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Design and development of sugarcane harvester for small and marginal farmer

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Abstract
The shortage of labour during harvesting season and the various types of harvester were available in the market, but they are costly (about 1.2 crore) and has been designed and develop a sugarcane harvester for small and large farmers at an affordable cost. The harvester consisted of main parts main frame, engine (3.73 kW), gear box (20:1), counter shaft, horizontal shaft, vertical shaft, cutter, handle and ground wheel. In sugarcane harvester, power transfer from engine to the cutter and ground wheel through the counter shaft, horizontal, vertical shaft with the help of bevel gear. The weight of the harvester with the engine is 60 kg. It was found that the sugarcane harvester gave 0.1303 ha/h average effective field capacity and 78 per cent field efficiency with minimum labour requirements (5 man-h/ha) as compared to the traditional method of harvesting. The cost of operation was found to be Rs /ha 2067.60/ which was the lowest from traditional (Rs /ha 11200/) with additional saving (Rs /ha 9132/) and total harvesting losses was 2.69 per cent in case of sugarcane harvester.

Keywords: Sugarcane harvester, engine, gear box, bevel gear, cutter, shaft and pulley.

Introduction
Sugarcane, (*Saccharum officinarum* L.), is one of the several species of tall perennial true grasses of the genus Saccharum. Sugarcane is the source of sugar in all tropical and subtropical countries of the world belongs to family Poaceae. Sugarcane is an important commercial crop (industrial crop), with acreage of about 4 million hectares and production of 300 million tonnes in India. Without the mechanization of the sugarcane harvesting, conventional harvest method is still adopted, which demand very high amount of labour, the labour productivity is low, and the cost of harvest is high.
The purpose of developing single row harvester is to reduce cost and time required for sugarcane harvesting. Sugarcane harvester which is economical, more efficient and cuts the sugarcane and it will be helpful for marginal and small farmers, By using this harvesting machine, we can also solve the problem of labour shortage.
This project work aims to develop sugarcane harvesting machine which is more efficient and having simple mechanism for cutting the sugarcane at a faster rate and should low cost that is affordable by the rural farmers, easy to maintain and less laborious to use. The machine consisted of main parts i.e. engine (petrol, 3.73 kW, 3000 rpm), gear box (20:1), coupling, frame, cutter frame, counter shaft, horizontal shaft, vertical shaft, cutter and ground wheel. All this parts of a machine was mounted on the frame. The wheel was attached to this frame. The petrol engine was mounted on the frame which provides the power to the wheels to move by means of a gear and chain mechanism and it also provides the power to the cutter. Frame was constructed by joining angle of mild steel of rectangular box section members to get rectangular shaped frame of used drilled machine for fixed cutter frame to the main frame by used nut and bolts.
In India agriculture is facing serious challenges like scarcity of agricultural labour, not only in peak working seasons but also in normal time. This is mainly for increased nonfarm job opportunities having higher wage, migration of labour force to cities and low status of agricultural labours in the society. (Jain *et al.* 2013) [1]
In manual harvesting to cut one acre of sugarcane 15-16 labours are required they take 3 days to cut one acre. By using this machine problem of the labour crises can be reduced. Comparing with manual harvesting only 18% of labours are required, it makes the process faster hence reduces most of the harvesting time and labour required to operate the machine is also less. This machine is helpful for both small and big farmers. (Ratod *et al.* 2013) [1]. To overcome these problems this project work aims to develop low cost sugarcane harvesting machine which is more efficient and having simple mechanism for cutting the sugarcane at a faster rate.

Materials and Method

This part deals with the design and development of sugarcane harvester for sugarcane crop. A developed sugarcane harvester consists of Frame, engine, gear box, counter shaft, vertical shaft, horizontal shaft, cutter, handle and ground wheel. The various factors involved in the development were operational safety, cost of production and availability of parts and easy of construction. The operation and adjustments were made simple so as to be used by the farmer.

Frame

It constructed by joining angle of mild steel of size 50×50×5 mm in rectangular box section members to get rectangular shaped frame of 1200×500 mm respectively, using drilling machine for fixing cutter frame to the main frame by using nut and bolts shape frame of 1700×200 mm respectively.

1. Engine

A 5 hp diesel engine running at 3000 rpm was used as prime mover. Engine was source of power in sugarcane harvester transfers power from engine to cutter, through gear box, horizontal shaft and vertical shaft with the help of bevel gear.

Power transmission

a. Selection of power source

The cutting force required to cut one cane is 106.57 N. (Zode *at al*. 2015) Calculation of power required for sugarcane harvesting is given below;

T = Fr --- (1)

Where,
T = Torque of the cutter, N-m
F = Force required to cut sugarcane, N; and.
r = Radius of the cutter, m
T = 13.32 N-m

$$P = \frac{2\pi NT}{60} --- (2)$$

P = 2.77 kW
Therefore the selected engine gives the power of 3.730 kW but the power required to cut the sugarcane is 2.775 kW. Hence this engine is selected.

b. Design of pulley and belt drive

Table 1: Belt criteria

S. No.	Section belt	Power range in, kWs	Top width, mm.	Bottom with, mm.	Thickness, mm.	Weight per meter length in N
1	B-section	2-15	17	9	11	1.98

Source: Khurmi, 2014

If the power range 1.5 to 15 kW, diameter, it is preffered to use a pulley having 200 mm diameter and B- belt section (Jain *et al*. (2013) [1]

Diameter of pulley, mm (Both, driver and driven pulley)	=	200
Bevel gear(No. of teeth) (Both, driver and driven gear)	=	16
Coefficient of friction	=	0.3
Grove angle of pulley 2α (^{0})	=	40
Power, kW	=	3.730
Engine speed, rpm	=	3000

Find out the torque on engine sha

$$P = \frac{2\pi NTE}{60}$$

Where,
T_e = Torque on the engine shaft, N-m;
N = rpm;
T_e = 11.87 Nm

Velocity of the belt

$$V = \frac{\pi \times d \times N}{60} \qquad --- (3)$$

Where,
V = Velocity;
D = Diameter of pulley; and.
N = Speed of pulley;
V = 31.41 m/s

According to Indian Standard (IS: 2494 - 1974) dimension of v-belt is if the power is 2-15 kW then length B-section pulley having 17 mm, top width, 9 mm bottom with and 11 mm thickness.

Area of the belt

$$A = [\tfrac{1}{2} \times 11 \times 4^2] \times 2 + 9^2 \quad --- (4)$$

A=125 mm^2

Capacity

$$\text{Capacity} = e^{\frac{0.27\times\pi}{\sin 20}}$$

Where,
$d_1 = d_2$ =Diameter of driver or diameter of driven pulley, mm;
ϴ=π radians (D_1=D_2)
Capacity = 11.942

Constant

$$K = \frac{\text{Capacity} - 1}{\text{Capacity}} --- (5)$$

Where,
K = Constant
K = 0.9162

Length of belt

L = 2C+ π × (D_1+D_2)/2 + (D_1-D_2)^2/4C - (6)
L = 2×50 + 3.14× (20+20)/2×(20-20)^2/4×50

Where,
L = Length of belt, mm;
D_1 = Diameter of driver pulley, mm;
D_2 = Diameter of driven pulley, mm; and.
C = Centre to centre distance of belt, mm;
L = 1600 mm

Number of belt required

$$= \frac{\text{Total power transmitted (kW)}}{\text{Power transmitted per belt (kW)}} - (7)$$

= 0.53

Hence the belt required one.

Centrifugal stress

$$\sigma_C = \frac{W}{g} \times V^2 \times 10^6 \quad --- (8)$$

Where,
σ_c = Centrifugal stress;
W= weight of belt;
g = Acceleration due to gravity; and
V= Velocity of belt
σ_c =1.006N/mm^2
σ_c

Centrifugal tension

T_c = Centrifugal stress × Area of cross section of belt.

Where,
T_c = Centrifugal tension;
= $\sigma_c \times$ A
=1.006 × 125
T_c=125.75 N

Power transmitted per belt

$$P = \frac{(T_1 - T_C)kv}{1000} \quad --- (9)$$

Where,
k=cons tant
v = velocity of the belt
T_1 = Tension in tight side, N;
T_c = Centrifugal tension, N;
K = Constant;

Hence, power transmitted per belt=3.73
T_1=255.35 N

$$\sigma_1 = \frac{T1}{A}$$

$$\sigma_1 = \frac{255.35}{125}$$

σ_1=2.04 N/mm2,

Initial tension (T_0)

$$2\sqrt{T_0} = \sqrt{T_1} + \sqrt{T_2} \quad --- (10)$$

Where,
T_o = Initial tension in belt;
T_1 = Tension in tight side; and
T_2 =Tension slack side;

$$\frac{\sigma_1 - \sigma c}{\sigma_2 - \sigma c} = e^{\frac{\mu\theta}{\sin\alpha}} \quad --- (11)$$

Where,
$\theta = \mu$, radian;
α = Grove angle of pulley, 20^0;
μ = Coefficient of friction, 27;

$$\frac{2.04 - 1.006}{\sigma 2 - 1.006} = 11.94$$

σ_2=1.09 N/mm^2

$T_2=\sigma_2 \times$A

Where,
T_2 = Tension in slack side;
A = Area of belt; and.
σ_2 = Tensile stress;
T_2 =1.09 × 125
T_2=136.51 N
$2\sqrt{To} = \sqrt{289.04} + \sqrt{139.375}$
T_0 = 195.93N

1. Gear box

The gear box was used to increase torque and reduced the speed of a prime mover shaft. This means that the output shaft of gear box rotates at as lower than the input shaft. The gear box has gear ratio20:1.it reduces the engine speed at the ground wheel.

2. Counter shaft

a. Design of Counter shaft

A 5 hp engine running at 3000 rpm was used as prime mover. The Counter shaft has 3000 rpm, because same teeth of driver and driven gear. Hence, the torque transmitted to the counter shaft will be same of engine shaft.

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} \quad --- (12)$$

Where:
N_1 =Speed of driver gear;
N_2 =Speed of driven gear;
T_1 =No. of teeth of driver gear; and.
T_2 =No. of teeth of driven gear;
N_2 = 3000 rpm

b. Transmission ratio

$$= \frac{T_2}{T_1} = \frac{N_1}{N_2} = 1$$

c. Torque on the Counter shaft

$T_C = T_e \times 1$ -- (13)

Where,
T_c = Torque on counter shaft, Nm; and.
T_e = Torque on engine shaft, Nm;
T_c = 11.87 Nm

4. Horizontal shaft

a. Design of horizontal shaft

The horizontal shaft has 3000 rpm, because same diameter of driver and driven pulley. Hence, the torque transmitted to the counter shaft will be same of counter shaft.

$$\frac{N_2}{N_3} = \frac{D_2}{D_1} \quad --- (14)$$

Where:
N_2 =Revolution of driver pulley;
N_3 =Revolution of driven pulley;
D_1 =Diameter of driver pulley; and
D_2 =Diameter of driven pulley.
Hence, N_3 = 3000 rpm

a. Transmission ratio
Transmission ratio = 1

b. Torque on the horizontal shaft.
$T_h = T_c \times$ Transmission ratio
$T_h = T_c \times 1$

Where,
T_h = Torque on horizontal shaft, Nm; and
T_c = Torque on counter shaft.
T_h = 11.87 Nm

c. Design for diameter of horizontal shaft

$T_1+T_2+W_P$ --- (15)

Where,
T_1=Tension on Tight side
T_2=Tension on slack side
W_P=Weight of pulley
= 255.35+136.51+ (2×9.81)
= 411.48 N

Moment at A
411.48×740=R_C ×890
R_C=342.12 N
R_A+R_C = 411.48
R_A= 411.48 - 321.23
R_A= 69.36 N

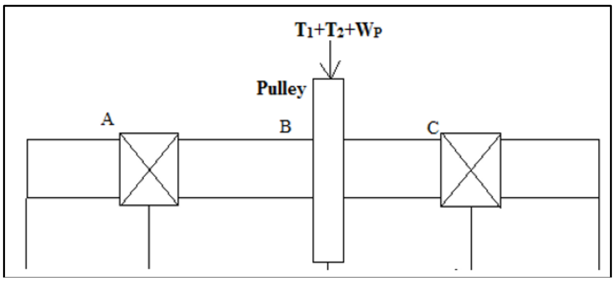

Fig 1: Horizontal shaft

Bending moment at A
M_b=0

Bending moment at B,
M_b= 69.36 ×740
M_b= 51326.4 N-mm

Bending moment at C
M_b=0

$D_h=[16/\pi\zeta_{ed}]\times[K_tM_t]$ ---(16)

Where,
D_h= Diameter of shaft, mm;
ζed = τallowable stress, MPa;
K_t= Equivalent torque, Nm; and
M_t= Equivalent bending moment, Nm.

According to ASME code, ζ_{ed}=55 N/mm^2 without keyway
$D_h=[16/\pi\times55]\times[1.5\times51326.40]$
D_h =21.56 mm.

Vertical shaft
The horizontal shaft was the shaft, which intersects the vertical shaft with the help of Bevel gear, which transmits the power from the horizontal shaft to a vertical shaft at 90^0 with the help of bevel gear. The bevel gear is used to transmit the power between two shafts, which are non-parallel or intersecting, but coplanar.

a. Speed calculation of horizontal shaft

$$\frac{N_1}{N_2} = \frac{T_2}{T_1}$$

Where:
N_1=Revolution of driver gear;
N_2 =Revolution of driven gear;
T_1 =No. of teeth of driver gear; and
T_2 =No. of teeth of driven gear.
N_2= 3200 rpm

b. Transmission ratio
Transmission ratio = 1

c. Torque on the vertical shaft:-
T_v =8.89N-m

Where,
T_v = Torque on vertical shaft

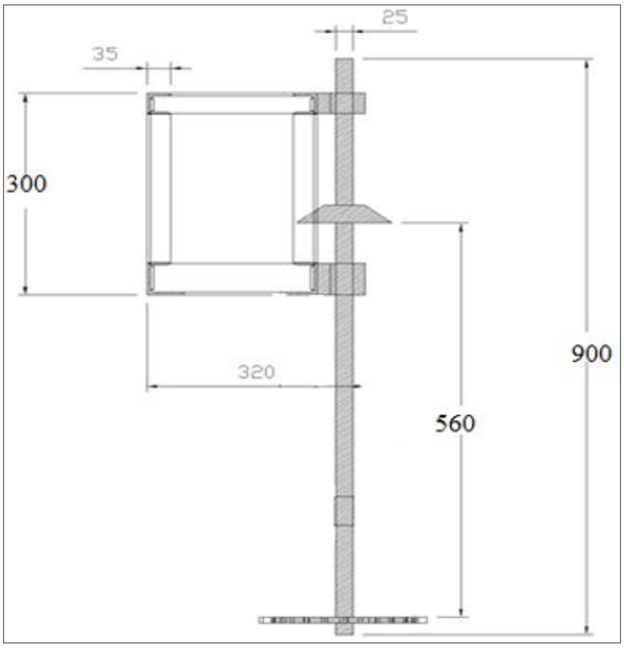

Fig 2: Vertical Shaft

d. Design for diameter of vertical shaft
Moment at A
(537.16×130) - (R_C×300) + (147.3×700) = 0
172940.8 = (R_C×300)
R_C = 576.4693 N
R_A+R_C = 537.16+147.3
R_A = 107.99 N
Bending moment at A
M_b=0

Bending moment at B
M_b=107.99×130
M_b=14038.7 N-mm
Bending moment at C
M_b=147.3×400
M_b=58920 N-mm
Bending moment at D
M_b=0
Diameter of the shaft
$D_V = [16/\pi\zeta_{ed}] \times [K_t M_t]$ --- (17)

Where,
D_h = Diameter of shaft, mm;
ζed = τallowable stress, MPa;
K_t= Equivalent torque, Nm; and
M_t= Equivalent bending moment, Nm.

According to ASME code
ζ_{ed}=55 N/mm^2 Without keyway
D_v =[16/π×55]×[1.5×58920]
D_v =20.1521 mm

4. Cutter

The output shaft of the engine which connects to the gear box with the help of coupler and gear box has two output shaft one for speed reducing and other output shaft (same engine speed) for transmitting power from the horizontal shaft to the vertical shaft with the help of bevel gear. The cutter was mounted at the bottom of the vertical shaft. Bevel gear was used transfer the power from the horizontal to the vertical shaft of the cutter assembly.

a. Calculation for speed of cutter

Shear force required to cut the wood is found to be 450 N and shear force required to cut the sugarcane is 106.57 N. (Zode *at al*. 2015) [23]. So, shear force required to cut sugarcane is less than the wood cutting.
Pulley is mounted to the output shaft of the engine and through the belt drives the power is transferred to the horizontal shaft of the cutter assembly. Bevel gear is used transfer the power from horizontal to the vertical shaft of the cutter assembly.

$$\text{Gear ratio} = \frac{n_1}{n_2} = \frac{Z_2}{Z_1} \quad --- (18)$$

Where,
Z_1 = Bevel gear, driver pinion = 16;
Z_2 = Driven gear, driven pinion = 10;
n_1 = Speed at vertical shaft of = 3000 rpm.; and
n_2 = speed of cutter = 4800 rpm.

5. Handle height

Handle height (position) in working task have been standardized by many research workers. Chaffin *et al*. (1983) are commended the minimum height 800-900 mm for Indian workers. Therefore machine handle height was kept at 900 mm.

6. Ground wheel

Transportation wheel or ground wheel was the main component of the single row sugarcane harvester, which were touches on ground surface. We select two 830×30size rubber tube tyre wheels. This facilitates easy movement of the harvester in the field.

a. Speed of ground Wheels

The output shaft of the engine was keep that 3000 rpm for the 1st gear ratio raising 20:1 So, the speed of the output of the gear box is 150 rpm

$$\text{Gear rtio of gear box} = \frac{N_1}{Ng}$$

Where,
N_1= Engine speed, rpm;
N_g = Speed of output of gear box;
Gear ratio was 20:1

Then apply above equation.
Ng = 150 rpm
Hence the speed (N_g = 150 rpm) was found that the output of gearbox
Now using formula for find the rpm of ground wheel

$$\frac{N_s}{N_w} = \frac{Z_2}{Z_1}$$

Where:
Z_1 = Small sprocket teeth;
Z_2 = Larger sprocket teeth;
N_g = speed of the ground wheel shaft; and
N_w = Speed of the ground wheel.

$$\frac{150}{N_w} = \frac{45}{15}$$

N_2 = 50 rpm
Hence, found that the speed of ground wheel 50 rpm

Table 2: Selection of material for light weight engine operated sugarcane harvester

S. No.	Particular	Material	Size	Quentity
1	Diesel engine (kW)		2.982	1
	Gear box	Mild steel	20:1	1
	Cutter(mm)	Steel alloy	250	1
	Bevel gear	Steel alloy	16 & 10	1 & 1
	Bearing	UCP205		4
		UCP206		2
1	Main frame, mm	Mild steel	900×500×50	2
2	Cutter frame, mm	Mild steels	360×260×50	1
3	Horizontal shaft, mm	Mild steel	350×25	1
4	Vertical shaft, mm	Mild steel	900×25	2
5	Ground wheel shaft, mm	Mild steel	830×30	1
6	Handle, hollow pipe ,mm	Mild steel	350×270×35	2

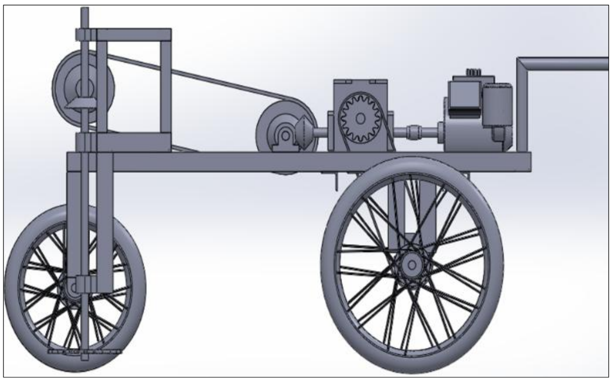

Fig 3: Isometric front view of sugarcane harvester

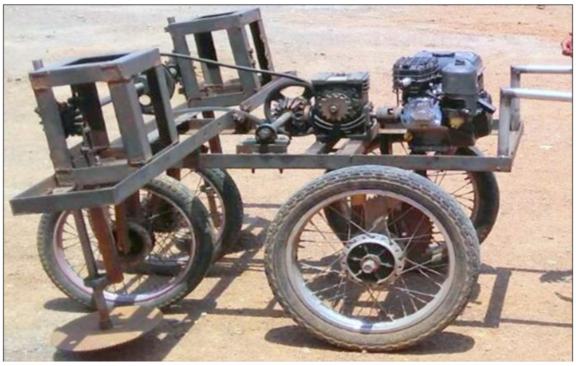

Fig 4: Harvesting machine after fabrication

Result and Discussion

The sugarcane harvester was designed and fabricated. After testing this harvesting machine in the field it was found that the effective field capacity of sugarcane harvester was 0.1303 ha/h at operating speed of 1.03 km/h and found field efficiency was 78 %. The cost of harvesting machine was 50,000. The cost of operation found 2067.60 Rs/ha. The purpose of developing this paper was to develop machine to reduce the cost and time required for sugarcane harvesting. We were also solving the problem of labour shortage.

Table 3: Comparison of field capacity

Harvesting implements/methods	EFC, ha/h	Time req., H	Man day per ha	Cost, Rs./ha
Developed harvester	0.1303	0.198	5	2067.60
Gadasa	0.0168	59	30	10500
Local cutting equipment	0.0134	74.12	30	11200

Conclusion

Design and development of sugarcane harvester to reduce the cost and time required for sugarcane harvesting. The sugarcane harvesting machine, which were economical, more efficient and cut the sugarcane at a faster rate and it was helpful for small scale farmers and unskilled labours can also be operated without difficulties by using this harvesting machine. Thus, on the basis of information obtained through the study, the following conclusion could be inferred

1. The developed harvesting machine having two row cutters gave a better field performance compared to the traditional method.
2. The mode of power transmission and speed for ground wheel and cutter were found satisfactory.
3. Engine power found adequate for the designed width (100cm) of cut.
4. It is recommended that use of the harvester at an average forward speed of 1.03 km/h to harvest the sugarcane crop.
5. The performance of developed harvester was found satisfactory, It gave field capacity 0.1303 ha/h with 5 men-h/ha.
6. The fabrication cost of the machine came around Rs. 50,000/
7. Comparatively found economical (harvesting cost 2067.60 Rs/ha) than that of traditional (Rs/ha 10500)

Reference

1. Jain J, Karne S, Ratod S, Vinay N, Thotad, Kiran P *et al*. Design and fabrication of small scale sugarcane harvesting machine. 2013; 2(3):2278-0149.
2. Liu Q, Ou Y, Qing S, Song C. Cutting force test of sugarcane stalk. Trans. Chinese Soc. Agric. Eng. 2007; 2(7):90-94.
3. Mello RDC, Harris H. Cane damage and mass losses for conventional and serrated base cutter blades. Proc Aust Soc. Sug. Cane Technology. 2000; 22:84-91.
4. Mello RDC, Harris H. Angled and serrated blades reduce damage, force and energy for a harvester base cutter. Proc. Conf. Australian Soc. Sugar Cane Tech, 2001, 1212-1218.
5. Moontree T, Rittidech S, Bubphachot B. Development of sugarcane harvester using small engine in Northeast Thailand, International Journal of Physical Sciences. 2012; 7(44):5510-5917.
6. Neves JLM, Marchi AS, Pizzinato AAS, Menegasso LR. Comparitive testing of a floating and a conventional fixed base cutter. International Society of Sugar Cane Technologists. 2001; 24:257-262.
7. Núñez O, Spaans E. Evaluation of green-cane harvesting and crop management with a trash-blanket. Sugar Tech. 2008; 10(1):29-35.
8. Pachkhande NM, Rade VD, Nagapure GV. Small Scale Sugarcane Cutter Machine., International journal for engineering applications and Technology, 2015, 2321-8134.
9. Patil M, Patil P. Optimization of blade angle for cutting system of sugar cane harvester. Intl. Indexed and Refereed res. J. 2013; 42(4):49-52.
10. Quick DdJ. Base cutting apparatus for sugarcane, 1977. harvester.http// www.google.co.in /patent/US 4019308
11. Ranveer A, Tambuskar DP. Design and analysis of attachment of sugarcane harvester for a tractor. International journal of engineering sciences and research technology. 2015; 4(8):2277-9655.

12. Roberto Da, Mello C, Harris H. Cane damage and mass losses for conventional and serrated base cutter blades. aust. Soc. Sugar Cane Technol, 22, 84-91.
13. Salassi ME, Champagne LP. Estimated costs of soldier and combine sugarcane harvesting stytems in Louisiana. D.A.E. 1996; 703:59-6.
14. Samaila S, Mohammed M, Sharief Al, Ahmed A. Development of a tool to determine the energy required to cut and top sugarcane. AUJT, 2012, 16(1).
15. Semenzato R. A simulation study of sugar cane harvesting. Agric. Syst. 1995; 47(4):427-437.
16. Singh I, Solomon S. Post-harvest quality loss of sugarcane genotypes under sub-tropical climate, deterioration of whole stalk and billets. Sugar Tech. 2003; 5(4):285-288.
17. Song R, Li S, Sun X, Ma F, Hu S. Experimental research on influence factor of cutting-force of sugarcane harvest machine. J Agric. Mech. Res. 2006; 7:128-132.
18. Sunil K, Mathanker Tony E, Grift Alan C, Hansen. Effect of blade oblique angle and cutting speed on cutting energy for energy cane stems. Bio systems engineering. 2015; 133:64-70.
19. Taghinezhad J, Alimardani R, Jafari A. Effect of Sugarcane Stalks' Cutting Orientation on Required Energy for Biomass Products. Internatıonal Journal of Natural and Engineering Sciences. 2012; 6(3):47-53.
20. Viator HP, Wang JJ. Effects of residue management on yield after three production cycles of a long-term sugarcane field trial in Louisiana. J Am. Soc. Sugar Cane Tech. 2011; 31:15-24.
21. Whiteing C, Norris CP, Paton D. Facilitation of best practice to reduce extraneous matter and cane loss. Bses. 2002.
22. Yadav RNS, Sharma MP, Kamthe SD, Tajuddin A, Sandeep Y, Raj Kumar T. Performance evaluation of sugarcane chopper harvester. Sugar Tech. 2002; 4(3-4):117-122.
23. Zode PM, Shelke GD, Awathale MP, Borikar SS, Khante AP. Design of sugarcane harvesting machine. International Journal for Innovative Research in Science & Technology, 2015, 1(11).