Journal of Applied Biological Sciences 6 (3): 69-75, 2012
ISSN: 1307-1130, E-ISSN: 2146-0108, www.nobel.gen.tr

Design and Development of a Cutting Head for Portable Reaper Used in Rice Harvesting Operations

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Received: May 07, 2012
Accepted: June 12, 2012

Abstract

In this study, a cutting head for a portable brush cutter was designed and for harvesting four Iranian rice varieties, two varieties of high yielding named Khazar and Fajr and two varieties from local varieties named Binam and Hashemi. Cutting head consisted of a circular saw blade with 24 cm diameter and 2 mm thickness. Designed blade had 136 teeth with 0° rake angle, 30° clearance angle and 6 mm pitch. A simple windrowing system made from aluminum sheet was designed and constructed. The cutting head installed on existent brush cutter and test was conducted in field conditions. For each type of variety, the cutting energy and critical blade speed was computed. Results indicated that compared to local rice varieties Maximum power consumption of about 1.132 kW was obtained for Khazar variety. Results also showed that rice losses of the portable reaper were lower than manual harvesting and field capacity of machine was 4.20 times greater than manual harvesting.

***Keywords**:* Rice harvesting, rice reaper, brush cutter, cutting energy

Abbreviations

d	stalk diameter (m)	P_{ks}	idling power (kWm^{-1} of cutting width)	E_0	cutting energy for cutting of one stalk (J)
S_{max}	maximum cutting force (dan)	E_{sc}	specific cutting energy (kJm^{-2})	F_{max}	maximum cutting force (N)
Δm	equivalent mass (kg)	E	modulus of elasticity (MPa)	r	radius of disk (m)
c	constant between 3.13 and 4.43.	J_z	Mass moment of inertia about axis of rotation z (Kgm^2)	ω	angular velocity (rads^{-1})
t	thickness of wall (mm)	V_f	forward speed (ms^{-1})	m	mass of disc (kg)
P_{wt}	total powered required (kW)	W_c	Cutting width (m)	I	moment of inertia of stem (m^4)

INTRODUCTION

Rice is one of the most important foods for human and has a basic roll in secure of food for people of Iran and world. In 1996, rice was consumed by about 5.8 billion people in 176 countries (Van Nguu Nguyen, 2000). Harvesting is an important field operation for any food grain crops and itis cutting process carried out when the crops attains such physiological maturity that a maximum recovery of quality product is obtained. Harvesting a crop at an appropriate stage of maturity minimize the field losses, thereby, increasing the total yield as well as head yield (Mujumdar et al., 2003).

Harvesting of field crop is considered a labor intensive operation and takes about 185-340 man-h/ha to cut and bundle paddy or wheat crops (Michael et al., 1987) and 170-200 man-h/ha for cutting paddy crop (Koniger, 1953). Results of investigation in harvesting of rice crop in Iran showed that reapers have maximum effective field capacity and effective field capacity by hand harvesting tools is minimum (Hasanjani et al., 2007).

Koniger (1953) studied the principle of cutting plant material and stated that the mechanized separation occurred at a predetermined and well-defined location in the material in contrast to crushing where several failure planes usually developed randomly (Ganesh et al., 2007). The cutting process in all cases was initiated when the edge of the knife first made contact with the material. During the continued motion of the knife, the contact forces and stresses increased and a stress pattern was built up inside the stalk until failure conditions were reached. Chancellor (1988) stated that the biological materials commonly subjected to cutting can be classified into two general categories (Mujumdar et al., 2003):

1. Non-fibrous materials having uniform properties in all directions at the time of cutting, the cells of these materials being usually turgid with liquid cell materials.

2. Fibrous materials with high tensile strength fibers oriented in a common direction and with a comparatively low strength materials bonding the fibers together. For cutting biological materials, operation of a sharp or serrated-edged knife is employed. Shear failure is achieved either by using a single cutting element such as a sickle, rotary cutters or flail type cutter or by employing double cutting element as in reciprocating-type cutters.

In all cutting process, failure in shear or impact or both is possible when a system of forces act on the material. Before shear failure, the material is invariably first compressed then bend which increases the work required in a cutting operation (Bainer et al., 1978). Yore et al (2002) in order to aid the development of novel header systems for combine measured the cutting force and average cutting energy of rice straw. Treatments involved single and multiple stems. Result showed that cutting location (node/internode) and number of stems (crop density) are significant factors in cutting force and energy while rice variety is not. Shearing energy was highest directly at the node and decreased by a factor 2 moving into the adjacent internodes. The shearing energy directly was proportional to the number of stems. Tavakoli et al (2010) compared the mechanical properties between two variety of rice straw (Hashemi and Alikazemi) in three internodes position down from ear. The shear strength of Hashemi variety decreased towards the third internode while there was no distinct trend for that of Alikazemi variety. The shearing energy of both varieties increased significantly towards the third internode. The young's modulus in bending for both varieties decreased towards the third internodes. Zareiforoush et al (2010) evaluated the effect of loading rate and internode position on the mechanical properties of rice straw. The result showed that loading rate had only effect on the bending strength and the internode position had significant effect on the shear strength, shearing energy and young modulus and did not have any significant effect on the bending strength. O'Dogherty et al (1991) studied the impact cutting behavior of grass and straw stems with sharp and blunt blades. At low cutting speeds of grass stem, about 65% of the energy was utilized in overcoming friction. For straw the frictional component was relatively low (5-10) %and stem kinetic energy was equal about 20% of the total energy input. Tuck et al (1991) studied the performance characteristics of rotary cutting mechanisms when cutting single and groups of grass stems. Results showed that when cutting groups of stems most uncut stems occurred at speeds of 20 m/s and less for blunt blades.

Persson (1993) designed, built and tested a rotary counter shear mower. It consisted of two concentric counter-rotating discs. Results of tests showed that increase of forward speed will improve the cutting performance. Cutting speed with this type of rotors is less than other type of rotary disc cutters. Field experiments on alfalfa showed that the power consumption was less than 1.6 kW/m of cutting width. The rotary countershear mower worked satisfactory in fine crops, tangled crops and crops mixed with residue. Ghahraeiet al (2008) designed and developed a special cutting system for sweet sorghum harvester. Developed cutting mechanism in this research had a rotary disk with 50 cm diameter and four cutting blade. The stalks cut with the impact inertia forces at the linear velocity of 27 m/s by cutting blade. Harvesting tests in sweet sorghum farm with forward speed of 5km/h and tow series of blade with angles 30° and 45° on stalk were accomplished. Blade with 45° angle accomplished a fine cutting on stalks. Field test of harvester for harvesting of 1 ha had total harvesting time of 45 minute including gathering of harvested stalk without any crushes or uncut stalks. Bautista et al (2005) designed a rotary cutting reaper for rice. Their purpose was replacing the reciprocating cutter bar assembly with a rotary cutting system borrowed from grass cutters. These rotary cutters require fewer blades and less manufacturing tolerance. From the laboratory studies, the number of blades per disc was set a three; blade tip speed was set as 23- 30 m/s and forward speed ranged from 2.8 t0 3.3 km/h.

In recent years several reapers and Chinese brush cutters were entered in Iran. Imported brush cutters don't have satisfactory function and needed some modification to improvement of theirs ability for rice harvesting. An existent rice brush cutter was evaluated but it didn't work well for Iranian rice so a cutting head was designed, constructed and evaluated for Iranian rice plant. Therefore the objectives of this study were design and constructing of a rice reaper suitable for Iranian rice varieties.

MATERIAL AND METHOD

In this research a cutting head system was designed suitable for portable reapers and four varieties of Iranian rice stem named Fajr and Khazar from high yielding rice varieties and Binam and Hashemi from local varieties were selected for the experiment. The head of an imported Chinese brush cutter model BG 430 was removed and a new cutting head for Iranian rice plant was designed and replaced. This cutting head consisted of a circular saw blade that utilizes impact cutting system for cutting of stems. In shear failure of plant stem that have counter shear, if the distance between blade and counter shear is few, supports against cutting force is supplied by the counter shear. In absence of country shear all of this supports should be supplied by the plant. This supports supplied by the bending strength of remained parts of plant under the cutting line and moment inertia of parts of plant above the cutting line. For design of a special cutting system for numbered plant with due attention to physical properties of rice stalk computing the cutting speed, impact cutting force, impact cutting energy and power required for cutting of stalk with blade is necessary. This energy and power depend on variety, diameter of stalk, maturity stage, moisture content and bevel angel (Persson s, 1993).For defining the critical cutting speed or minimum speed required for effective cutting stalks in impact cutting, equation (1) was used that obtained from dimensional analyze (Sitkey G, 1986).

$$\dot{y}_{cr} = V_{cr} = c\sqrt{\frac{dS_{max}}{\Delta m}} \qquad (1)$$

$$\Delta m = \frac{s}{a} \qquad (2)$$

Where d is stalk$^{diameter's}$ (m), S_{max} is maximum cutting force (daN), Δm is equivalent mass (kg) and c is the constant between 3.13 and 4.43. In impact cutting consumed energy for overcoming shearing resistance of the stem is equal to the energy required for quasi-static cutting plus energy expended

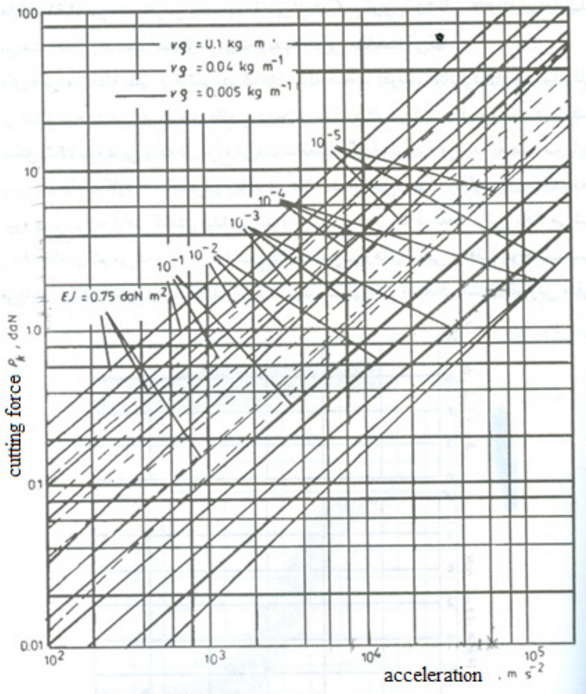

Fig. 1. Relation between force, acceleration and characteristics of stalk (Sitkey G, 1986)

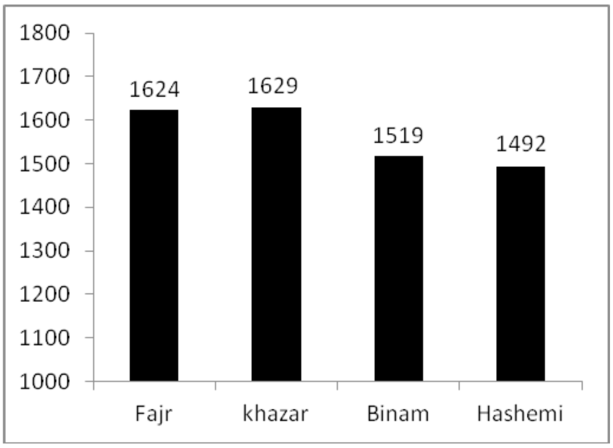

Fig. 2. Static ultimate shearing strength for four ricevarieties (Tabatabaee et al., 2006)

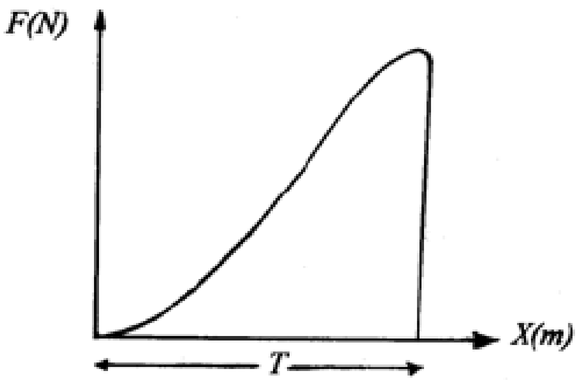

Fig. 3. Diagram of cutting force versus blade movement (x) in stalk diameter (T) (Persson S , 1987).

Table 1. Average of measured values for physical properties of rice stalks

variety	Thicknessof stalk (mm)	Diameter of stalk (mm)	Cross sectional area of stalk (mm^2)
Khazar	1.9438	6.3875	16.98
Fajr	1.6125	5.64	12.578
Binam	1.2125	4.7	8.08125
Hashemi	1.1125	4.5938	7.3225

in overcoming friction (Srivastava et al., 1993). Relation between bending force, acceleration and stem characteristics is shown in Fig. 1. Acceleration of stem was obtained from Fig. 1 and placed in equation 2 to obtain equivalent mass and then peripheral speed of blade could be obtained.

Rice stalk like of most cereal has circular and hollow shape, thus its moment of inertia obtained from equation 2 as bellow:

$$I = \frac{3\pi d^3 t}{32} \quad 2$$

Where t is thickness of wall (mm) and d is diameter of stalk (mm). If the bending strength of stem is so great that support all of cutting force, minimum velocity of blade movement is zero and cutting accomplish like of shear cutting. Static cutting properties of four varieties are showed in Fig, 2 and Physical characteristics of four varieties are showed in Table 1.

Decline of cutting height in order to increase the bending strength of a part of stem above the cutting line and decrease of cutting force by using of sharp blade both are adequate in decrease of minimum cutting speed. Increase of cutting height decreases the cutting force as well as its effectiveness; however, it increases deflection and displacement of stem which results in grain-losses during harvesting.

Young's modulus of stalks

Young's modulus for stalks obtained from research of Tavakoly et al (2010) is in the range of 0.33-1.21 MPa with average of 0.78. In this research it was assumed that young's modulus for all the varieties have equal.

Cutting energy and required power

Selective blade was in the form of a circular saw blade with diameter of 24 cm so angular velocity of blade was computed. For estimate the total power required for cutting, equation 3was used (Srivastava et al., 1993).

$$P_{wt} = \left(P_{ks} + E_{sc} V_f\right) W_c \quad 3$$

Where P_{wt} is total powered required (kW), P_{ks} is idling power (kWm^{-1} of cutting width), E_{sc} is specific cutting energy (kJm^{-2}), V_f is forward speed (ms^{-1}) and W_c is cutting width (m). Cutting force increase from zero in initial of cutting and start of contact between blade and stalk into a maximum value and then become zero again when cutting completed. When blade passed a distance equal to diameter of stalk into the stem, cutting is completed (Fig. 3). The area under the curve is equal to required cutting energy for cutting of one stalk (Persson S, 1987) From Fig.3:

$$E_0 = F_{max}\frac{d}{2} \quad 4$$

Where F_{max} is maximum cutting force (N) and d is stalk diameter (m). Specific cutting energy obtained by dividing cutting energy by width cross sectional area of stem. Saw idling power consumption can be expressed as:

$$P_k = \frac{J\omega^2}{2} \quad 5$$

Where J is mass moment of inertia for circular blade (Kgm^2) and ω is its angular velocity ($rads^{-1}$). Mass moment of inertia for a rigid disc with radius of r, mass of m about axis of rotation z (figure4) can be estimate from equation 6.

$$J_z = \frac{mr^2}{2} \quad 6$$

Where m is mass of disc and r is radius. Carbon steel selected for construction of disc that has density about 7.85 gcm^{-3}.

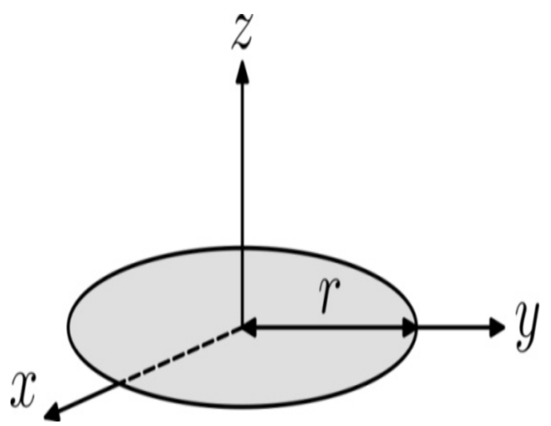

Fig. 4. Rotating disc about axis rotation of z

Design of blade tooth

For plants having a larger diameter than the pitch of the teeth, cutting resistance is considered to be much less than plant having pitch larger than the plant diameter (Kavashima, 1951). So, proper amount of tooth for the blade obtained.

RESULTS AND DISCUSSION

Cutting speed

By equation 2 and Table 1 value for stem moment of inertia was calculated. For obtaining velocity, Young's modulus was multiplied in moment of inertia. By using ultimate tensile strength from Fig.2 and cross sectional area from Table 1, maximum cutting force computed and acceleration of stalk from Fig.1was obtained. Then the critical speed for four varieties computed and showed in Table 2. With reference to computations, suitable range of speed for cutting one stem of high yielding varieties is 22-32 m/s and that of local varieties was considered to be16-25 m/s. the amount of cutting energy in nodes is higher than internodes (Yore, 2002) so, for restitution effect of misaligning stems position (node or internode) during cutting, speeds between 25-35 m/s was chosen.

Table 2. Computed critical cutting speed for the studied varieties

variety	EI	Maximum cutting force (N)	Acceleration (ms^{-2})	Δm (kg)	Minimum speed (ms^{-1})	Maximum speed (ms^{-1})
Hashemi	0.00128	1.15	6×10^4	1.82×10^{-4}	16.87	23.87
Binam	0.0015	1.253	6.2×10^4	1.98×10^{-4}	17.08	24.19
Fajr	0.0034	2.08	7.2×10^4	2.83×10^{-4}	20.15	28.53
Khazar	0.006	2.82	8×10^4	3.45×10^{-4}	22.59	31.98

Table 3. Energy requirement for cutting stem of the studied varieties

varieties	Maximum cutting force (N)	Cutting energy (J)	Special cutting energy (kJm^{-2})
Khazar	27.66	88.33	5.2
Fajr	20.42	57.58	4.57
Binam	12.28	28.86	3.57
Hashemi	10.925	25.09	3.426

Cutting energy and power consumption

Angular velocity of discs with spot the maximum computed speed equal to 269.23 rad/s obtained. Cutting width assumed to be 2/3 of disc diameter and was equal to 16 cm. by using of data corresponding to maximum cutting strength and cross sectional area needed cutting energy for cutting one stalk computed and showed in Table3.

Mass of disc with 24 cm diameter and 2 mm thickness is equal to 710.25 gr. So its mass moment of inertia obtained and is equal to 5.1133×10^{-3} Kgm^2. By using of equation 5 idling power obtained and is equal to 0.217 *kW* and by dividing it by cutting width of reaper, idling power obtained equal to 1.34 Kw/m. Consumption power of reaper from equation 3 computed and showed in table 4. Forward speed of portable reaper commonly is in the range of 0.7-1.1 m/s. In this research maximum forward velocity of reaper was used that is equal to hand speed of operator from right to left in course of cutting.

Design of blade teeth

The details of blade teeth of the header are shown in Fig.5. According to studies of Tuck et al (1991) the critical speed of a triangular toothed disc with 0° rake angle, 30° clearance angle and 6 mm pitch was lowest (Fig. 5). Thus the value of teeth corresponded to Khazar variety (136 teeth) was selected for this purpose. The final shape of circular saw blade is showed in Fig. 5.

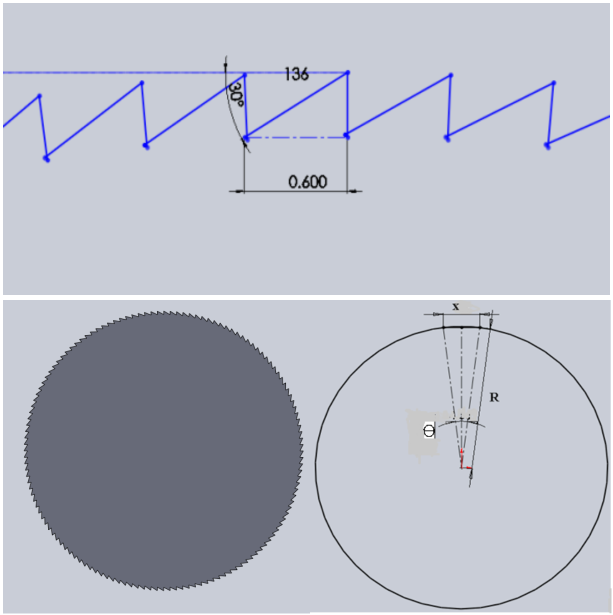

Fig. 5. Schematic of blade tooth of the header (up), schematic representation of blade with radius of R and pitch of x (left), final shape of circular saw blade (right)

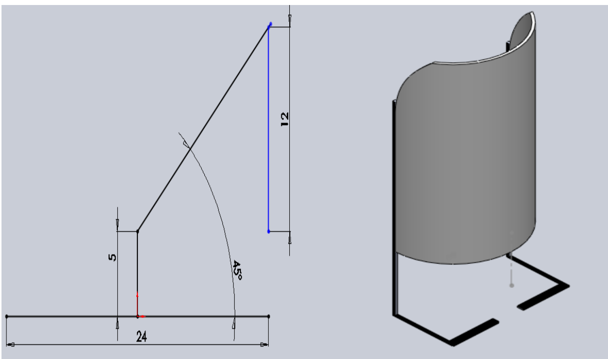

Fig. 6. Schematic and dimensions of cutting head (left), schematic of windrowing system (right)

Table 6. Height and panicle length of the tested varieties

variety	Average height of shrub (cm)	Cluster length (cm)
Fajr	107.7	-
Khazar	126	28.7
Binam	106	28.1

Design of windrowing system

In order to windrowing the harvested plant an aluminum sheet with cylindrical shape was used that installed at the upper portion of the cutting blade. By using of this system, cut straws gathered and transported with width movement of operator hand until the ending of distinct cutting width, then voided and rowed. Height and panicle length of the tested varieties are showed in Table 6. radius of sheet choose equal the blade radius and its distance from blade surface computed 13 cm. schematic and dimensions of cutting head showed in Fig. 6. With considering 10 cm cutting height, 5 cm shaft length, 2mm blade thickness and 13 cm distance of rower from blade surface, heights of rower was 40 cm. it's made from aluminum sheet and its schematic showed in Fig.6. Designed blade was made from carbon steel and installed on an existent machine (brush cutter model BG 430) with designed aluminum windrower.

Field evaluation

In this study, the machine was evaluated for harvesting two rice varieties namely Hybrid and Hashemi in the experimental farms of the Rice Research Institute of Iran (RRII), Rasht, Guilan, Iran. Used machine with designed cutting head is shown in Fig.7 and the final form of harvested crop is shown in Fig. 8. Results indicated that the forward speed of the operator was measured to be 1 kmh^{-1} and cutting width in each blade movement was 1.5 m. The total harvesting time in each plot of 50 m^2 was measured to be8 min. The labor requirements for harvesting was obtained about 26.7 man-hha^{-1}and that of manual harvesting considering 14 labor in 8 working time was about 112 man-hha^{-1}. Thus, field capacity of machine is about 4.20 times greater than manual harvesting. Results of investigation in other countries (Van Nguu Nguyen, (2000) showed that field

Table 4. Total power consumption of cutting head duringrice harvesting

variety	Idling power (kWm^{-1})	Special cutting energy (kJm^{-2})	Forward speed (ms^{-1})	Cutting width (m)	Consumption power (kW)
Hashemi	1.34	3.42	1.1	0.16	0.818
Binam	1.34	3.57	1.1	0.16	0.845
Fajr	1.34	4.57	1.1	0.16	1.021
Khazar	1.34	5.2	1.1	0.16	1.132

Table 5. Amount of teeth correspond to stalk diameter

Variety	Stalk diameter (mm)	Selective pitch (mm)	2θ	Circumference (cm)	Arc length (cm)	Amount of teeth
Khazar	6.3875	6	2.65	81.68	0.6	136.16
Fajr	5.64	5	2.204	81.68	0.5	163.36
Binam	4.7	4	1.76	81.68	0.4	204.2
Hashemi	4.5938	4	1.76	81.68	0.4	204.2

Fig. 7. Final form of used rice reaper with designed head

Table 7. Losses percentage of rice grain before of harvesting and after harvesting with designed cutting system based on percentage of product performance

After harvest (%)		Before harvest (%)		
Hybrid	Hashemi	Hybrid	Hashemi	repetition
0.45	0.97	0.07	0.09	1
0.82	0.63	0.05	0.07	2
0.92	1.02	0.06	0.12	3
0.75	0.74	0.09	0.05	4
0.73	0.84	0.06	0.08	average

Fig. 8. Harvested crop with designed cutting head system.

capacity of machine is seven times greater than field capacity of manual harvesting depending on operator's skill, variety and harvest conditions.

Experiments were conducted on 4 repetition and values of filed losses before harvesting and as well as after harvesting was measured and showed in Table 7. Other research conducted by Hasanjani et al (2007) showed that losses in cutting stage were about 1.015% for manual harvesting. Values of field losses in harvesting with this machine are lower than manual harvesting. The total weight of machine was about 9.5 kg and is suitable for field condition of paddy crops in Iran because of marshy conditions of paddy. In this condition use of self-propelled reapers is impossible and manual harvesting takes more time and labors thus increase time harvesting and costs.

CONCLUSION

In this paper we designed and constructed a cutting head system for harvesting Iranian rice plant by portable reaper. According to this study, Khazar variety has maximum cutting force and so needed maximum cutting energy equal to 88.33 J. Among studied varieties, high yielding varieties required cutting speed more than local varieties and critical cutting speed of Iranian varieties is in range of 25-35 m/s. Power consumption by a rotating blade with 24 diameter in maximum status is corresponded to Khazar variety and equal to 1.132 kW, so an one cylinder internal combustion engine can operate this cutting head. Designed blade was circular saw and had 24 cm diameter, 136 teeth with 0° rake angle, 30° clearance angle and 6 mm pitch (Fig. 5) and is proper for wooden material and straws during harvesting time. Results of filed experiments with this cutting system showed that losses of harvesting was lower than manual harvesting and operations was done faster since the field capacity of machine is 4.20 time faster than manual harvesting.

Acknowledgements

Authors are grateful to Tabriz University and Rice Research Institute of Iran (RRII) for scientific and financial support, and providing the experimental facilities for this project.

REFERENCES

[1] Bainer R, Kepner RA, Berger EL (1978) Principles of farm machinery, 3 rd edn. Willey, New York.

[2] Bautista E, Regalado JS, Juliano A, Ishihara S, Monobe H, Ramos J, Molinawe L (2005) The PhilRice-JICA rotary rice reaper: redesigning a technology for Filipino farmers and manufacturers. Rice is life: scientific perspectives for the 21st century 7: 229-232.

[3] Chakraverty A, Mujumdar AS, VijayaRaghavan GS,Ramaswamy HS (2003) Handbook of post-harvest technology cereals, Fruits, Vegetables, Tea and Spices. Marcel Dekker Inc, p 883.

[4] Chancellor WJ (1988) Cutting of biological materials. Handbook of Engineering in Agriculture, Vol 1. CRC prero INC, p 35.

[5] Ganesh CB, Gunner KH (2007) Low cost mechanical aid for rice harvesting. J Appl Sci. 7(23):315-318.

[6] Hasanjani H, Hoseyni M, Khademolhoseyni N, Alizade M (2007) Evaluation of different harvesting method in Guilan. J Agric Sci 9(1): 23-38.

[7] Kawasthima M (1951) Survey of shape and cutting force of a serrated sickle on the market. Memoir, Coll Agric Utsunomiya University, Japan, 1951.

[8] Koniger R (1953) Tentative theory for the cutting of plant stems. Grundlagen der Landtechnik 5: 96-97

[9] Michael AM, Ojha TP (1987) Principles of agricultural engineering, Vol 1. New Dehli, ML Jain for Jain Brothers.

[10] O·Dogherty MJ, Gale GE (1991) Laboratory studies of the dynamic behavior of grass, straw and polystyrene tube during high-speed cutting. J Agric Eng Res. 49: 33-57.

[11] Pandey MM, Devnani RS (1981) Development of improved CIAE sickle for harvesting cereals. Agric Mech in Asia, Africa and Latin America. 12: 54-58.

[12] Persson S (1987) Mechanics of cutting plant material. ASAE monograph No 7, American Society of Agriculture, p 288.

[13] Persson s (1993) Development of a rotary counter shear mower. Trans ASAE. 36(6): 1517-1523
[14] Sitkey G (1986) Mechanics of agricultural materials. Elsevier science publisher, p 476.
[15] Srivastava AK, Goering CE, Rohrbach RP (1993) Engineering principles of agricultural machines. ASAE textbook No 6, p 601.
[16] Tabatabaee Koloor R, Borgheie A (2006) Measuring the static and dynamic cutting force of stems for Iranian rice varieties. J Agric Sci Tech. 8: 193-198.
[17] Tavakoli M, Tavakoli H, TavakoliMh, Haghayegh Gh (2010) Comparison of mechanical properties between two varieties of rice straw. Advance J Food Sci and Tech. 2(1): 50-54.
[18] Tuck CR, O,Dogherty MJ, Barker DE, Gale GE (1991) Laboratory studies of the performance characteristics of mowing mechanisms. J Agric Eng Res. 50: 61-80.
[19] Van Nguu Nguyen (2000) FAO Rice Information. Vol 2.
[20] Yore MW, Jenkins BM, Sumers MD (2002) Cutting properties of rice straw. ASAE Annual International Meeting, Chicago, USA, 026154p.
[21] Zareiforoush H, Mohtasebi SS, Tavakoli H, Alizadeh MR (2010) Effect of loading rate on mechanical properties of rice straw. Aust J Crop Sci. 4(3): 190-195.