Performance Evaluation of a 15.5 cm Screw Conveyor during Handling Process of Rough Rice (*Oriza Sativa* L.) Grains

Hemad Zareiforoush[1*], Mohammad Hasan Komarizadeh[1], Mohammad Reza Alizadeh[2]

1. Department of Mechanical Engineering of Agricultural Machinery, Faculty of Agriculture, University of Urmia, P.O. Box 165, Urmia 57135, Iran
2. Rice Research Institute of Iran (RRII), P.O. Box 1658, Rasht 41235, Iran

hemad.zareiforoush@yahoo.com

Abstract: In the current research, some experiments were conducted to investigate the effect of screw diametric clearance and screw rotational speed on the performance characteristics of a screw conveyor, during handling process of rough rice grains. The performance specifications were evaluated in terms of conveyor actual volumetric capacity, volumetric efficiency, specific power and net power requirements. A screw conveyor with the housing diameter of 15.5 cm, screw diameter of 13 cm and screw shaft diameter 3.5 cm having the length of 150 cm was constructed for conducting the experiments. The results revealed that the specific power requirement of the conveyor increased significantly (P<0.01) with increasing the screw diametric clearance and screw rotational speed. The net power requirement of the conveyor increased significantly (P>0.01) with increasing the screw rotational speed; whilst the value found to be decreased with increasing the screw clearance (P<0.01). As the rotational speed of the screw conveyor increased, the actual volumetric capacity increased up to a maximum value and further increases in speed caused a decrease in capacity. The volumetric efficiency of the screw conveyor decreased significantly (P<0.01) with increasing the screw diametric clearance and screw rotational speed. Considering the widely utilization of screw conveyors in agricultural grains handling processes, the information obtained in this study could be very useful in proper design and adjustments of this type of implements with respect to conveying materials characteristics. [Nature and Science 2010;8(6):66-74]. (ISSN: 1545-0740).

Key words: Screw conveyor, Power, Clearance, Rotational speed, Volumetric efficiency, Capacity

1. Introduction

There are several methods used to convey agricultural materials. The selection of conveying method depends upon the nature of application and on the type of material being conveyed. The agricultural materials may be granular, powder, fibrous, or any combination of these. Generally, conveying is accomplished by a combination of mechanical, inertial, pneumatic, and gravity forces. Conveyors utilizing primarily mechanical forces are screw, belt, and mass conveyors. Screw conveyors are popular devices for conveying farm products. They are very effective conveying devices for free flowing or relatively free flowing bulk solids, giving good throughput control and providing environmentally clean solutions to process handling problems because of their simple structure, high efficiency, low cost and maintenance requirement. Screw conveyors vary in size from 75 to 400 mm in diameter and from less than 1 m to more than 30 m in length (Athanasiov et. al., 2006). The performance of a screw conveyor, as characterized by its capacity, volumetric efficiency, and power requirements, is affected by the conveyor geometry and size, the properties of the material being conveyed, and the conveyor operating parameters such as the screw rotational speed, screw clearance and conveying angle (Srivastava et al., 2006).

For economical installation and dependable performance, the capacity and power requirement of each component of a system must be accurately predicted. In recent years, several studies have been conducted by researchers to determine the performance characteristics of screw conveyors. There are some papers in this area:

Konig and Riemann (1960) examined the influence of inlet screw diameter on screw conveyor capacity and reported a nearly linear increase in capacity with increased inlet screw diameter up to a maximum point. After reaching to the point, capacity decreased. However, power required continued to increase with inlet-screw diameter after the optimum diameter for capacity was reached. Stevens (1962) tested performance of several auger conveyors. He indicated that less than 50% of the power was used in moving grain along the tube. Some of the extra power required must be consumed at the intake hopper, where considerable circulation of grain was observed. O'Callaghan (1962) studied the influence of intake length on power requirements for vertical screw conveyors operating at different speeds. Burkhardt (1967) tested the effects of pitch (distance between adjacent screw flights), radial clearance, hopper exposure and hopper level on the performance of screw feeders. Peart et al. (1967) developed a performance-test procedure for screw conveyors which characterizes capacity, volumetric efficiency and power requirement. Carleton et al. (1969) discussed the performance of screw conveyors and screw feeders based on experiments on the effects of screw geometry, speed, fill level and material properties. McFate and George (1971) reported higher volumetric efficiencies with larger diameter conveyors. Bloome et al. (1976) indicated that capacity of a screw conveyor is affected by its diameter, intake length, conveying angle, rotational speed, and moisture content of grain. Rautenbach and Schumacher (1987) derived a set of parameters by dimensional analysis to calculate the power consumption and transport capacity and compared two geometrically similar screws. Chang and Steele (1997) evaluated effects of flight type, incline angle, intake length, and rotation speed on grain damage, power requirement, conveying capacity, and conveying energy efficiency for conveying corn with a screw conveyor. Nicolai et al. (2006) analyzed large portable screw augers performance specifications. They determined the capacity, volumetric efficiency, and power requirements for 20 cm (8 in) and 25 cm (10 in) diameter conveyors operating in a speed range of 250 to 1100 rpm at inclination angles of 13, 20, and 30 degrees for conveying corn.

However, reviewing of the literature showed that there is no result concerning the screw conveyors power and throughput analysis during handling process of rough rice (*Oriza Sativa* L.) grains. Nowadays, screw conveyors are widely being used in rough rice harvesting and post-harvesting equipments. For example, in a rice combine, screw conveyors are used to move cut crop on the platform to the feeder housing, clean grain from the bottom of the cleaning shoe to the grain tank, and to unload the grain tank onto a wagon or a truck. Screw conveyors are also used at grain elevators and farmsteads to load grain storage bins and on feedlots for feed distribution. Screw conveyors are also being used in various parts of field threshing machines and other similar implements.

Hence, the objective of this research was to evaluate the effects of screw clearance (6, 9, 12 and 15 mm) and screw rotating speed on of a screw conveyor throughput capacity and power requirements during rough rice grains handling process. Considering the widely utilization of screw conveyors in agricultural grains handling processes, the information obtained in this study could be very useful in proper design and adjustments of this type of implements with respect to conveying materials characteristics.

2. Materials and methods

2.1. Samples preparation

The rough rice grains used in the current research were obtained from the Rice Research Institute of Iran (RRII), Rasht, Iran. The variety evaluated in this research, Hashemi, is one of the local varieties of rough rice grains in the northern provinces of Iran, which is characterized by slender kernels and long awns (Alizadeh *et al*., 2006). Before starting the experiments, the samples were cleaned to remove all foreign materials such as grit, chaff, straw, and stems. The initial moisture content of the samples was determined by oven drying method at 130±1 °C for 24 h (Pan *et al.*, 2008). It became evident that the initial moisture content of the samples was 11.2% (w.b.).

2.2. Experimental set up & procedure

A screw conveyor with the housing diameter of 15.5 cm (6 in), screw diameter of 13 cm (5 in) and screw shaft diameter 3.5 cm (1.4 in) was constructed for conducting the experiments. The conveyor was 150 cm long and had a standard screw pitch (the distance between adjacent screw flights). The inlet section of the conveyor was 32 cm long. The conveyor was driven by a 1.5 kW electric motor through belt and pulley. The performance specifications of the screw conveyor were determined in terms of conveyor actual volumetric capacity, volumetric efficiency, specific power and net power requirements. The performance characteristics were investigated as a function of screw clearance (the diametric distance between the rotating flight and its stationary housing wall) and screw rotational speed.

In order to investigate the effect of screw clearance on the performance specifications of the screw conveyor, four diametrical clearances, namely, 6, 9, 12 and 15 mm were selected. For achieving to these levels, an apparatus was specifically made for this research with the capability of adjusting the screw clearance between the rotating flight and its stationary housing wall. The screw clearance was adjustable by installing the conveyors housing on a lifting mechanism (Figure 1).

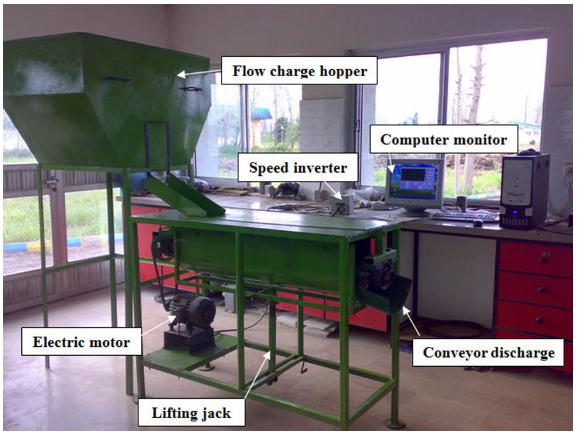

Figure 1. Screw conveyor experimental set up

The effect of screw rotational speed on the screw conveyor performance characteristics were evaluated by selecting five levels of rotational speeds of 200, 300, 400, 500 and 600 rpm. The desired rotational speeds for the screw conveyor were adjusted using a speed inverter (LG model IC5, Korea) which was contacted to the drive electric motor, and then the rotational speed of screw conveyors was measured using a digital photo/contact tachometer (Lutron model DT-2236, Taiwan) on the conveyors shaft.

At each experiment, the rough rice grains were poured from a big gravity flow charge hopper to the conveyor intake section and allowed the conveyor to operate at selected condition for a few minutes. This was defined as the conveyor run-in time. During experiments, adequate flow from the big gravity flow charge hopper was maintained to the intake section of the conveyor to assure that the intake section was totally submerged.

The screw conveyor actual volumetric capacity was determined through measuring the weight of conveyed grains over a known time. A weigh scale with an accuracy of 0.01 g (FLINTEC model PTS10000, Sweden) was used for this purpose. The actual volumetric capacity was expressed in bushels (one bushel = 1.244 cubic feet) per hour (ASABE, 2006). In reality the actual capacity of a screw conveyor is considerably less than the theoretical capacity. This results in loss of volumetric efficiency. The volumetric efficiency (E_v) is defined as (Srivastava *et al.*, 2006):

$$E_v = \frac{Q_a}{Q_t} \qquad (1)$$

where: Q_a is the actual volumetric capacity (m^3/min) and Q_t is theoretical volumetric capacity (m^3/min) that can be expressed by the following (Srivastava *et al.*, 2006):

$$Q_t = \frac{\pi}{4}\left(d_{sf}^2 - d_{ss}^2\right) l_p \, n \qquad (2)$$

where: d_{sf} is screw flight diameter (m), d_{ss} is screw shaft diameter (m), l_p is the pitch length (m) and n is the screw rotational speed (rpm).

In order to express the screw conveyor throughput capacity in terms of the volumetric capacity, the values of Q_a and Q_t should be multiplied at the conveying grains bulk density (Srivastava *et al.*, 2006). The bulk density of the rough rice variety used in the current research at the moisture content of 11% is 390 kg/m (Zareiforoush *et al*., 2009).

Since the conveyor was driven by means of an electric motor, the power requirements were measured by means of a power meter with the capability of monitoring (Roohi, 2003; Roohi *et al*., 2005). The instantaneous values of power data was continuously monitored on a computer every second. At each experiment, all power data was recorded with the computer using a software program and the recorded data was stored on a spreadsheet for later statistical analysis and regression determination. The power requirements were determined in terms of the specific power of the screw conveyor and the net power, that is to say the power needed for handling the rough rice grains. The specific power requirement of screw conveyor was calculated from the following equation (Srivastava et al., 2006):

$$P'_s = \frac{P_s / L}{Q_a \rho_b} \qquad (3)$$

where: P_s' is the specific power requirement of screw conveyor (W s/kg m), P_s is the total power needed when the screw conveyor is transporting the grains (W), L: the length of conveyor (m), Q_a is the actual volumetric capacity of conveyor (m^3/s) and ρ_b is the conveying materials bulk density (kg/m).

Thus, the specific power is the power required to convey a unit mass throughput rate per unit conveyor length.

The net power requirement for conveying the rough rice grains (P_r) was defined as:

$$P_n = P_s - P_u \qquad (4)$$

where: P_n is the net power requirement for conveying the grains with the screw conveyor (W) and P_u is the unload power, which is needed for the conveyor when it is operating empty (W).

2.3. Experimental design and statistical analysis

The experiments were conducted to a factorial statistical design. Considering combination of the evaluated factors, 20 treatments were evaluated in the form of completely randomized block design. At each treatment, the experiments were replicated four times and then the mean values were reported. The experimental data were analyzed using analysis of variance (ANOVA) and the means were separated at the 5% probability level applying Duncan's multiple range tests in SPSS 16 software program and analysis of regressions was performed using Microsoft Excel 2007 software.

3. Results and discussion

3.1. Volumetric capacity & volumetric efficiency

As seen in Table 1, variance analysis of the data indicated that the effects of screw clearance and screw rotational speed on the volumetric capacity and volumetric efficiency were significant at the 1% level of probability; while the interaction effect of screw clearance × screw rotational speed was not significant on the volumetric capacity and efficiency (P>0.05).

Table 1. Analysis of the variance of the parameters considered on the actual volumetric capacity (Q_a), volumetric efficiency (E_v), specific power (P'_s) and net power (P_n) requirements

Source	DF	Q_a (bu/h)	E_v (%)	P'_s (W)	P_n (W)
SC	3	14589.43[a]	134.29[a]	956.15[a]	459.22[a]
SS	4	17552.43[a]	884.41[a]	13720.61[a]	4804.57[a]
SC × SS	12	293.94[ns]	11.08[ns]	91.22[a]	88.38[ns]
Error	60	7.06	8.17	4.55	7.31

[a] Corresponding to significant at the 1% level of probability; ns: Corresponding to no significant difference; SC: Screw clearance; SS: Screw speed.

The volumetric capacity of the screw conveyor with respect to screw rotational speed at different screw clearances is illustrated in Figure 2. As shown, at all of the clearances investigated, with increasing the screw rotational speed, the volumetric capacity increases and reaches to a maximum point and after this point, the volumetric capacity starts to decrease. Srivastava *et al*. (2006) has suggested that there may be two factors responsible for this behavior: (1) the restriction as grain flows into the intake of the conveyor, and (2) the centrifugal force due to the rotation of the grain mass at higher rotational speeds. Konig and Riemann (1990) examined the influence of inlet screw diameter on screw conveyor capacity and reported a nearly linear increase in capacity with increasing inlet screw diameter up to a maximum point. After reaching to the point, capacity decreased. As it can be seen from Figure 2, the maximum capacity of the screw conveyor occurred between the rotational speeds of 400 and 500 rpm. This range of the conveyor speed for maximum capacity was independent of the screw clearance. Chang and Steele (1997) evaluated the performance characteristic of the inlet section of a 15.2 cm screw conveyor. They reported that the conveying capacity of the inlet section of a screw conveyor increased from 32.1 to 42.8 and 24.9 to 34 t/h, respectively, for two corn lots evaluated, as the rotational speed of conveyor increased from 413 to 690 rpm. The results also revealed that with increasing the screw clearance, the volumetric capacity of the screw conveyor decreased (Figure 2). This may be due to a decrease in the active layer (the layer which is conveyed by auger rotation) of the conveying grains as a result of increasing the distance between the screw rotating flight and conveyor housing.

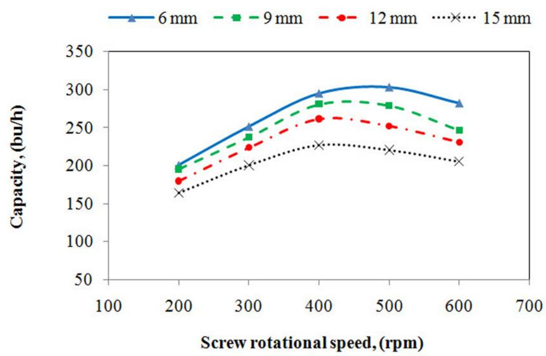

Figure 2. Effect of screw rotational speed on the volumetric capacity for the screw conveyor at: × 6 mm, ■ 9 mm, ● 12 mm, and p 15 mm screw clearances

The effect of screw rotational speed on the conveyor volumetric efficiency at different screw clearances is shown in Figure 3. From the figure, it becomes evident that with increasing the rotational speed of the conveyor, the volumetric efficiency decreases. It seems that if the screw rotational speed is increased sufficiently, the centrifugal force may become so restrictive as to cause the volumetric efficiency to be declined. This can be also expounded by the effects of materials vortex motion resulting from higher centrifugal forces at higher rotations of the screw flights. Vortex motion arises as a result of internal friction, friction between the granular material and surface of the helical blade, and the infinitely variable helix angle of the helical flight from the outer periphery of the blade to the shaft. The vortex motion, together with the degree of fill, govern the volumetric efficiency and, hence, the volumetric throughput (Roberts, 1999). It can also be seen from Figure 3 that with increasing the screw clearance, the volumetric efficiency decreases. As mentioned, this could be attributed to the decrease in the active layer of the conveying grains as a result of increasing the distance between the screw rotating flight and conveyor housing. Brusewitz and Persson (1969) reported that the screw clearance can affect the volumetric efficiency. They indicated that the diametric clearances up to 5-7% have little effect on the volumetric efficiency, but a drop in efficiency of 0.7% per 1% increase in clearance can be expected.

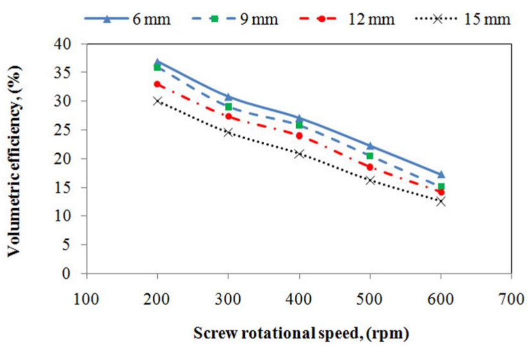

Figure 3. Effect of screw rotational speed on the volumetric efficiency for the screw conveyor at: × 6 mm, ■ 9 mm, ● 12 mm, and p 15 mm screw clearances

The mean values of volumetric capacity and volumetric efficiency for the evaluated screw conveyor at different screw clearances and screw rotational speeds are presented in Table 2. As shown, the highest value of the volumetric capacity (303.64 bu/h) was obtained at the screw clearance of 6 mm and screw rotational speed of 500 rpm; while the lowest value of the volumetric capacity (163.77 bu/h) was obtained at the screw clearance of 15 mm and screw speed of 200 rpm. The highest value of volumetric efficiency (36.89%) was acquired at the screw clearance of 6 mm and screw rotational speed of 200 m; whilst the lowest value of the volumetric efficiency (12.55%) was obtained at the screw clearance of 15 mm and screw speed of 600 rpm.

The equations representing relationship between the volumetric efficiency of the screw conveyor with respect to the screw rotational speed at different screw clearances with their coefficient of determination (R^2) are presented in Table 3.

Table 2. Mean values of volumetric capacity (Q_a) and volumetric efficiency (E_v) for the evaluated screw conveyor at different screw clearances and screw rotational speeds

Screw speed (rpm)	Screw clearance							
	6 mm		9 mm		12 mm		15 mm	
	Q_a (bu/h)	E_v (%)	Q_a (bu/h)	E_v (%)	Q_a (bu/h)	E_v (%)	Q_a (bu/h)	E_v (%)
200	201.11 (10.93)*	36.89 (2.01)	195.54 (10.91)	35.87 (3.87)	179.82 (9.68)	32.98 (2.71)	163.77 (9.26)	30.04 (1.88)
300	251.88 (11.09)	30.80 (4.78)	237.47 (9.53)	29.04 (1.16)	223.71 (6.72)	27.35 (0.82)	200.68 (9.14)	24.54 (2.34)
400	295.45 (11.34)	27.09 (1.09)	281.03 (10.29)	25.77 (1.92)	261.71 (8.11)	24.01 (0.74)	227.32 (11.25)	20.85 (1.31)
500	303.64 (12.62)	22.28 (1.36)	279.39 (10.87)	20.49 (1.34)	252.54 (11.16)	18.53 (0.96)	220.77 (12.67)	16.19 (0.98)
600	282.67 (12.17)	17.28 (0.78)	246.97 (9.74)	15.09 (0.95)	231.25 (9.67)	14.14 (0.98)	205.37 (10.71)	12.55 (0.78)

*Figures in parentheses are standard deviation. Q_a: actual volumetric capacity, and E_v: volumetric efficiency.

Table 3. Equations representing relationship between the performance characteristics of screw conveyor and screw rotational speed at different screw clearances

Performance characteristic	Screw clearance (mm)	Relationship	R^2
Volumetric efficiency	6	E_v = -477E-4S_S + 45.96	0.995
	9	E_v = -501E-4S_S + 45.28	0.991
	12	E_v = -465E-4S_S + 42.01	0.996
	15	E_v = -433E-4S_S + 38.16	0.995
Specific power	6	P'_s = 1495E-4S_S + 20.70	0.991
	9	P'_s = 1767E-4S_S + 14.12	0.985
	12	P'_s = 1924E-4S_S + 12.07	0.992
	15	P'_s = 2196E-4S_S + 8.95	0.997
Net power	6	P_n = 1135E-4S_S + 23.61	0.899
	9	P_n = 1011E-4S_S + 25.05	0.883
	12	P_n = 1008E-4S_S + 21.94	0.881
	15	P_n = 1002E-4S_S + 18.26	0.875

E_v: volumetric efficiency, P'_s: Specific power, P_p: Net power and S_S: Screw rotational speed.

3.2. Specific power & Net power

Based on the results of statistical analysis presented in Table 1, the effects of screw clearance and screw rotational speed on the specific power and net power were significant at the 1% probability level. Although the interaction effect of screw clearance × screw rotational speed on the specific power was significant (P<0.01), the effect was not significant on the net power (P>0.05). The effect of screw rotational speed on the specific power of the screw conveyor at different screw clearances is illustrated in Figure 4. As shown, at all of the screw clearances evaluated, the specific power of the screw conveyor increased with increasing the screw rotational speed. This can be due to the fact that with increasing the screw rotational speed, the power needed for auger rotation increases. Moreover, the volume of the materials being conveyed at higher levels of screw rotational speeds is higher. The results confirms Srivastava *et al.* (2006) conclusion that the power requirements of a screw conveyor increases with increasing the screw rotational speed. Chang and Steele (1997) reported that with increasing the screw rotational speed from 413 to 690 rpm, the average power requirements for the inlet section of a 15 cm conveyor increased from 189 to 338 W and 209 to 350 W, respectively, for two corn lots evaluated. They concluded that the power requirements for the inlet section tested were about 28 to 33% of the total power requirements for the 3 m long 15 cm diameter screw conveyor reported by White *et al.* (1962). Nicolai *et al.* (2004) determined the power requirements of large portable augers operating in a speed range of 250 to 1100 rpm at inclination angles of 13, 20, and 30 degrees. They reported that for every 100 rpm increase in screw speed for a 25 cm conveyor an increased power of 0.8 kW was needed for inclination angles greater than 20°. The power requirement was reduced to 0.5 kW for each 100 rpm increase at the transport position of 13° inclination.

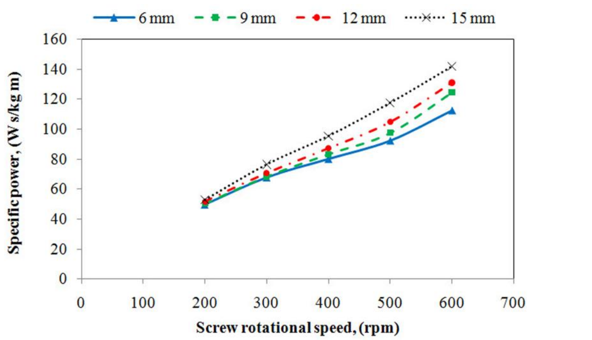

Figure 4. Effect of screw rotational speed on the specific power of the screw conveyor at: × 6 mm, ■ 9 mm, ● 12 mm, and p 15 mm screw clearances

Based on the results presented Figure 4, it can be inferred that the specific power of the screw conveyor increases with increasing the screw clearance. This result can be explained by the equation (3). According to the equation, the specific power requirement is directly proportional to the total power and inversely proportional to the actual volumetric capacity. In the equation, conveyor length and bulk density of the material are constant. With increasing the screw clearance both the actual volumetric capacity (Table 2) and the total power requirement of the conveyor decreased. Therefore, it can be concluded that the effect of actual volumetric capacity on the specific power is greater than that of the total power which caused the specific power to be increased with increasing the screw clearance. The results obtained in this research in the case of the effect of screw clearance on the specific power requirement of a horizontal screw conveyor were inconsistent with the results reported by Srivastava et al. (2006) who have reported that for horizontal screw conveyors, an increase in the diametric clearance causes a slight decline in the specific power. This may be due to the combinative effect of total power requirement and actual volumetric capacity on the specific power.

The effect of screw rotational speed on the net power at different screw clearances is shown in Figure 5. As it can be seen, at all of the clearances tested, the net power increased with increasing the screw rotational speed. This may be due to the increase in feed rate resulted from increasing screw speed. In other words, the increase in feed rate required greater energy for handling the extra material, causing an increase in the power requirements.

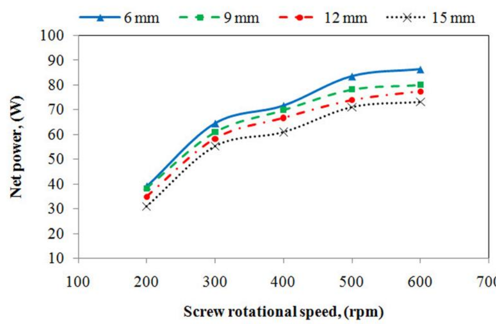

Figure 5. Effect of screw rotational speed on the net power of the screw conveyor at: × 6 mm, ■ 9 mm, ● 12 mm, and p 15 mm screw clearances

From Figure 5, it becomes evident that the net power requirement decreased with increasing the screw clearance. This can be due to a decrease in the mass of the materials being conveyed at higher levels of screw clearances. This can also be explained by a decrease in the value of frictional forces between the conveying grains and the conveyor housing wall at higher levels of screw clearances. The increasing trend of the net power with respect to the screw rotational speed was approximately similar to that of the actual volumetric capacity (Figures 2 & 5). This is most possibly due to the fact that both the net power and actual volumetric capacity are chiefly proportional to the mass of the materials being conveyed.

Table 4. Mean Values of Power Requirements for the Screw Conveyor at Different Screw Clearances and Screw Rotational Speeds

Power requirements	Screw speed (rpm)	Screw clearance (mm)			
		6	9	12	15
Specific power (W s/kg m)	200	49.84 (3.39)*	50.48 (1.80)	51.77 (1.61)	52.71 (1.78)
	300	67.83 (4.61)	68.45 (2.72)	70.61 (1.54)	76.36 (4.56)
	400	80.14 (2.15)	83.32 (3.70)	87.15 (1.83)	95.36 (4.36)
	500	92.27 (3.97)	97.44 (4.92)	104.66 (3.29)	117.54 (3.41)
	600	112.35 (2.96)	124.34 (5.01)	130.94 (5.24)	141.90 (4.61)
Net power (W)	200	39.07 (3.29)	38.24 (4.26)	34.86 (3.84)	31.03 (3.68)
	300	64.49 (4.81)	60.91 (3.11)	58.32 (2.08)	55.30 (3.92)
	400	71.62 (3.16)	69.90 (4.83)	66.69 (3.43)	60.02 (3.26)
	500	83.50 (3.14)	78.24 (3.22)	73.89 (3.36)	71.12 (4.51)
	600	86.30 (4.01)	80.11 (5.72)	77.46 (3.12)	73.21 (4.93)

*Figures in parentheses are standard deviation.

The mean values of specific power and net power requirements for the investigated screw conveyor at different screw clearances and screw rotational speeds are presented in Table 4. The highest value of the specific power (141.90 W s/kg m) was obtained at the screw clearance of 15 mm and screw rotational speed of 600 rpm; whilst the lowest value of the specific power (49.84 W s/kg m) was attributed to the screw clearance of 6 mm and screw speed of 200 rpm. The highest value of the net power (86.30 W) was acquired at the screw clearance of 6 mm and screw rotational speed of 600 m; while the lowest value for the net power (31.03 W) was obtained at the screw clearance of 15 mm and screw rotational speed of 200 rpm.

The equations representing relationship between the specific power and net power requirements of the screw conveyor with respect to the screw rotational speed at different screw clearances with their coefficient of determination (R^2) are presented in Table 3.

4. Conclusions

The specific power requirement of the screw conveyor increased with increasing the screw clearance and screw rotational speed. The net power requirement of the conveyor increased with increasing the screw rotational speed; whilst the value decreased with increasing the screw clearance. As the rotational speed of the screw conveyor increased, the actual volumetric capacity increased up to a maximum value and further increases in speed caused a decrease in capacity. With increasing the screw clearance and screw rotational speed, the volumetric efficiency of the screw conveyor decreased.

Acknowledgment:

The authors would like to thank the Rice Research Institute of Iran (RRII) and University of Urmia for providing the laboratory facilities and financial support for this project. The authors are also grateful to Kaveh Mollazade and Hamed Tavakoli for their cooperation on this research.

Correspondence to:
Hemad Zareiforoush
Department of Mechanical Engineering of Agricultural Machinery, Faculty of Agriculture, University of Urmia 57135, Iran
Telephone: +098-131-6690052
Cellular phone:+98-132-7822329
Emails: hemad.zareiforoush@yahoo.com

References

[1] Alizadeh MR, Minaei S, Tavakoli T, Khoshtaghaza MH. Effect of de-awning on physical properties of rough rice. Pakistan Journal of Biological Science 2006;9:1726–1731.
[2] ASABE Standards. Terminology and Specification Definitions for Agricultural Auger Conveying Equipment. In: St. Joseph, MI, USA: ASAE S374. 2006:257–258.
[3] Athanasiov A, Gupta ML, Fragar LJ. An Insight into the Grain Auger Injury Problem in Queensland, Australia. Journal of Agricultural Safety and Health 2006;12(1):29−42.
[4] Bloome P, Harp S, Brusewitz G. Auger conveyors. In: Cooperative Extension Service, Oklahoma State Univ. USA: OSU Extension Facts No. 1105. Stillwater, Okla. 1976.
[5] Brusewitz A, Persson S. Performance Evaluation of Screw Augers. In: Copyright American Society of Agricultural and Biological Engineers. Michigan, USA. 1969.
[6] Burkhardt GJ. Effect of Pitch Radial Clearance, Hopper Exposure and Head on Performance of Screw Feeders. Transactions of the ASAE 1967;10(1):685–690.
[7] Carleton A, Miles J, Valentin, F. A Study of Factors Affecting the Performance of Screw Conveyors and Feeders. Transactions of the ASME 1969;91:329–334.
[8] Chang CS, Steele JL. Performance Characteristics of the Inlet Section of a Screw Auger. Applied Engineering in Agriculture 1997;13(5):627–630.
[9] Konig A, Riemann U. Investigation on Vertical Auger Conveyors. NIAE Translation. Landtechnische Forschung 1990;10(2):45–51.
[10] McFate KL, George RM. Power-Capacity Relationships of Nominal 8-inch Screw Conveyors when Handling Shelled Corn. Transactions of the ASAE 1971;14(1):121–126.
[11] Nicolai R, Ollerich J, Kelley J. Screw Auger Power and Throughput Analysis. ASAE/CSAE Annual International Meeting, Ottawa, Ontario, Canada. 2004: Paper NO: 046134.
[12] Nicolai R, Dittbenner A, Pasikanti S. Large Portable Auger Throughput Analysis. ASABE Annual International Meeting, Portland, Oregon. 2006: Paper NO: 066043.
[13] O'Callaghan JR. Some Experiments on the Intake Process in a Vertical Screw Conveyor. Journal of Agricultural Engineering Research 1962;7(4):282–287.
[14] Pan Z, Khir R, Godfrey LD, Lewis R, Thompson JF, Salim A. Feasibility of Simultaneous Rough Rice Drying and Disinfestations by Infrared Radiation Heating and Rice Milling Quality. Journal of Food Engineering 2008;84:469–479.
[15] Peart RM, McKenzie BA, Herum FL. Dimensional Standards and Performance-Test Procedures for Screw Conveyors. Transactions

of the ASAE 1967;10(5):667–669.
[16] Rautenbach R, Schumacher W. Theoretical and Experimental Analysis of Screw Feeders. Bulk Solids Handling 1987;7:675–680.
[17] Roberts AW. The Influence of Granular Vortex Motion on the Volumetric Performance of Enclosed Screw Conveyors. Powder Technology 1999;104:56–67.
[18] Roohi GR. Study of Energy Consumption in the Hulling and Whitening of Three Rough rice Varieties in Guilan, Iran. Master of Science Thesis, Tehran University, Tehran, Iran. 2003.
[19] Roohi GR, Minaei S, Payman H. Designing, Manufacturing and Evaluation of a Power Meter with the Capability of Data Monitoring. Third National Conference of Agricultural Machinery Engineering and Mechanization in Iran, Kerman, Iran. 2005.
[20] Srivastava AK, Goering CE, Rohrbach RP, Buckmaster DR. In: Engineering Principles of Agricultural Machines, Second Edition, ASABE. Copyright American Society of Agricultural and Biological Engineers. Michigan, USA. 2006.
[21] Stevens GN. Performance Tests on Experimental Auger Conveyors. Journalof Agricultural Engineering Research 1962;7(1):47–60.
[22] White GM, Schaper LA, Ross IJ, Isaacs GW. Performance Characteristics of Enclosed Screw Conveyors Handling Shelled Corn and Soybeans. Indiana Agricultural Experiments Station, Purdue Univ. 1962. Research Bulletin NO. 740.
[23] Zareiforoush H, Komarizadeh MH, Alizadeh MR. Effect of Moisture Content on Some Physical Properties of Rough Rice Grains. Research Journal of Applied Science, Engineering and Technology 2009;1(3):132–139.

4/5/2010