Design and Analysis of a Centrifugal Separator for the Separation of Pith from Bagasse

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***Abstract*-Among the by-products that we get from sugarcane, bagasse is the most relevant and important. As the natural resources are being depleted, use of bagasse as an alternative resource is being encouraged. The pith from the useful fibrous material of sugarcane is separated by various means viz. dry depithing, wet depithing and chemical depithing. The use of chemicals for pith separation is expensive so mechanical ways are used for pith separation. The purpose of the project is to reduce the pith content and separate it from the useful fibre at a faster rate. The design and calculations of the centrifugal separator for pith separation are explained in the paper.**

I. INTRODUCTION

Small scale industries create an innovative idea to accompany the agricultural growth. The intention of proposed work is to develop product that separates the non fibrous material i.e. pith from fibrous material i.e. fibre in the bagasse. Bagasse is produced after the crushing of sugarcane with extraction of juice. Bagasse consists of fibre, pith and sand particles. The worldwide pulp and paper industry is gradually realizing that there is shortage of the traditional raw material of cellulose fibre. Bagasse is a fibrous residue remaining after the extraction of sweet juice from sugarcane. Till recently the bagasse generated in the sugar mill was mainly utilized as fuel for generation of steam and power by sugarcane mill itself and only a small portion was available for other uses mainly paper making.

Bagasse is produced after the crushing of sugarcane with extraction of juice. This bagasse contains the fibres, pith and sand particles. Each tons of sugarcane delivered to processing mills yields 740 kg of juice and 260 kg of moist bagasse.

Bagasse is an abundant resource with easy accessibility, cost effectively, high compressibility and moisture retention capability. Bagasse represents a potential source of fibre for the paper industry without further compromising the environmental concern. It is cheap, renewable each year, presently it does not have an alternative economically attractive value added usage, and however it has adequate chemical and mechanical properties for paper making. When leaving the last mill tandem, raw bagasse, contains 55-60% of fibre. The other fraction, rich in pith or parenchymatous tissue (30-35%), being non fibrous in nature and rich in juice, contributes to various problem.

Bagasse is also used for thermal power plant as a fuel and this is also majorly used in production of papers and pulp, agglomerated boards, polymers, construction bricks etc.

Effective depithing and cleaning is the key for the successful production of quality acceptable pulp and paper from bagasse. The main purpose of this project is to reduce the pith content in bagasse; mainly the purpose of pith reduction conventionally takes a long period to execute itself. The project is completely automated and effectively reduces pith and separates fibre.

The Project benefits the industry in many ways. It improves Calorific Value of the boiler fuel. Fast processing of the manufacturing of agglomerated board. Maximum amount of pith is removed from bagasse in minimum time.

II. CONSTRUCTION & WORKING

The system consists of a single phase motor running at a speed of 1440 rpm. The motor is connected to the central shaft by using belt and pulley arrangement. The speed reduction is in the ratio 1:2.The system is divided in three stages. Each stage consists of hammers which are linked together by a dovel pin, Each stage is separated by using filters of 5mm, 3mm and 2mm. The whole setup is surrounded by a circular perforated sheet. The system is supported by a rectangular frame.

Sugarcane is inserted in the system through a hopper. As the sugarcane travels in the downward direction, because of the high speed of shaft the hammers rotate at a high speed, the sugarcane is crushed between the perforated sheet and the hammer surface. Using centrifugal force exerted on crushing hammers, pith formation takes place. At the bottom there is an arrangement for a tray fitment for collection of pith produced.

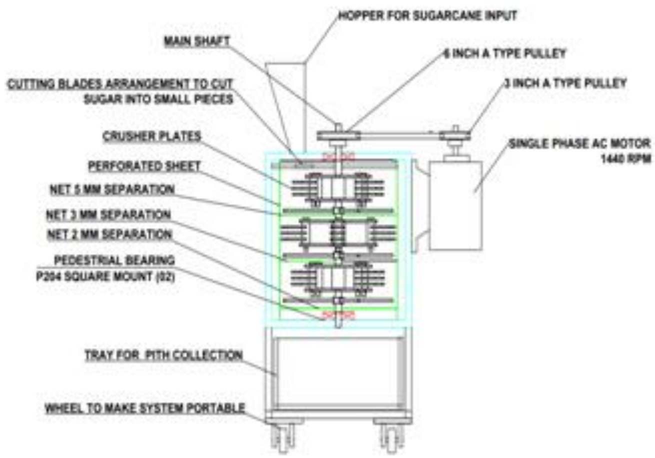

Figure No 1: Basic construction model

III. MECHANICAL DESIGN

1. Hammer:

Length = 100 mm

Width: W1 =45 mm W2=30 mm

Thickness = 4 mm

Material : Mild Steel

Volume of hammer = (l×b×t) - 2×(B×h/2)×t +(π×R^2)×t/2 – (π×r^2)×t/2

= (90×45×4) - 2×(7.5×90/2)×4 + (π×22.5^2)×4/2 - (π×15^2)×4/2

V = 15266.5 mm^3

Where,

l = length of the rectangular portion

b = breadth of rectangular portion

t = thickness of rectangular portion

B = base of triangular portion

h = height of triangular portion

R = radius of larger circle

r = radius of smaller cut circle

Density of Mild Steel = 7850 kg/m^3

Mass of hammer = ρ×v

= 7850×15266.5×10^{-9}

m = 0.1198 kg

Weight of hammer = m×g

= 0.1198×9.81

W = 1.1756 N

2. Angle Plate:

Consider angle plate as cantilever beam.

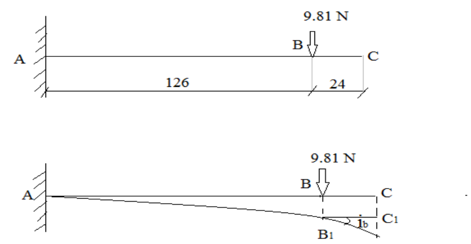

Figure No 2: Cantilever Beam

Actual load at B = (Mass of 3 hammers) + (Mass of Cuff)

= (3×0.1198) + (0.3)

= 0.6594 kg

Consider, load as 1 kg approximately.

Let, b = Length of the angle plate = 150 mm

I = Moment of Inertia

E = Modulus of Elasticity

W = Weight of the angle plate

ib = Angle of deflection for angle plate

I = bt^3/12 = 150×t^3/12 = 12.5×$t^3 mm^4$

E = 210 GPa = 210×$10^9 N/mm^2$

= 210×$10^9 \times 10^{-6}$

E = 210×$10^3 N/mm^2$

W = 9.81 N

ib = (w×b^3) / (2×E×I)

= (9.81×150^3) / (2×210×10^3×12.5×t^3)

=6.306/t^3

CC2 = BB1 = yb = (w×b^3) / (3×E×I)

= (9.81×12.6^3) / (3×210×10^3×12.5×t^3)

= 2.491/t^3

C2C1 = b×ib = 24×(6.306/t^3)

= 151.34/ t^3

CC1 = yc = (2.491/t^3) + (151.34/t^3)

= 153.83/t^3 mm

When t = 5.3581, yc = 1 mm

But y_c should be as less as possible for safety purpose

Consider t = 6 mm for y_c = 0.81 mm

3. Dimensions of angle plate:

Length = 150 mm

Width = 45 mm

Thickness = 6 mm

Material = Mild Steel

Volume of angle plate = (volume of rectangular part) - (volume of hole)

= (l×b×t) - (π×r^2)×t

= (137.5×45×6) – (π×7.5^2)×6

V = 36065.25 mm^3

Mass of angle plate = ρ×v

= 7850×36065.25×10^{-9}

m = 0.2831 kg

Weight of angle plate = m×g

= 0.2831×9.81

W= 2.7773 N

4. Anvil Rod:

Rod diameter = 4 mm

Length = 238 mm

Volume of anvil rod = π×r^2×l

= π×2^2×238

V = 2990.79 mm^3

Mass of anvil rod = ρ×v

= 7850×2990.79× 10^{-9}

m = 0.0234 kg

Weight of anvil rod = m×g

= 0.0234×9.81

W = 0.2303 N

5. Semi-circular anvil plate (solid):

d =30 mm

r=15 mm

l=360 mm

volume of anvil shaft = π/4×$(r/2)^2$×l

V = π/16 $(15)^2$ ×360

V=15904.31 mm^3

V=1.590 × 10^{-5} m^3

Mass of semi-circular anvil shaft = ρ×v

=7850 ×1.590×10^{-5}

m = 0.1248 kg

Weight of semi-circular anvil shaft =m×g

=0.1248×9.81

W =1.2244 N

6. Perforated sheet:

r = 240 mm

l = 360 mm

circumference of perforated sheet = 2×π×r = 2×π×240

=1507.96 mm =1.50796 m

Area of perforated sheet = 1.50796 ×0.360

A =0.5428 m^2

Area of 2.88 m^2 perforated sheet is 4 kg then calculate for 0.5428 m^2 area.

(2.88/0.5428) =(4/x)

x =0.7538 kg

7. G.I circular plate

D =240 mm

d = 25 mm

\t =0.5 mm

volume of plate = π/4×(D^2-d^2)×t

=π/4(240^2-25^2)×0.5

V = 2.237 × 10^{-5} m^3

Mass =ρ×v

=7850 ×2.237×10^{-5}

m = 0.1756 kg

Weight of circular plate =m×g

W=0.1756×9.81

W =1.2244 N

8. Design of hammer cuff:

l = 70 mm

D = O.D. = 28 mm

d = I.D. = 24 mm

volume of hammer cuff = π/4×(D^2-d^2)×l

$= \pi/4(28^2-24^2)\times 70$

$=11435.39\ mm^3$

$=1.143\times 10^{-5}\ m^3$

Mass of hammer cuff = ρ×v

m = 0.08796 kg

Weight of hammer cuff = m×g

= 0.08796×9.81

W =0.8806 N

9. Design of hammer shaft :

Consider it as a simply supported beam

Mass of 3 hammers = (0.12717 × 3) kg = 0.38151 kg

Mass of 2 bearings = (0.125 × 2) kg = 0.25 kg

Mass of hammer cuff = 0.303 kg

Total Weight =9.1675 N

At C & E = 4.5837 N

At D ,

Centrifugal force = $\frac{m*v2}{r}$

∴ r =18.86 mm

ω =(2 π n)/ 60

= (2 ×π× 80)/60

∴ ω = 8.37 rad/s

∴ m = 1.335 kg

∴ Centrifugal force = $\frac{m\times v^2}{r}$

= (1.335 × (0.157)²)/0.01886

∴ F = 1.74 N

∴ Torque = (60 × 10^6 × P)/(2× π × n)
P = 0.1256 KW

∴ T =(60 × 10^6 × 0.1256)/(2 × π × 80)
T = 14 × 10^3 Nmm

For design considerations ,

T = T × 1.6 = 23.90 ×10^3 Nmm

$\Sigma M_A = 0$

= (4.5837 × 5.5) – (1.74× 50.19)+ (4.5837 × 66.5)-R_B×72

∴ R_B =3.37 N

$\Sigma M_B = 0$

= -R_A×72+4.5837×66.5-1.74×21.81+4.5837×5.5

∴ R_A = 4.056 N

B.M at A and B = 0

At C = 4.056 × 5.5 = 22.31 Nmm

At D =4.056×50.19 -4.5837×44.69= -1.27 Nmm

At E =4.056 × 66.5 -4.5837×61 + 1.74×10.81= 8.92 Nmm

∴ M = 22.31 Nmm

Equivalent bending moment:

$M_e = 1/2\ (M + \sqrt{T2 + M2})$

∴ M_e = 11961.16 Nmm

Equivalent twisting moment :

$T_e = \sqrt{T2 + M2}$

∴ T_e =23900 Nmm

$T_e = \pi/16(d^3\times ς)$

$23900 = \pi/16(d^3) \times 63.33$

∴ d = 12.43 = 15 mm

$ς = (0.5\ S_{ut})/\ F.S$

Material $40C_8$,

F.S = 3

$ς = (0.5\ S_{ut})/\ F.S$

= (0.5 × 380)/3

∴ ς =63.33 Nmm

Volume $=\pi/4\ (d^2)\times l$

Volume = $1.272 \times 10^{-5}\ m^3$

m = ρ×v

∴ m = 0.09998 kg

W = m× g

=0.0998×9.81=0.979 N

10. Hammer shaft bearing :

Radial load : F_r = 1.74 N

Axial load : F_a = ((3×0.12717)+0.303)×9.81

= 6.71 N

$P = X\ F_a + Y\ F_r$

∴ P = 8.45 N

∴ $(L_{10})_h$ =40,000 hours

$(L_{10}) = (60 \times n \times (L_{10})_h)/10^6$

$C = P \times (L_{10})^{1/3}$

$= 8.45 \times (192\ )^{1/3}$

∴ C= 48.45 N

But comparing it with design data book,

C = 1560 N

d = I.D =15 mm

D = O.D =24 mm

Designation = 61802

B = 5 mm

C_O = 815 N

11. Design of central shaft:

Weight of 4 hammer shaft = 3.9192 N

Weight of 12 hammers =14.964 N

Weight of 2 G.I plate = 3.458 N

Weight of 8 bearing for hammer shaft =9.81 N

weight of angle plate = 29.8224 N

Total weight = 61.97 N

Assume,

Weight of main shaft bearing =m × g

= 0.4× 9.81

W = 3.924 N

Length of anvil plate = 238 mm

Diameter = 5 mm

Volume = π/4 (d^2)× l

= 4673.11 mm^3

∴ V = 4.673 × 10^{-6} m^3

Mass = density × volume

= 0.0366 kg

∴ Weight =0.3598 N

∴ Weight of main shaft bearing = 3.924 N

∴ Weight of 4 anvil angles = 4× 0.3598 N

Total weight = 5.3692 N

W_1,W_3,W_5 = Weight of each stage

W_2,W_4 = Weight of bearing + anvil angle

W_3 = Total weight + Bagasse weight

= 61.97 + 49.05

∴ W_3 = 111.02 N

∴ W_1=W_5=61.97 N

∴ W_3=111.02 N

∴ W_2=W_4=5.36 N

$\Sigma M_A = 0$

=61.97×200+5.36×260+111.02×320+5.36×380+61.97×440-R_B×505

∴ R_B= 155.67 N

$\Sigma M_B = 0$

=61.97×65+5.36×125+111.02×185+5.36×245+61.97×305-R_A×505

∴ R_A =90 N

B.M at A & B = 0

At C = 90 × 200 =1800 Nmm

At D = 90 ×260 -61.97×760=19681.8 Nmm

At E = 90×320-5.36×60-61.97×120 = 21042 Nmm

At F =90×380-61.97×180-5.36×120-111.02×60 = 15741 Nmm

At G = 90×440 -61.97×240-5.36×180-111.02×120-5.36×60

= 10118.4 Nmm

∴ M = 21042 Nmm

∴ T = 60 × 10^3 Nmm

Equivalent twisting moment ,

$T_e = \sqrt{T2 + M2}$

=63582.74 Nmm

Equivalent bending moment :

M_e =1/2 (M +$\sqrt{T2 + M2}$)

=1/2(21042+63582.74)

∴ M_e = 42312.37 Nmm

T_e = π/16(d^3×ς)

63582.74= π/16(d^3)×63.33

∴ d = 17.22 mm

Take diameter as 25 mm.

Volume =π/4 (d^2)× l

∴ Volume = 2.47× 10^{-4} m^3

m = ρ×v

∴ m = 1.945 kg

W = m×g

W =19.08 N

IV. MATERIALS USED

PARTS	MATERIAL	QUANTITY
Hammer	MS	36
Angle Plate	MS	6
Anvil Rod	MS	6
Perforated Sheet	MS	3
Dowel Pin	MS	12
Main Shaft	MS	1
Bearing	MS	2

V. CONCLUSION

Due to high efficiency and good results obtained in the overall performance assessment of the process, we use pith as a replacement of paper and pulp industry. The remaining material form the paper and pulp industry which is thrown out, is utilised in those machine and used for various purposes.as it is cheaper, it is economically beneficial and profitable.as it has ability of low absorption of water it is widely being used into todays industry.

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