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DEVELOPMENT OF A STRAW SHREDDER AND PERFORMANCE ANALYSIS

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Abstract*- According to the titled paper a straw shredder machine was designed and constructed for the purpose of utilizing the unused straw for briquetting. The different components of the straw shredder were designed according to the specifications. The rollers were designed with respect to the pinion for obtaining desired size of raw materials. Two blades were used for cutting the straw according to the desired size. The blades were driven by an electric motor, which transmits power to the blades via a pulley arrangement. Rollers were rotated by worm gear and pinion arrangement. Spur gears were provided for the same rotation of two rollers. The size of straw that were found after performance test was in acceptable limit and the production rate was also keep pace with the size. During the construction, it was kept in mind to use the local components, while considering the construction cost.*

Keywords: Straw Shredder Machine, Briquetting, Worm gear, Size of Straw.

1. INTRODUCTION

Biomass refers to all direct and indirect products of photosynthesis such as rice straw, wheat straw, rice husk, saw dust, baggage, coconut coir, corn, algae, groundnut shell etc. Biomass fuel is considered, as one of the major sources of energy is most developing countries. In Bangladesh, recent survey shows that about 66% of the primary energy is now being supplied through some form of biomass energy .[1] But unplanned and crude use of biomass energy affect the ecology and environment and we can effectively utilize a very little amount of energy from this vast source. In this context, by using improved form of biomass residue and their combustion is only potential solution. In order to reduce industries operational cost as well as to meet the requirement of raw material.

For bio-fuel production, biomass must be processed and handled in an efficient manner. Due to its high moisture content, irregular shape and size, and low bulk density, biomass is very difficult to handle, transport, store, and utilize in its original form. Densifications of biomass product into durable compacts are an effective solution to these problems and it can reduce material waste. Upon densification, many agricultural biomass materials, especially those from straw and Stover, result in a poorly formed pellets or compacts that are more often dusty, difficult to handle and costly to manufacture. This is caused by lack of complete understanding on the natural binding characteristics of the components that make up biomass. [2]

Biomass briquette technology has been developed in two distinct directions. Europe and the United States pursued and perfected the reciprocating ram or piston press for the rice husk and other easy material such as saw dust, softwood, bagasse etc. Japan has independently invented and developed the screw press technology for the above materials. Japanese machine are now being manufactured in Europe under licensing agreement [3].

It is very difficult to cut the straw by manual labor to desired size. It is almost impossible to supply sufficient amount of required sized straw to run a machine by cutting it manually. It increases the duration and increases the establishment cost. Moreover, in the existing machine which is not able to shred the straw that is prerequisite criteria of briquetting process? Actually, briquetting with rice straw cannot possible by sizing it with manual labor. So, its need to shred the straw to required small pieces for the process of briquetting. Improving the present machine is required for the small fragments of the straw. [4]

2. COMPONENTS OF THE UNITS

The main components that comprise the unit are as follows:

1) Base structure
2) Motor
3) Pulley
4) V-belt
5) Main shaft
6) Bearing
7) Worm gear and pinion
8) Spur gear
9) Roller
10) Feeder
11) Cutting blade

Figure 1 shows the diagram of the constructed straw shredder

3. DESIGN AND CONSTRUCTION

3.1 Pulley Design:

Velocity ratio of belt drive is the ratio between the velocities of the driver and driven pulley.

Assumption,

D_1=diameter of the driver pulley=45mm

D_2=diameter of the driven pulley

n_1=speed of the driver pulley in rpm=1250 rpm

n_2=speed of the driver pulley in rpm=370 rpm

We get $n_1 D_1 = n_2 D_2$, from page 357, [5]

So, diameter of the driven pulley, D_2 =152 mm

From page 445 [5],

2% slip is satisfactory for leather on steel or iron. So, cutting blade speed will be 362.6 rpm.

3.2 Roller Design:

Assume roller diameter =58 mm

Perimeter =π (diameter)

=182.21 mm

182.21 mm passing by roller in 1 revolution

So, the required size 10 mm is passing by roller in 0.0548 revolutions

Now .5 revolution of cutting blade is equal to .0548 revolutions of roller. So, 362.6 revolutions of cutting blade will be equal to 40 rpm.

3.3 Gear Design

Assume,

N_1=Speed of the worm gear

N_2 =Speed of the pinion

T_1 =Teeth on worm gear

T_2 =Teeth on pinion

Now$N_1 T_1 = N_2 T_2$; from page 357 [5]

Let, $T_2 = 36$

From above equation, number of starts on worm gear will be 4. So, worm gear is quadruple start.

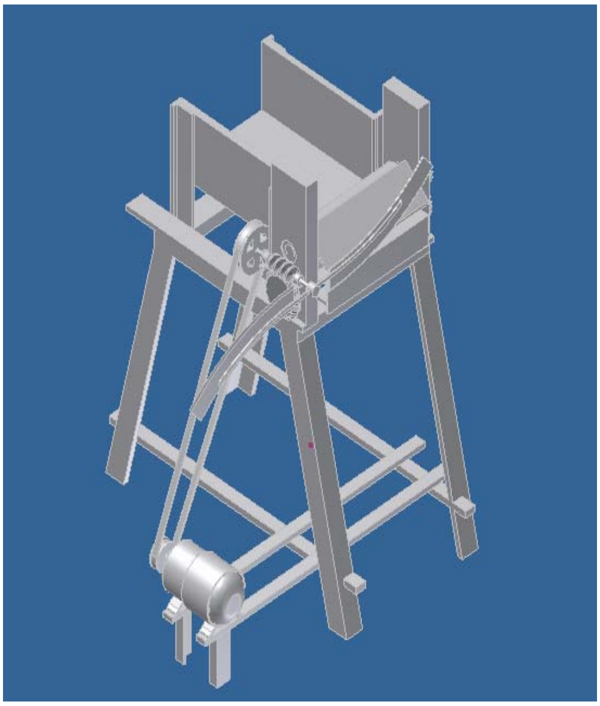

Fig 1: Schematic diagram of a straw shredder.

4 .RESULT AND DISCUSSION

Table 1: Data for the straw shredder at rpm 357 of cutting blade

Observation no.	Time(min)	Weight(kg)	Production rate(kg/hr)	Average production rate(kg/hr)
1	15	5.34	21.36	
2	15	5.7	22.8	22.12
3	15	5.56	22.2	

The developed straw shredder, which is mainly constructed for sizing the straw in required size, has the advantages for producing briquette. Table 1 shows production rate for different observations. In this straw shredder over weight of cutting blade, need to be concerned. However, for briquetting with rice straw, sizing is the most important factor. After performance test, the cut size was looking like as Figure 2. For this reason, rice straw would not use as raw material though it is the highest available raw material among all others.

If briquetting technology with rice straw can be established throughout our country, we can overcome our energy crisis largely, reduce our natural gas consumption for household purpose and ultimately our national economy will be strengthened.

Fig 2: Photographic view of cut straw.

5. ECONOMIC ANALYSIS

The life cycle cost of the straw shredder includes fixed cost like construction cost; and variable cost like raw material cost, operating and maintenance cost, repair cost of components etc. over its useful life.

The economic analysis of the output material has been done on the basis of one-hour capacity of the straw shredder and the present market price of the raw materials. Table 2 shows the total life cycle cost of the machine. All analysis is calculated in local currency Taka.

The total cost of one complete straw shredder machine = Tk. 6175 Taka

Economic life of the machine= 5 years

Assuming working days per year = 280 days

Working hours per day = 8 hours

Depreciation has been calculated with straight - line method when the salvage value of the machine considered as Tk. 1000.00 for its economic life 5 years.

Machine depreciation cost per year = (6175-1000)/5 = 1035 Taka

So, the Machine depreciation cost per hour = (1035/280*8) = 0.46 Taka

Power consumption for electric motor 0.746 kW, where the price per kWh electricity is Tk. 13.00

So, the energy consumption cost = (0.746*13) = 9.7 Taka

One labor can operate the machine when his daily labor cost is considered as Tk. 200.00

So, the labor cost per hour = (200/8) = 25 Taka

Time required to produced 22.4 kg of required size straw = 1 hour

Raw materials required to produce 22.4 kg of required size straw = 25 kg

Table 2: Total life cycle cost of the constructed straw shredder

Type of cost		Amount (Taka)
Fixed cost	1. Construction cost	6175.00
Total fixed cost		6175.00
Variable cost	1. Machine operating cost	
	a) Energy consumption cost	9.7
	b) Labor cost	25.00
	2. Maintenance cost (Blade sharpening & lubricating oil)	1.00
	3. Repair cost (Blade & belt replacement)	0.30

Total variable cost	36.00
Machine depreciation cost	0.46
Total cost	6211.46

For 25 kg straw the operating cost including raw material cost is 36 Tk. So, the operating cost for per kg of straw is (36/25) = 1.44 Tk.

6. CONCLUSIONS

From the experiment of the designed machine the following conclusion may be drawn:

1) A straw shredder has been designed and constructed.
2) The optimum size of cut straw was found in the acceptable range.
3) The machine fabricated is economically viable to end users.

7. REFERENCES

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8. NOMENCLATURE

Symbol	Meaning	Unit
D_1	Diameter of the driver pulley	(m)
D_2	Diameter of the driven pulley	(m)
n_1	Speed of the driver pulley	r.p.m
n_2	Speed of the driver pulley	r.p.m
N_1	Speed of the worm gear	r.p.m
N_2	Speed of the pinion	r.p.m
T_1	Teeth on worm gear	dimension less
T_2	Teeth on pinion	dimension less