DESIGN & ANALYSIS OF COTTON GINNING MACHINE FOR SMALL SCALE FARMERS

Rajvardhan Patil[1], Atharva Kawade[2]

[12]Department of Mechanical Engineering, Vishwakarma Institute of Technology, Pune, Maharashtra, India

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Abstract - *Cotton has held the highest place amongst the family of fibers - natural or artificial from time immemorial. With the several rich and exceptional properties, it has (including comfort). Cotton is the King of Fibers and will remain in this position for centuries to come. In India, various cotton ginning machines are, Roller ginning machines saw ginning machines, and double roller ginning machines, but they are of exceptionally high cost and large in shape and weight. We aim to design and develop a low-cost Roller cotton ginning machine that will help farmers and small-scale enterprises remove the seeds from the cotton at their home level instead of going to a big ginning factory. This Project describes the Design of various components of the Mini Cotton Ginning machine. Hence, in this Design, various parts are necessary, and the Design of various parts will improve the design quality of those parts. This Project involves processes like Design, fabrication, analysis, and assembling of different components. The fresher and small farmer or businessman can start a business by investing less capital.*

Key Words: **Cotton, Ginning Machine, Roller Ginning, Design Procedure, Layout, Fabrication of Parts, Analysis, Efficiency.**

1. INTRODUCTION-

Cotton is a principal source of income for many farmers and other stakeholders in India. Fiber quality is a crucial factor determining cotton price and quality of cotton textile products. Fiber quality is mainly characterized by fiber length, strength, and micronaire, and the textile industry has a preference for long and robust fibers of moderate micronaire for producing high-quality yarns. The quality of cotton samples can only be assessed after ginning, i.e., separating fibers from cottonseed. The cotton used to be ginned in India on commercial size Double Roller (DR) and Saw Gins, which were infeasible for ginning small cotton samples needed for assessing fiber quality attributes. A portable, standalone, small size ginning machine was needed for quick ginning of a small quantity of a large number of samples for meeting the requirement of cotton breeders, traders, ginners, and farmers for preparation of seed for sowing. In the absence of such a kind of machine in India, stakeholders either relied on Charkha type manually operated device for ginning of a small number of samples or manual separation of fibers from raw cotton. Such a practice was time-consuming, and fiber quality results were also not representative of commercially Ginned samples. There were some instances of import of small ginning machines from the UK at a very high cost. Therefore, we intended to develop portable ginning machines as a primary tool such that farmers can themselves gin their seed cotton of straight varieties picked from their cotton field and the seeds for next sowing.

2. EASE OF USE

The only purpose of this Project is to understand the fundamental knowledge of the Design and mechanism of the Double Roller ginning machine. The Design is environmentally friendly and uses simple mechanism properties such as double roller ginning, raw cotton feeding, and seed separating systems. The Design done to increase the knowledge of designing, mechanism, and forces. This Project consists of designing and fabrication of an automatic saw ginning machine considering various essential parameters. In this Project, designing & developed a machine to Gin the raw cotton into seed-free cotton so the farmers and small-scale entrepreneurs can gain a high profit by selling seed-free cotton direct in the market as well as; the study of manufacturing was significant in order to carry out this Project. This Project consists of designing the different parts of this ginning machine considering forces and ergonomic factors for people to use.

3. DOUBLE ROLLER GIN

It consists of two spirally grooved leather rollers pressed against a fixed knife and a pulley and belt drive mechanism. Two moving blades combined with seed grids constitute a central assembly known as a beater, which oscillates through a crank or eccentric shaft close to the fixed knife. When the seeded cotton is fed to the machine in action, fibers that adhere to the rough surface of the roller are carried in between the fixed knife and roller such that the fibers are partially gripped between them. The oscillation beats the seed and separates the fibers. This process is repeated a many time, and due to push-pull action, the fibers are separated from the seed, carried forward on the roller, and then dropped out of the machine. The Ginned seeds drop down through the grid, which oscillates along with the beater. This Gin is for any variety of cotton, i.e., short, long, or extra-long staple, by simple settings and retains maximum fiber length and natural fiber parameters. This ginning machine can be used for all capacity requirements, i.e., small, medium, and large. The machine being straightforward, it can be used in the rural atmosphere hence can provide a local solution to many farmers for value addition in cotton.

4. PARAMETERS OF COTTON GINNING

4.1 Moisture Content:

Moisture content is the percentage of water vapor (which we call moisture) present with cotton lint before or after ginning. While considering the quality of cotton lint, the moisture content is an important parameter, ultimately responsible for the increase or decrease in ginning rate and quality of cotton. Moisture levels in cotton are significant for successful ginning as if moisture is too high while ginning; it forms small lumpy balls called neps. On the other hand, if it is too dry, the fiber breaks or can cause static electricity. For efficient cleaning and drying systems, it becomes necessary to consider the appropriate moisture content in seed cotton.

The recommended moisture level is up to 8 % is acceptable except for certain areas unless intentionally added by farmers or intermediaries. Due to which it gives better cleaning efficiency, and some trash gets mixed clean. As various people add water, the ginning factory must be fixed the percentage level of moisture, depending upon the local condition. Recommends that for efficient Gin, cleaning cotton operation, and preserving the intrinsic fiber quality, the moisture percentage must range from 6.5 to 8 % for upland cotton and 5 to 6 % for Pima cotton. The cotton that is too moist does not separate into locks but remains in wads which can choke ginning process—suggested that 7% moisture content serves best for lower electrical consumption and maximum ginning rate. The moisture content is an essential factor that helps to determine the quality of Ginned fiber.

4.2 Trash Content:

The primary objective of a cotton gin is to separate cotton fiber from cottonseeds. However, before separating the cotton fibers from seeds, all non-lint material associated with the seed cotton must be extracted to obtain quality cotton. This non-lint material is called trash. It consists of bark, stick, leaf, pepper trash, grass, hulls, seed coat fragments, and motes left behind in the lint shown in Fig. As the name suggests, the bark is the outer covering of sticks and is somewhat stringy and not easy to separate from the lint material. Pepper trash refers to small broken or crushed pieces of the leaf; hulls are the outer coverings of the cotton ball. Immature cottonseeds are referred to as motes

Figure 1 - Trash contents

Seed cotton. There are two types of harvesting equipment; one is the spindle picker and the cotton stripper. Trash Content is the ratio of the total trash area to the image area, where the trash area is measured using trash meters. Trash meters count the number of pixels identified as trash based on specific threshold criteria for a known area of the cotton sample. The selection of ginning technology ultimately depends upon the percentage of trash content. They are stated that trashy cotton requires extensive machines. Double Roller machines remove less trash content than saw ginning. Usually, 75% -85% trash of total trash content must be removed from seed cotton. Strippers collect up to six times more leaves, burs, sticks, and trash than the spindle picker machine. This higher ratio of trash to lint requires additional equipment for cleaning and trash extraction. Stripper harvested cotton may produce 1000 pounds of trash per 500 pounds bale of lint, compared to 150 pounds per 500 pounds bale from spindle picking.

4.3 Staple Length:

Staple length is the measure of the length of cotton fiber; it is the genetic property. It is an essential attribute of fiber. Three length properties are essential: (1) staple length or the average length of the longer half of the fiber; (2) the percentage by weight of the fibers shorter than half an inch, referred to as short fiber Content (SFC); and (3) length uniformity index (UI) or the average fiber length as a percentage of staple length. When the cotton is taken from the farms or stored as raw cotton, it has maximum staple length, thereafter due to some mechanical processes carried out on raw cotton result in decreased length of the fiber. For every cotton industry, it becomes essential to focus on staple factors because it relates much to the company's profitability as the product's price (cotton bales) is directly proportional to the staple length. The staple length of modern cotton varieties results from years of breeding and is not something that the ginner can produce.

4.4 Selection of Machine in Ginning:

This factor mainly refers to the heart of the ginning process. The selection of the machine mainly depends upon the quality of the cotton. Most of the ginners were unaware of the selection criteria of ginning technologies.

It is better to have a saw ginning machine for a short-staple length of 28 mm, higher trash content, and machined picked cotton. Single roller ginning is most suitable for medium, long, and extra-long staple length, low trash content, and handpicked cotton having fuzzy seeds. However, it requires additional cleaning equipment. Double roller ginning is suitable for all types of cotton, handpicked with low trash content, and having black seeds. Roto bar ginning is used in the overall world mainly for Pima cotton in the USA, black seed cotton, having long and extra-long staple length .it is suitable for machined picked cotton but not good for fuzzy seed cotton. The roller gin is used on high-quality, fine fibred, extra-long-staple cotton because it maintains fiber length and low neps levels. An estimated 79% of the production of cotton is roller Ginned in India. Roller ginning is less efficient than saw ginning in processing trashy and immature handpicked seed cotton.

5. DATA ACCUMULATION & CALCULATIONS

In the present study, we have accumulated all the necessary data of the existing DR Ginning machine and carried out the design calculations to create the existing CAD model of the Double Roller Ginning Machine. Existing machine Data: Data obtained from the existing machine: Rated Power = 1 HP, Power factor = 1.1 Speed = 1425 RPM the machine output capacity is 25-30 kg/hr.The optimum roller speed is 140 rpm. The leather roller available is of the diameter of 150 mm Two rollers rolling in the opposite direction with roller speed of 140 RPM, 1HP motor with 1425 RPM used Roller 1 is connected with a motor using belt and pulley reduction mechanism Roller 2 is connected with motor with gear reduction and small pulley reduction mechanism

5.1 Roller 1 drive mechanism:

Roller 1 drive mechanism

Rated Power of motor

P_r=746 Watt

Design Power,

$P_r = P_r * K1$

P_d = 746 *1.1 = 820.6 Watt

From design data book

Designation A,

Normal width of pulley = 13mm

Nominal thickness = 8mm

Motor Pulley diameter (D1) = 75mm

Roller pulley diameter = D2

No. of strands = 6

Speed of motor (N1) = 1425 rpm

Speed of roller pulley = N2

$\frac{N1}{N2}$ =VR=10.17

$\frac{D1}{D2}$ = VR

D2 = 75*10.17 = 765mm

Length of belt,

Centre distance = 75 + 765 = 840 mm

$$L = (\prod/2)(D1 + D2) + 2C + \frac{(D1 + D2)^2}{4C}$$

$$L = \prod/2)(75 + 765) + 2(558) + \frac{(50 + 508)^2}{4(840)}$$

L = 3208.8mm

Consider oefficient of friction between belt and pulley,

μ = 0.3

For an open belt angle of contact,

$$\sin(\alpha) = \frac{R_1 - R_2}{x}$$

$\alpha = \sin^{-1}(0.14)$

α= 24.2

ϴ = 180- 2(24.2) = 131.6

$$ϴ = 131.6 * \frac{\prod}{180} \text{ rad} = 2.29 \text{ radian}$$

T1 = tension in tight side

T2 = tension in slack side

$$\frac{T1}{T2} = e^{\mu \theta}$$

$$\frac{T1}{T2} = e^{0.3*2.29} = 1.987$$

T1 = 1.987 T2

Where velocity of belt,

$$V = \frac{\prod d_2 N_1}{60}$$

$$V = \frac{\prod *75*1425}{60}$$

V = 5.6 m/s

$$P = \frac{(T1-T2)*V}{1000}$$

$$P = \frac{(T1-T2)*5.6}{1000}$$

(T1-T2) = 133.2 N

Substitute the value of T1 from tension ratio

1.987T2-T2 = 133.2

T2 = 134.95 N

T1 = 268.14 N

Initial Belt tension,

$$T_0 = \frac{(T1+T2)}{2}$$

T_0 = 201.5 N

Pulley1 is connected directly on motor shaft Pulley1 torque = 5 Nm.

Torque acting on Driven pulley

$$T_{driven} = \frac{(T1-T2)D_{Driven}}{2}$$

$$T_{driven} = \frac{(200.1)*0.508}{2} = 50.8 \text{ Nm.}$$

Pulley Torque and speed ratio,

T_{Driven} * N1 = T_{Driven} * N2

$$N2 = \frac{5*1425}{50.8} = 140 \text{ rpm}$$

5.2 Roller 2 drive mechanism:

Roller 2 drive mechanism

Rated Power of motor

P_r=746 Watt

Design Power,

$P_r = P_r * K1$

P_d = 746 *1.1 = 820.6 Watt

Gear1 of 19 teeth connected on the motor shaft, meshed with gear2of 89teeth

Hence,

t3 = 19 and t4 = 89 N3=1425 rpm

Gear ratio is given by,

$$\frac{T4}{T5} = \frac{N1}{N2}$$

N4 = 304 rpm

Small pulley rotating on the same shaft of gear2 and large pulley on roller2,

Small pulley speed (N5) = 304 rpm

Roller pulley (N6) = 140 rpm

From data book Designation A,

Normal width of pulley = 13mm

Nominal thickness = 8mm

Pulley diameter (D5) = 75mm

Roller pulley diameter = D6

No. of strands = 6

$\frac{N5}{N6}$ =VR=2,17

$\frac{D5}{D6}$ = VR

D6 = 75*2.17 = 163mm

Length of belt,

Centre distance = 75 + 163 = 283 mm

$L = (\prod/2)(D5 + 6) + 2C + \frac{(D5 + D6)^2}{4C}$

$L = (\prod/2)(75 + 163) + 2(238) + \frac{(75 + 163)^2}{4(238)}$

L = 909mm

Consider coefficient of friction between belt and pulley,

$\mu = 0.3$

For an open belt angle of contact,

$\sin(\alpha) = \frac{R_1 - R_2}{x}$

$\alpha = \sin^{-1}(0.18)$

α= 10.36

Θ = 180- 2(10.36)

$\Theta = 159 * \frac{\prod}{180}$ rad = 2.78radian

T3 = tension in tight side

T4 = tension in slack side

$\frac{T3}{T4} = e^{\mu \theta}$

$\frac{T3}{T4} = e^{0.3*2.78} = 2.3$

T3 = 1.987 T4

Where velocity of belt,

$V = \frac{\prod d_5 N_5}{60}$

$V = \frac{\prod*75*305}{60}$

V = 1.194 m/s

$P = \frac{(T3-T4)*V}{1000}$

$P = \frac{(T3-T4)*1.194}{1000}$

(T1-T2) = 624.8 N

Substitute the value of T1 from tension ratio

2.3T4-T4 = 624.8

T4 = 480.6 N

T1 = 1105.38 N

Initial Belt tension,

$T_0 = \frac{(T3+T4)}{2}$

T_0 = 792.9 N

Actual RPM and torque transmission from motor to roller:

Motor RPM = 1425 RPM

Motor Power = 746 watt

Torque of motor,

$P = \frac{2\prod * N*T}{60}$

$P = \frac{2\prod * 1425*T_{Motor}}{60}$

$746 = \frac{2\prod * 1425*T_{Motor}}{60}$

M_{otor} = 5 Nm.

$\frac{Tgear1}{Tgear2} = \frac{t1}{t2}$

$$T_{gear2} = \frac{89}{19} * 5 = 23.4 \text{ N.m}$$

Gear 2 and pulley 1 is connected on same shaft,

pulley1 torque = 23.4 Nm.

Torque acting on Driven pulley

$$T_{driven} = \frac{(T3-T4)_{Driven}}{2}$$

$$T_{driven} = \frac{(1105.38-480.6)*00.163}{2} = 50.9 \text{ Nm.}$$

Pulley Torque and speed ratio,

$D_{riven} * N5 = D_{riven} * N6$

$$N6 = \frac{23.4*304}{50.9} = 140 \text{ rpm}$$

6. PROTOTYPE

Figure 2- Front View of the wooden prototype

Figure 3- Side View of the wooden prototype

7. CAD MODEL

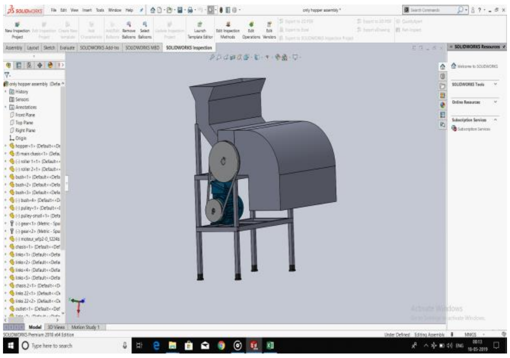

Figure 4- Front View of the Final Ginning Machine (Cad Model)

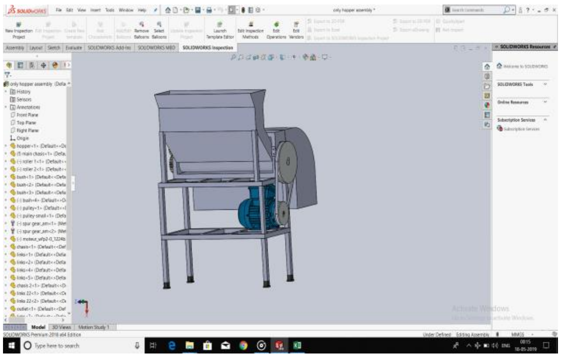

Figure 5- Side View of the Final Ginning Machine (Cad Model)

8. ANAYLISIS:

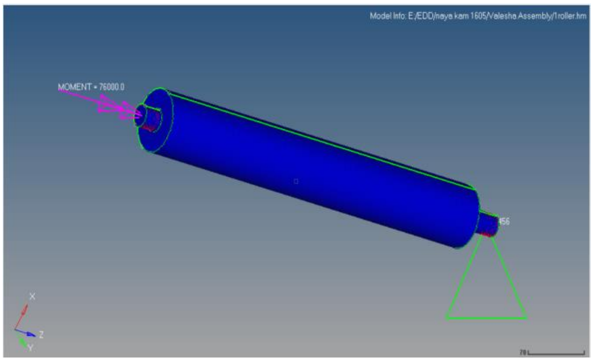

Figure 6 – Momentum Analysis on Roller Bar

$$\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{L}$$

Where

T = Torsional moment = 76000 Nmm

J = Polar moment of inertial = $\frac{\pi D^4}{32}$

G = Modulus of Rigidity = 80 GPa

τ = Shear Stress

L = Length of Shaft = 500 mm
R = Radius of shaft = 70 mm
Theoretical value

$\theta = \frac{TL}{JG}$ = 0.0002015 rad = 0.02°

Analytical value

$\tan\theta = \frac{dl}{R} = \frac{0.0399}{70}$

θ = 0.03°

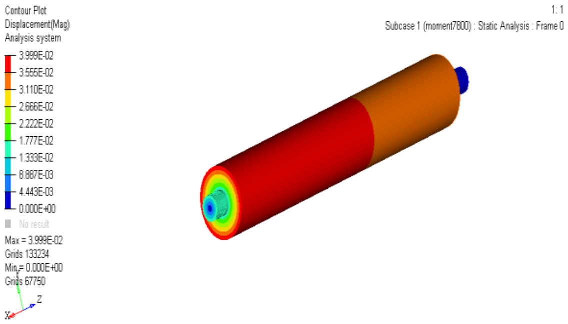

Figure 7– Roller Bar Deformation Analysis

Theoretical value

$\tau = \frac{TR}{J}$ = 38.59 N/mm^2

Analytical value

τ = 36.67 N/mm^2

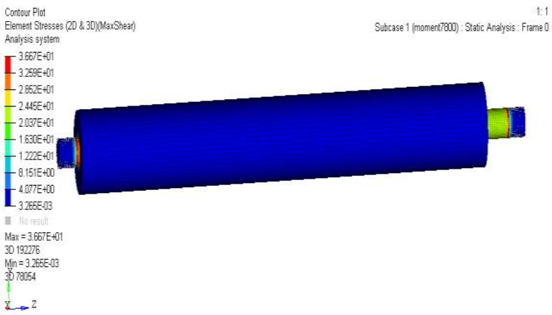

Figure 8– Roller Bar Shear Stress Analysis

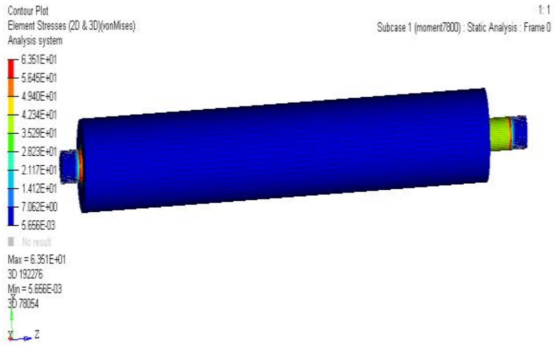

Figure 9– Roller Bar Shear Strain Energy Analysis

9. RESULT IN DISCUSSION

From the design calculations, both fiber rollers rotating at 140 rpm in opposite directions with the help of 4 pulleys and two gears, and it is seen that with 700mm length fiber rollers rotating at 140 rpm, we can achieve 35-40 Kg/hr capacity. From the life expectancy calculation, we have obtained the life of the knife more than one year(approx.) of working. From the Linear static analysis, the maximum stresses developed in the structure is 74 MPa. It is observed that the maximum stress (74 MPa) developed in the structure is considerably less than the yield stress (250 MPa) of the structure material.

10. CONCLUSION

The above design procedure has been adopted for the fabrication of a Compact Size Cotton Ginning machine for small scale farmers . The product durable and efficient. It can be used for both household and small scale industrial purposes. This Design gives significant advantages in the case of power consumption. The required power for the above-stated capacity is one hp. Our designed machine is lightweight, compact, and slim in construction. It is easy to operate and transport . This project aims to target the small scale farmers in rural regions where there are significant losses in cotton storage and segreigation due to inadequate and inefficient manufacturing processes.

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BIOGRAPHIES

Rajvardhan Patil, Student at Mechanical Engineering Department,
Vishwakarma Institute of Technology, Pune

Atharva Kawade, Student at Mechanical Engineering Department,
Vishwakarma Institute of Technology, Pune