Large Portable Auger Power and Throughput Analysis

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Abstract. Historically small screw type grain augers (4 through 6 in. diameter) have been evaluated for throughput and power requirements. This research investigates these parameters for 8 through 14 in diameters. Specifically five grain augers were tested for throughput and power requirements when operating at full capacity and rated speed. They were a 12 and 14 in top drive and a 8 in., 10 in., and 12 in. bottom drive with swing hopper. Each auger was evaluated at transport position, 20 deg inclination angle and 30 deg inclination angle.

Power requirements for the bottom-drive swing augers were over twice the requirements of a top drive. Each auger required and additional 4 hp when the inclination angle was increased from transport position (13 deg) to 20 deg. An additional 5 to 6 hp was required when the inclination angle was increased from 20 deg to 30 deg.

Throughput for the bottom-drive swing hoppers did not significantly change as the inclination angle increased, but was reduced by 25% for the top drive augers. For the same diameter augers the bottom-drive swing hopper augers had from 6 % to 25 % more throughput than the top-drive auger for inclination angles 13 deg to 30 deg respectively.

Keywords. Auger, Screw Conveyor, Power requirements, Capacity.
Introduction

Screw Conveyers (augers) are used to convey free flowing materials such as grain to more difficult fibrous materials such as straw and alfalfa. At gain elevators and on the farmstead, augers are used to move grain to and from storage. In these applications the conveyor consists of a rotating shaft which carries a helicoid flighting through a stationary tube. Factors affecting capacity include auger dimensions (diameter, auger geometry), shear-plane flighting orientation, auger speed, angle of inclination, commodity being conveyed, and entrance-opening configuration. Rehkugler and Boyd (1962) proposed an application of a dimensional analysis model to predict screw conveyor performance. This tool is quite rigorous and requires several simplified assumptions. The process of conveying by a screw conveyor is a complex process, thereby making the process difficult to analyze and to develop a model to predict power requirements. Therefore most performance investigation is done by measuring results from a with full-scale equipment.

Pert et al. (1967) developed a performance-test procedure for screw conveyors which characterizes capacity, volumetric efficiency and power requirement. Screw conveyor performance data exist for screws 15 cm (6 in) and smaller diameters, but capacity and power requirements for screws larger than 15 cm (6 in) in diameter are missing. Nicolai et al. (2004) investigated 20 and 25 cm (8 and 10 in) diameter screw conveyor moving corn at various inclination angles.

The objective of this investigation was to continue the investigation started by Nicolai et al. (2004) by determining the power requirements and throughput of 20, 25, and 30 cm (8, 10, and 12 in) diameter bottom-drive screw conveyer with a swing hopper, and 30 and 35 cm (12 and 14 in) top-drive augers moving corn at various inclination angles.

Material and Methods

For the top-drive evaluations two tube diameters (30 and 35 cm [12 and 14 in]) screw conveyors were evaluated for throughput and power requirements. The conveyors were 15.5 m (51 ft) long with an intake configuration of 40.6 cm (16 in) intake length. The plastic inlet charge hopper had a 123 cm (48 in) top diameter and was 45.7 cm (18 in) deep. Adequate corn flow from the gravity-flow wagon was maintained to the charge hopper to assure that the inlet section of the auger was totally submerged. Each auger had a “run-in” time of at least 20 minutes with dry corn prior to commencing test. Both augers were designed to operate at 1000 rpm.

The bottom-drive evaluations consisted of three tube diameters (20, 25 and 30 cm [8, 10 and 12 in]). The conveyors were 15.5 m (51 ft) long. The swing-hoppers were mechanically driven and were charged with corn to assure that the short augers in the swing-hopper were submerged during the test. Design operating speed for the 20 cm auger was 540 rpm and 1000 rpm for the 25 and 30 cm augers.

Three inclination angles (transport position [i.e. 13°], 20°, and 30°) were used in the evaluation. Each configuration combination was replicated three times providing at least 20 data points per configuration. For each test run the auger was operated at a slow speed until the complete auger was filled to capacity, then the speed was increased to the design rpm’s and continued for approximately one minute or until the gravity-flow wagon was empty.

Corn used for the experiment ranged from 13 to 15.4% moisture content.
Performance test procedures purposed by Peart, et.al (1967) for screw conveyors were followed. During each trial a gravity flow wagon, equipped with a weigh scale (Fig. 1) was continuously monitored every two seconds to determine throughput, i.e. bushels per hour.

Horsepower of the auger was determined by measuring the shaft speed and torque. Shaft speed was measured using a gear tooth sensor and shaft torque was measured using a strain gage (CEA-06-250US-120). A custom setup was used to calibrate the strain gage to represent the torque on the shaft. ‘TorqeTrack 9000 digital radio telemetry system’ was used to transmit the rotating shaft strain gage voltage to data acquisition module (Iotech Personal Daq 56).

Throughput was determined by comparing the weight change of the grain trailer over a known time. The trailer was equipped 4 with Weigh-Tronix weigh-bars and a scale indicator with voltage output option.

A software program was written in LabVIEW to calculate horse power from gear tooth sensor frequency output and strain gage voltage, and throughput from weigh-bar indicator voltage. Shaft speed, torque, horse power and throughput values were filtered by averaging 5 samples using a moving average method to eliminate the noisy values. The LabVIEW program saved the all filtered values in a excel sheet.

Two waveform graphs on the LabVIEW front panel program showed the horsepower and throughput continuously. These graphs provided a real-time visual performance of the augur during each run.
Results and Discussion

The performance of a screw conveyor can be characterized by capacity, volumetric efficiency and power requirements. Parameters effecting performance include conveyor speed, angle of inclination, conveyor size, and properties of material being conveyed.

Capacity.

Table 1 shows the combined throughput results for augers tested from this research with that obtained and reported by Nicolai et al. (2004) which data is shown as italics. Throughput rates for the top drive augers decreased from 0.4% to 2.0% per degree as the inclination angle increased, whereas the bottom-drive augers with a swing hopper did not significantly change as the inclination angle increased. Thus, the throughput changed less or not at all for the bottom-drive with swing hopper as the inclination angle increased. The lack of change for the bottom-drive auger may be contributed to the swing drive hopper force feeding the auger rather than allowing gravity to fill the auger as with the top-drive.

Also the volumetric efficiency of the bottom-drive auger with a swing hopper is maintained as the inclination angle is increased whereas the volumetric efficiency decreased for the top-drive augers. The reason may be contributed to the swing drive hopper force feeding the auger.

Table 1. Maximum throughput at auger speeds listed.

<table>
<thead>
<tr>
<th>Auger Diameter cm (inch)</th>
<th>Top-drive Bu/min</th>
<th>Bottom-drive with swing hopper Bu/min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Transport 20 deg</td>
<td>30 deg</td>
</tr>
<tr>
<td>20 (8)</td>
<td>38*</td>
<td>37*</td>
</tr>
<tr>
<td></td>
<td>34*</td>
<td>39</td>
</tr>
<tr>
<td>25 (10)</td>
<td>68*</td>
<td>55*</td>
</tr>
<tr>
<td></td>
<td>45*</td>
<td>72</td>
</tr>
<tr>
<td>30 (12)</td>
<td>100</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>77</td>
<td>106</td>
</tr>
<tr>
<td>35 (14)</td>
<td>147</td>
<td>131</td>
</tr>
</tbody>
</table>

*Reported in an earlier paper by Nicolai et al. (2004).

Power requirements

Table 2 shows the power requirements for each of the augers tested for this research as well as the two augers tested and reported in Nicolai et al. (2004). The power required to operate an auger increased as the angle of operation increased. The swing hopper with bottom-drive required more power to operate than the top drive augers.

The horsepower for the bottom-drive with swing hopper auger increased at a faster rate (0.74 HP/Deg versus 0.14 HP/Deg) than the top-drive auger as the inclination angle increased. This difference in rate of change can be contributed to the throughput of the two auger types. The rate of change of horse power in the top drive augers is smaller because it carries less grain with each increase in inclination angle. The data shows that since throughput does not drastically change in swing drive augers at a larger inclination angle, horsepower and energy spent must rise to compensate for the larger mass of grain to be raised to a higher elevation.
Table 2. Power change per 100 rpm increase.

<table>
<thead>
<tr>
<th>Auger Diameter</th>
<th>Inclination angle degrees</th>
<th>Top-drive KW (hp)</th>
<th>Bottom-drive with swing hopper KW (hp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 cm (8 in)</td>
<td>13</td>
<td>3.8(5.2)*</td>
<td>10.2 (13.7)</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>4.1(5.5)*</td>
<td>13.7 (18.4)</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>4.0(5.4)*</td>
<td>16.8 (22.5)</td>
</tr>
<tr>
<td>25 cm (10 in)</td>
<td>13</td>
<td>5.0(6.8)*</td>
<td>22.3 (29.9)</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>5.6(7.5)*</td>
<td>23.6 (31.6)</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>5.4(7.3)*</td>
<td>30.0 (40.2)</td>
</tr>
<tr>
<td>30 cm (12 in)</td>
<td>13</td>
<td>16.8 (22.5)</td>
<td>35.4 (47.5)</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>17.7 (23.7)</td>
<td>38.5 (51.6)</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>18.6 (24.9)</td>
<td>44.7 (59.9)</td>
</tr>
<tr>
<td>35 cm (14 in)</td>
<td>13</td>
<td>20.7 (27.8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>21.7 (29.1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>25.7 (34.5)</td>
<td></td>
</tr>
</tbody>
</table>

*Reported in an earlier paper by Nicolai et al. (2004).

**Conclusion**

Data reported in this paper were obtained very similar to the procedure prescribed by Peart et al. (1967) except that no specific tests were made regarding grain damage.

Increasing the conveyor speed increased the capacity up to a maximum value and further increases in speed caused a decrease in capacity. The screw speed for maximum capacity averaged 823 rpm for both 20 cm (8 in) and 25 cm (10 in) diameter conveyor.

Volumetric efficiency decreased an average 3% for every 100 rpm increase in conveyor screw speed. Changing the conveyor inclination angle did not affect the volumetric efficiency relative to the screw speed.

Power requirements per conveyor screw speed were effected by inclination angle for top-drive augers but not for bottom-drive swing hopper augers.

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References


