. For details see references Gardner, 1963, and Verma, et al., 1977.

Figure 4. The bunker sand cleaning unit above and the reason why it's needed on the right.

Figure 2. Schematic of constant width triangular pulley-belt arrangement. (A) Pulleys in-time. (B) Pulleys out-of-time.

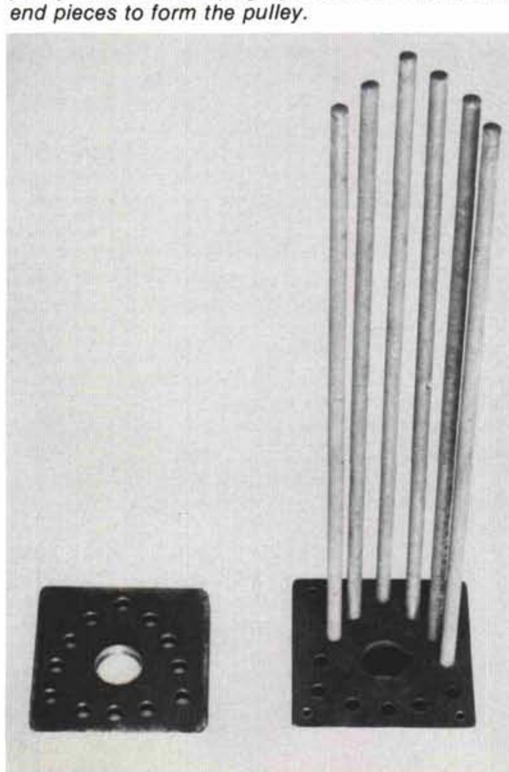


at the end of a conveyor belt with an arrangement so that a sand and trash mixture from the conveyor belt could be dropped on the cleaning bed at a predetermined rate. The cleaning bed pulleys were driven by a variable speed motor.

The following conditions were tested to determine the separating efficiency of the design:

1. Five Pulley RPM: 50, 100, 150, 200 and 250 RPM.
2. Three cleaning bed inclinations (angles from horizontal plane): 0 degrees, 10 degrees and 15 degrees.
3. Two sizes of gravel to simulate trash: (a) ¼ to ½ inch and (b) greater than ½ inch.

Figure 3. Construction of pulleys. (Left) Pulley end piece with ¼-inch holes outlining the triangular pulley cross-section. (Right) Steel rods between the end pieces to form the pulley.



4. Three rates of sand and gravel mixture fed onto the cleaning bed by the conveyor belt set at ½ mph linear speed to provide sand thicknesses of: (a) ½-inch thick sand and gravel mixture, (b) 1-inch thick sand and gravel mixture, and (c) 1½-inch thick sand and gravel mixture. Assuming the bunker cleaner is set to pick up a layer of sand ¼ inch deep, the above conditions simulate operating speeds of 1, 2, and 3 mph.
5. Two sand moisture contents: (a) dry sand and (b) moist sand.
6. All tests were replicated twice. Some preliminary tests indicated that the most satisfactory mode of operation was to introduce a pre-weighed amount of sand and known number of gravel particles on the cleaning bed. Therefore, 10, 20, and 30 pounds of sand was introduced at ½, 1, and 1½ inch thickness, respectively. With the sand 50 large and 100 small gravel particles were mixed. The sand and gravel were collected at three locations: (a) under the first half section of the cleaning bed, Section 1, (b) under the second half section of the cleaning bed, Section 2, and (c) at the end of the cleaning bed, Section 3.

RESULTS AND DISCUSSION

Data from the laboratory tests were analyzed to determine design criteria for best cleaning. The cleaning efficiency was determined by: (a) the separation of sand from gravel with collection in Sections 1 and 2, (b) the conveyance of large-gravel to the rear with collection in Section 3, and (c) the conveyance of small-gravel to the rear with collection in Section 3. For the best performance, 100 percent sand and no gravel should be collected in Sections 1 and 2, or 100 percent of the gravel of both sizes and no sand should be collected in Section 3.

The first set of tests was run using dry sand. For all operating conditions, 100 percent of the sand and 100 percent of the large gravel was separated. However, the small gravel separation was dependent upon the pulley RPM. As the pulley RPM was increased, more small gravel particles were conveyed to the rear, and at a 10 degree bed angle and 150 pulley RPM, 99 percent of the small gravel was transported to the rear of the cleaning bed.

Test results with the moist sand show that, in general, the sand separating efficiency increases as the pulley RPM are increased at all three bed angles. However, the small-gravel transporting efficiency decreases with increase in pulley RPM from 50 to 150 RPM and then increases as the pulley RPM is further increased to 250 RPM. The large-gravel transporting efficiency was 100 percent for all test conditions.

To determine the best operating condition, the overall cleaning efficiency was calculated by multiplying the sand-cleaning efficiency and the sand-gravel transporting efficiency. It was found that the best cleaning was obtained at 250 pulley RPM, 0 degree bed angle and ½ inch sand thickness. It appeared that the bed angle had little effect at 250 pulley RPM and ½ inch sand thickness.

THE FIELD UNIT

Based on the results of the laboratory test, a field unit with a cleaning bed 18 inches long and 24 inches wide was made, using the curved triangular pulley and belt system. The cleaning unit was mounted at the rear of a Trap King* bunker tractor (Figure 4). In front of the cleaning bed, a sand pick-up unit was mounted. The pick-up unit was made by using six, 6-inch square blades mounted at a 45-degree angle on a shaft. A shield was constructed to direct the sand and trash onto the cleaning bed. The pick-up unit rotated backwards, i.e., reverse to the direction of rotation of the tractor wheels. A collection basket made with ¼-inch hardware cloth was mounted at the rear of the cleaning bed and provision to vibrate it was made.

The unit works well when the sand is not wet and where the depth of cut is such that the sand entering the cleaning bed is not excessive. We have recorded 100 percent sand separation and trash transportation under good operating conditions. However, we have found that the pick-up unit is unable to pick up all trash and deposit it on the cleaning bed. Improvement in the design of the pick-up unit is recommended.

CONCLUSIONS

We have successfully demonstrated that the constant width curved triangular shaped pulleys can be used in a pulley-belt system for separating trash from sand. Pulleys of such cross-section can provide the necessary vibration to materials for size separation. A field unit was constructed using the new separating mechanism which performed well when sand was not wet.

ACKNOWLEDGEMENT

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