

Design of Manually Operated Portable Paper Recycling Machine

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Abstract:-In any big institution, especially educational institutions like schools or colleges, generation of large quantity of waste papers is quite apparent. And effective use of recycled paper is also possible (craft papers, registers etc). So, instead of disposing off the waste papers into trash, recycling them makes sense. This not only helps the institute in cost saving but will also ensure its contribution towards the protection of the environment.

Designing manually operated small-scaled paper recycling plant, which can be used in schools and colleges, ensures that a cheap and non-complex method of production of paper product is guaranteed. Accordingly design of the machine unit has been prepared with all necessary component specifications. Also 3D modeling and drafting has been done.

Keywords:-Paper Recycling, Design, Modelling, Waste, Conversion, Defibre.

I. INTRODUCTION:

Paper is one of the most important products ever invented by man. The primary raw material for the paper production is pulps fibres obtaining by a complicated chemical process from natural materials, mainly from wood. This fibres production is very energy demanding and at the manufacturing process there are used many of the chemical matters which are very problematic from view point of the environment protection. The paper recycling, simplified, means the repeated defibring, grinding and drying, when there are altered the mechanical properties of the secondary stock, the chemical properties of fibres, the polymerisation degree of pulp polysaccharidic components, mainly of cellulose, their supramolecular structure, the morphological structure of fibres, range and level of interfibres bonds. Paper recycling saves the natural wood raw stock, decreases the operation and capital costs to paper unit, decrease water consumption and last but not least this paper processing gives rise to the environment preservation. A key issue in paper recycling is the impact of energy use in manufacturing.

II. DESCRIPTION AND GENERAL LAYOUT OF MACHINE UNIT:

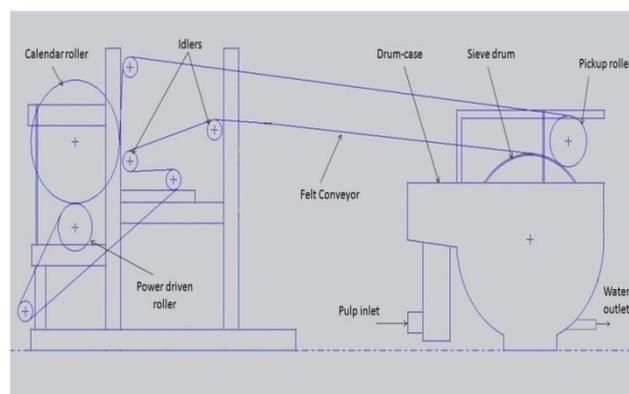
The manually operated paper recycling machine unit broadly consists of the following four systems:

- **Pulp feeding system:** It consists of the sieve drum, drum case and the pickup roller. Its function is the preparation of pulp slurry and feeding it.

- **Pulp transferring system:** It consists of the nylon felt conveyor and the set of idlers. Its function is to transfer the slurry to the calendaring system.
- **Calendaring system:** It consists of two calendar rollers. Here the pulp gets calendared to paper and then the paper is removed out.
- **Driving mechanism:** It consists of an electric motor, a gear box and a pulley-belt drive.

The bulk of the parts of the unit were fabricated using mild steel, this is because it is the easiest to be joined among all other metals. It is a very versatile metal, necessitating its use by many industries for fabrication of process unit equipment. Apart from its versatility, it is also very cheap and readily available compared to other metals.

2.1. General Layout:



The following figure shows the general layout of the various components of the machine unit. The driving mechanism (motor, gear-box, belt and pulley) is not shown.

2.2. Salient Features Of Machine Unit:

- Size of paper sheets to be made – approx. 297 x 210 mm (A4 size)
- No. of sheets taken out per batch – 3
- Speed of calendar drum from which paper is removed off – 18-20 rpm

The batch size implies the maximum no. of paper sheets of the given size that can be taken out in one complete revolution of the calendar drum.

The major dimensions of the various components of the unit are based on these three parameters. The size of each paper sheet and the no. of sheets per batch give the dimension of the calendar roller. Correspondingly, the dimensions of the other main rollers (the power-driven calendar roller, the sieve drum and the pickup roller) have been determined.

It is to be noted that, the thickness of the paper to be obtained is decided by the no. of turns the calendar drum is allowed to make before peeling off the paper from it (provided the feed is constant and consistent). Fresh layer of pulp gets coated over the previous layer with every new turn. Greater the no. of turns given before removing the paper, thicker is the final paper obtained.

III. WORKING OF MACHINE:

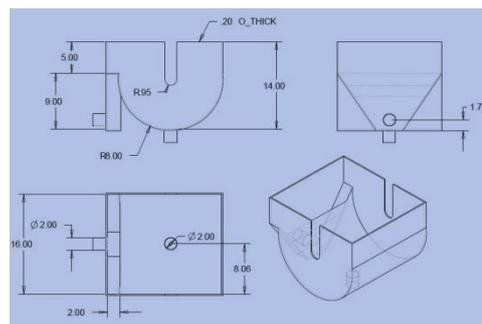
3.1. Preparation of Pulp Slurry:

The raw material for the paper recycling plant unit is paper pulp slurry. It is a mixture of approx. 50% pulp and 50% water. Generally, for big paper recycling plants, the source of raw material is the waste paper pulp from paper industry. But, as the machine unit fabricated under this project is of small scale and is meant for reusing and recycling the waste papers generated in a school or college, pulp slurry can be prepared locally. Additives can also be added to slurry to obtain certain desired properties of the paper.

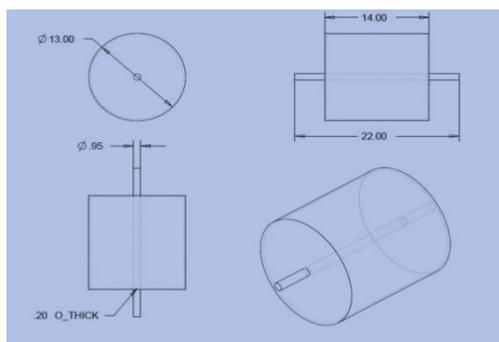
3.2. From Pulp to Paper:

- After the preparation of slurry, it is transferred into the sieve drum case. The drum case consists of a sieve drum. The function of the sieve drum is to transfer the pulp onto the conveyor belt.
- **Working of sieve drum** - Sieve drum is a hollow cylindrical drum whose entire lateral surface is covered with a sieve-like mesh. It has rectangular slots cut onto its lateral surface to allow flowing of

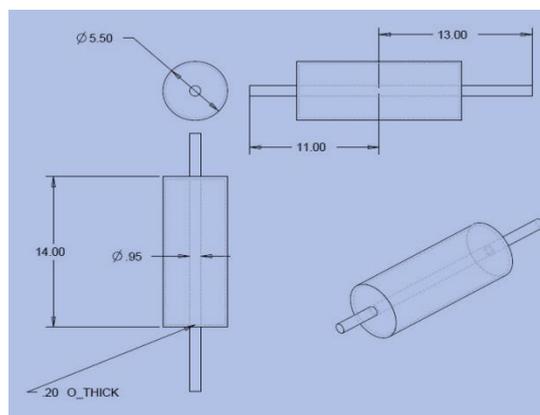
water through it. This drum is fitted inside the drum case.



The sieve drum keeps rolling in the drum case continuously at very small speed. The pulp slurry is fed to the small V-shaped collecting chamber which is a part of the drum case. As the drum is continuously rolling against the press roller (**pick-up roller**), the pulp gets stuck on the conveyor belt which passes between the two drums. The pick-up roller is rubber coated to increase friction on its surface so as to avoid slippage of the belt.



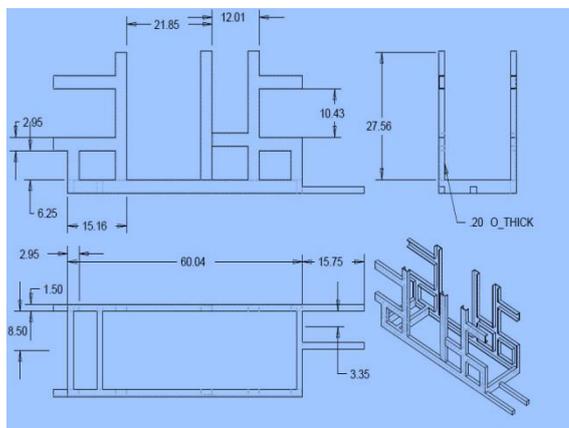
- **Felt conveyor** - The felt conveyor assists the flow of pulp. It is made up of nylon. The conveyor carries the pulp to a set of **calendar rollers** which comprises of two rollers - one of diameter bigger than the other. The belt passes between the two rollers and the paper gets stuck on the roller which is rolling.



- The smaller roller is the driven roller i.e. the **electric motor** shaft is connected to this roller shaft. This roller drives the other rollers, the idlers and the sieve-drum. This roller is rubber coated.
- ii. pair of arms carrying the pickup roller
These pivots enable the arms to make small angular motion about the joint. This flexibility is necessary as these arms have springs hooked to them.

IV. UNIT DESIGN

4.1. Main Frame:



4.2. Design of Gear Box:

The gear box has to make a speed reduction of 42:1. This reduction is made in two stages:

- Stage 1: Worm and worm-gear drive (reduction of 24:1)
- Stage 2: Spar gear drive (reduction of 1.7:1)

Design of worm gear drive:

We have, power to be transmitted $P_R = 0.746$ KW. It is assumed that the shafts of the gears are 225mm apart. The transmission ratio is 24:1 It is assumed that the gear is made of phosphor bronze.

Step1. Selecting no. of teeth

$t_w = 2$ for velocity ratio between 12-36
Therefore, $t_g = VR \times t_w = 24 \times 2 = 48$ which is greater than 29, hence O.K.

Step2. Selecting lead angle λ and pressure angle ϕ_n

Lead angle $\lambda = 6^\circ$ per worm tooth,

Therefore, $\lambda = 6 \times 2 = 12^\circ$

But, for compact design

$$\lambda = \tan^{-1} \sqrt[3]{\frac{N_g}{N_w}} = \tan^{-1} \sqrt[3]{\frac{1}{24}} = 19.1^\circ$$

Therefore, assuming $\lambda = 20^\circ$ and $\phi_n = 22.5^\circ$ (normally used)

Step 3. Determining pitch diameter and pitch line velocity of worm gear

$$D_g = m t_g = 48 \text{ m}$$

Let, $N_w = 900$ rpm (driven by electric motor)

$$\text{And, } V_p = \frac{\pi D_p N_g}{1000 \times 60} = \frac{\pi \times 48 \text{ m} \times 37.5}{1000 \times 60} = 0.094 \text{ m/sec (since } N_g = \frac{900}{24} = 37.5 \text{ rpm)}$$

Step4. Determining the design power and the tangential tooth load F_t

$$P_d = P_r \times K_1 \text{ where } K_1 = 1.75$$

$$\text{Therefore } P_d = .746 \times 1.75 = 1.3055 \text{ kW.}$$

$$F_t = \frac{P_d}{V_p} = \frac{1.3055 \times 10^3}{0.094 \text{ m}} = \frac{13.89 \times 10^3}{m} \text{ N}$$

Step5. Beam Strength F_B (by Lewis Equation)

$F_B = S_o C'_v b \gamma m$ where $S_o = 84 \text{ MPa}$ (for gear) SAE 65 phosphor bronze

$S_o = 350 \text{ MPa}$ (for worm) SAE 2320 case hardened

$$C'_v = 0.75 \text{ (trial value)}$$

$$b = 2.38 P_c \text{ where } P_c = \text{circular pitch} = \pi m$$

$$= 2.38 \times \pi \times m = 7.48 \text{ m}$$

$$\gamma = 0.314 + 0.0151(22.5^\circ - 14.5^\circ) = 0.435$$

$$F_B = 84 \times .75 \times 7.48 \text{ m} \times 0.435 \text{ m} = 205 \text{ m}^2$$

Step 6. Selecting standard module

Equating F_B to F_t , we get

$$205 \text{ m}^2 = \frac{13.89 \times 10^3}{m}$$

$$m = 4.07 \text{ mm}$$

selecting standard module $m = 5$

Step 7. Calculating D_g, V_p, F_t, C'_v

$$D_g = m t_g = 5 \times 48 = 240 \text{ mm}$$

$$b = 2.38 \pi \times 5 + 6.25 = 43.63 \text{ mm}$$

$$V_p = 0.094m = 0.094 \times 5 = 0.47m/sec.$$

$$F_t = \frac{13.89 \times 10^3}{5} = 2.778 \times 10^3 N$$

$$C'_v = \frac{6}{6+V_p} = \frac{6}{6+0.47} = 0.93$$

Since C'_v calculated is more than C'_v assumed hence design is OK

$$F_B = 84 \times 0.93 \times 7.48 \times 0.435 \times 5^2 = 6.35 \times 10^3 N$$

Since F_B is greater than F_t hence design is OK

Step 8. Pitch dia. of worm (D_w), mm

$$D_w = 2.4 \times \pi \times 5 + 27.5 = 65.2mm$$

$$\text{Also, } D_w < \frac{C^{0.875}}{1.132} = \frac{225^{0.875}}{1.132} = 101mm$$

$$D_w > \frac{C^{0.875}}{2} = \frac{225^{0.875}}{2} = 57mm$$

Since $D_w = 65.2mm$ fits to the range $101 > D_w > 57mm$ hence taking

$$D_w = 65.2mm$$

Step 9. Calculating the dynamic load on gear $F_d, F_d = \frac{F_t}{C'_v} = \frac{2.778 \times 10^3}{0.93} = 2987N.$

Step 10. Calculating the limiting wear strength $F_w, F_w = D_g \times b \times K_2$

$$= 240 \times 43.67 \times 0.70 = 7336.56N$$

Since, $F_w > F_d$ hence design is safe.

Step 11. Calculate face length

$$L_w = (4.5 + 0.02t_w)P_c = (4.5 + 0.02 \times 2) \pi \times 5 = 71$$

Dimensions of worm and gear are:

$$D_w = 65.2mm \quad D_g = 240mm$$

$$L_w = 71mm \quad b = 43.67mm$$

$$t_g = 2 \quad m = 5$$

4.3. Design of Pedestal Bearing:

Step 1 : Dynamic Load Capacities

We have,

$$P_1 = F_{r1} = 318.12N$$

$$P_2 = F_{r2} = 6619N$$

$$\text{Also, } L_{10} = \frac{60nL_{10h}}{10^6} = \frac{60(44)(8000)}{10^6} = 21.12 \text{ million rev.}$$

Considering the load factor, we get

$$C_1 = P_1 (L_{10})^{1/3} (\text{load factor}) = (318.12) (21.12)^{1/3} (2.5) = 2198.34N$$

$$C_2 = P_2 (L_{10})^{1/3} (\text{load factor}) = (6619) (21.12)^{1/3} (2.5) = 45740N$$

Step 2: Selection of bearings:

Bearings nos. 61805 and 6405 are suitable at B_1 and B_2 respectively.

4.4. Felt Conveyor:

- The felt is made up of nylon net – 40 mesh
- Approx. length - 3.9m – 4m
- Width – 13”

4.5. Details of the driving System:

4.5.1 Electric Motor and the integrated Gear Box

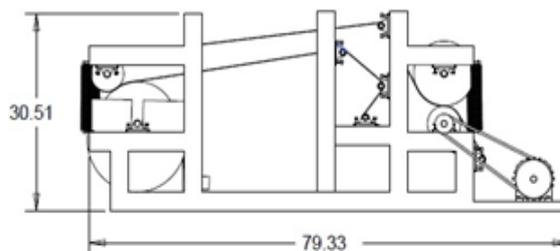
- Motor – 1 HP, A.C., 3-phase, 900 rpm
- Gear-box – 42:1 speed reduction, attached to motor

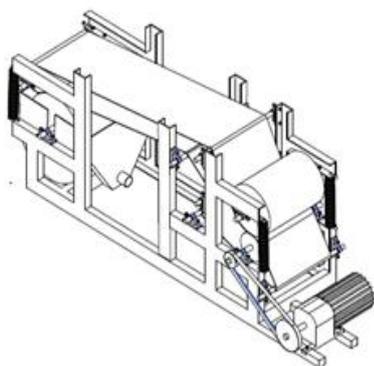
4.5.2 Belt and pulleys

- Speed increment ratio – 1:2
- Belt – ‘V’ shaped, Leather, B-type, 46 cm long
- Small pulley – attached to roller, dia. 3”
- Big pulley – attached to motor, dia. 6”

V. MAIN ASSEMBLY

5.1. Assembly Specification:





5.2. Component List:

1.	Sieve drum case	1	M.S Sheet, 2mm thick
2.	Sieve drum	1	M.S., 5mm thick
3.	Pickup roller	1	M.S., 5mm thick with rubber coat
4.	Calendar roller (big)	1	M.S., 5mm thick
5.	Calendar drum (small)	1	M.S., 5mm thick with rubber coat
6.	Idlers	5	M.S.
7.	Body frame	1	M.S Channels
8.	Felt conveyer belt	1	Nylon
9.	AC Motor with Gear box	1	-
10.	Pulleys	2	Cast Iron
11.	V-belt (B-type)	1	Leather
12.	Pedestal Bearings	18	-
13.	Tensile Springs	4	Carbon Steel

VI. CONCLUSION

Recycling of waste paper is beneficial not only from economic point of view but also for the protection of environment. It promotes conservation of one of our very important natural resource - trees. Considering this, a small-scale manually-operated paper recycling machine has been designed which can recycle waste paper for various productive purposes. The fabricated machine can serve dual purposes, it can be manned permanently at a stationary position or it could be shifted from one place to another as the case may be. The very low cost of running the machine, make it quite economically viable. The simplicity of operation of this machine ensures that no too much technical skill is needed to operate it.

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