Design Of Medium Duty Mechanical Press For Ginnery

J. F. Agrawal, R. D. Askhedkar[1] and P. M. Padole[2]

Department of Production Engineering
Y. C. College of Engineering
Nagpur

[1]Department of Mechanical Engineering
K. D. K. College of Engineering
Nagpur

[2]Department of Mechanical Engineering
V. N. Institute of Technology
Nagpur

ABSTRACT

Ginning is the process of separation of fiber from cottonseed. Composite ginnery performs ginning and pressing operations to convert lint cotton into a bale. The quality of baled cotton can be improved substantially by minimizing the handling of cotton. Presently 100 HP hydraulically operated press machine is used to compress 170 kg bale, the cost of which is exorbitant. Decentralization of ginnery is possible only if cost of press machine is reduced.
This paper discusses development and design of a low cost mechanical press for compressing 90 kg bale.

INTRODUCTION

Ginning is the first important processing activity that cotton undergoes, on its way from cotton field to textile mills, where it is spun into yarn and converted into fabric. It is a seasonal activity carried out for about 5-6 months in a year [2]#. By the time cotton enters the Ginnery, its quality in terms of fiber properties like length, fineness, strength, maturity etc, has already been decided and it would be the responsibility of the Ginnery to maintain the quality of cotton fiber. It is in this respect that cotton ginning plays very important role in the preservation of quality of cotton. But in India, it remained neglected and uncared for.

Ginning industry in India, today presents a dismal picture. The ginneries are many but their improper geographic location [2] and non-linkages with lint cotton packaging machine and spinning mills causes ginning industry to transport voluminous lint cotton at far distances.

NEED OF MEDIUM DUTY LINT COTTON MINI PRESS MACHINE

During the colonial rule in India, development of ginnery took place. The machinery used in a typical ginnery are Ginning machines, Lint Opener and 100 HP hydraulically operated Press Machine.

Figures in the square bracket represents reference number given on the last page.

For easy transportation of voluminous cotton to textile mills in India and abroad, lint cotton was packed at high density ranging from 580 kg to 640 kg per cubic meter [4], weighing 170-220 kgs. The size of bale was designed to suit the size of rail wagon ship container and its convenience in handling. Since then, same lint cotton-baling press machines are used with little modifications [5] in the process from mechanization to automation. Indian Standard has also specified certain norms for size, weight, density and moisture contained in the bale.

In one of the study [4], it was found that utilization of this machine is only 15%. It could be increased by transporting lint cotton from other ginneries to this place, will require additional expenses on transportation, losses in transit and affect quality. It was found through experimentation [5] that about 55 to 60 percent of the total energy required by the ginnery was consumed by the packaging system and also found that lower moisture content in cotton consumed 30 to 50 percent more electrical energy per kg of seed cotton processed.

Literature review [5] indicates that other cotton growing countries in the World like U.S.A., China etc. are compressing lint cotton into low-medium weight and low –medium density for their domestic consumption and high-density bales for overseas consumption. In India, domestic consumption has increased and export is minimal, still high-density bales are used. This may be due to the fact that the textile industries in India are located far away from cotton growing areas or ginneries and therefore these bales are required to be transported over long distances through rail/road transport. It is found that high-density lint cotton affects further processing in textile mills [5]. Further if bales are stored for a longer period, the quality of fiber deteriorates [5].

Apart from these, the press machines in ginneries are costly, (high initial operating cost and maintenance cost), labour intensive and unsafe. Looking into overall picture of cotton industry, it can be concluded that packaging of Indian cotton has never been entirely satisfactory from the point of quality, protection against loss, damages, economy in packaging and handling. This industry needs improvement in terms of better quality of cotton, low cost of processing and handling [4]. At present, however there are a number of obstacles in the way of accomplishing the adoption of various improved methods in cotton handling and processing practices, particularly as they relate to packaging. Improvement of ginnery is possible [4] only if initial cost of press is substantially reduced. This reduction can be achieved by pressing low-medium density bales [4] on mechanical screw type press.

Presently such presses are used to compress waste cotton. In this press a platen is fixed to screw, which compresses the lint cotton in box as it moves down.

NECESSITY FOR ESTABLISHING GENERALIZED EXPERIMENTAL MODEL FOR COMPRESSING LINT COTTON TO FORM A BALE

The process of compressing lint cotton to form a bale is a very complex phenomenon. The independent variables in the process [4] are the bale size (width and length of the package),

initial weight of the lint cotton, cotton fiber length, moisture content and basic cotton ingredients which are geographical area specific, like fineness, strength, maturity etc.
As soon as the platen starts moving from its topmost position, it is subjected to frictional load of mechanical power transmission system. The compressive load is almost non linear. During the last phase of compression, the load raise is most likely to be very steep. This steep rise in load during last phase of compression is likely to create shock load on the power screw and the transmission system. Hence this shock load take characteristic forms and the basis of press design. Applying the methodology of experimentation [4], extensive experimentation was planned and conducted on an existing mechanical press machine used for compressing waste lint cotton. From the data generated, a generalized experimental data based model has been established. This model forms the basis for the mechanical design of the press [4], which is detailed in this paper. The established experimental data based model is reproduced below Eq. (1), for the sake of ready reference.

$$F_c/W = 1.1259\text{x}10^{13}[\ (B/L)^{-28.018},\ M^{-0.2196},\ (gL/V^2)^{-5.5875},\ (V2\ I_t\ /\ L^3\ W)^{-0.5771},\ (tV/L)^{0.0739}\ ]\ \text{-(1)}$$

BASIS FOR DEVELOPMENT OF MECHANICAL PRESS

The proposed design of mechanical press for ginnery is based on the design of mechanical press utilized for preparing bales from waste cotton. The extensive experimentation [4] and time and motion study [6] executed on this press revealed following aspects for the further development of this press for compressing bales from fresh lint cotton for a decentralized composite ginnery.
1) Design of various elements of mechanical press machine are based on compressive force calculated from experimental data and following Eq. (2) is used [3] for its estimation-

$$T_i - I_e\ d^2\ \theta/dt^2 - W_f\ d/2\text{x}\ \tan\ (\alpha+\phi)\ \text{x}\ 1/G\ \text{x}\ 1.2 = 0\ \text{------(2)}$$

Table-1 Sample observations of Experimentation

.

W	90	80	70	60	50
M	5	7	8	6	9
V	0.01745	.01757	0.01755	0.01759	0.01765
t	7.665	3.055	4.275	2.7	0.055
F	9210	5511	4401	3528	2346

The above table shows that maximum compressive force exerted on the screw and other elements of press is 9210 kgf for compressing 90 kg lint cotton containing 5% moisture. Hence 10,000 kgf of force is used in designing elements of press.
2) The experimentation [4] revealed that optimum size and weight of bale compressed on this press would be 1200x480x470mm and 90 kg respectively.

3) Work study [6] carried out by authors indicate that the productivity of the machine can be improved from 3-4bales per hour to 6-8 bales per hour, if instead of one lint box, two lint boxes are provided so that the ideal time of the workers will be utilized for filling the lint cotton in one box while cotton is being compressed in another lint box by the screw of the press.

4) The economy in power consumption [1] can be achieved by modifying platens.

DESIGN OF MECHANICAL PRESS MACHINE

The main components of mechanical press, as shown in fig. 1 are-

1) Mechanical power transmission system, 2) Lint filling box, 3) Structure, 4) Platen

DESIGN OF MECHANICAL POWER TRANSMISSION SYSTEM

Mechanical power transmission system as shown in fig. 1, consists of a 10 hp, 1500-rpm electric motor, which drives the power screw at 55 rpm. This reduction of speed is achieved in two stages. First stage reduction is through a V- belt drive having reduction of 1:5 and second stage reduction uses spur gear box with speed reduction of approximately 1:6. The design consideration for various elements of transmission system are discussed below

Design of Screw The design of power screw requires considerations of strength of the screw in compression, shearing of the screw itself or of the threads, wearing of the threads and power requirements. In this system of screw and nut, nut is rotating and screw has axial translation with no rotation against the resisting force. As shown in figure 1, the axial compressive force F loads a square-threaded two power screws. The compressive force acting on each screw is 5000 kgf.

The power screws of press are subjected to shock compressive load during compaction of bale. It is simultaneously subjected to torsional shear stress caused due to friction between threads of nut and screw. As the unsupported length of screw is very high as compared to cross sectional area, this screw is design as a column with both ends guided.

One end of screw is fixed to the moving platen, which slides with guides that is in the box. The other end is guided by nut, which is rotary. Torque required for compressing bale and to overcome thread friction at collar is ascertained to be 920 N-m. It is found that slenderness ratio is about 300 and so core diameter based on Euler's equation [3] is about 75mm. The most common low cost material for screw shaft is low carbon steel similar to SAE 1015 formed by hot rolling and finished to size by turning. The coefficient of friction for this kind of material and slow motion of screw may be taken as 0.15. The screw is checked for principal stresses. The principal dimensions of screw are given in Table-2.

Design of nut The most important dimension in the design of nut is the height of the nut, which is governed by minimum number of threads in contact to sustain the torsional shearing stress and the bearing load. Cast iron is selected as a material for the nut because it is inexpensive, can be given desired form and has high compressive strength. It is observed that minimum number of threads required withstanding torsional shear stresses and bearing pressure is six. The major dimensions of the nut are given in Table-2.

Design of Gears It is decided to use 20-degree full depth spur gear for power transmission. Minimum numbers of teeth required on pinion are 14 for 20-degree full depth gear. For the economy, it is decided to select steel as material for the pinion and gear. It is also decided to use commercially cut gears. The module for the gear pair is evaluated by using Lewis formula [3] and design is checked for dynamic and wear load. The important dimensions of gear pair are given in Table-2.

Design of V-Belt Drive The V- Belt drive transmits a power of about 5.19 KW. Based on this power at pinion shaft pulley, B type V belt is recommended. The minimum pulley diameter and big pulley diameter are calculated and shown in Table-2. The standard power per belt for medium duty press machine running 8 hours comes out to 1.71 kw per belt, hence requires three V belts of B type.

Design of Lint Filling Box

Work-study [6] was carried out by authors on experimental press, reveal that the productivity of press is 3-4 bales per hour. On analysis of method, it is found that utilization of man and machine can be improved if two lint-filling boxes instead of one, as shown in fig. 1 are provided to the machine. The idle time of the workers will be utilized for filling the lint cotton in one box while cotton is being compressed in another box by the screws of the press.

The area of the box is 1200x480mm while its height is decided on the basis of compression ration, which is assumed to be as 5. Hence height of box will be about 2400mm. The box is prepared from various structural materials. The steel wheels, which roll on rails, are provided at bottom of the box. The steel rail is provided on either side of the box with stoppers. The important dimensions of box are given in Table-2.

Design of Structure

It is made up of channel, angles and the sheet as shown in figure-1. The structure is designed to withstand the compressive load exerted on the bottom and sides of box of structure during compression of bale. The structure is made up from hot rolled steel sections. The design dimensions of structural components are given in Table-2.

Design of Platen

The platen is designed as a flat plate subjected to uniform load and supported at two points, where it is connected to power screws. Uniformly distributed load on the platen is shock load. The platen is 1200x500mm cross section with six or eight wooden blocks of 25mm wide by 40mm deep slots spaced across the width of the platens that allow placement of restraining ties. Anthony (2001) evaluated through experimentation, several types of devices [1] if inserted in the platens, reduces force of compression. One of the more promising type was a specially configured insert affixed inside the existing slots in the platen and protruding beyond the platen surface by about 100mm as shown in fig 2. The inserts were shaped like an inverted, hollow and truncated V with a 25mm hole in the center for tie insertion. At maximum force of compression, as evaluated by Anthony [1], the density at tip of inserts decreases.

Anthony demonstrated that there is reduction in compressive force about 20% for one platen and 35% for two platens. The important dimensions of platen are given in Table-2.

Table-2 Design dimensions of Elements of Mechanical Press Machine

S.No	Element	Dimn./Qty.	
A	**Mechanical Power Transmission System**		
A1	**Screw**		
1	Pitch of Screw	14.5mm	
2	Major diameter	89.5mm	
4	Length of Screw	2150mm	
A2	**Nut**		
1	Outer diameter	150mm	
2	Max number of thread	6	
3	Collar- diameterxthickness	200x15mm	
A3	**Gears Element**	**Pinion**	**Gear**
1	No. of Teeth	14	74
2	Module mm	6	6
3	Tooth width mm	60	60
4	Addendum mm	6	6
5	Dedendum mm	7	7
A4	**V-Belt Drive**		
1	Motor pulley diameter	125mm	
2	Larger pulley diameter	640mm	
3	Length of belt	2850mm	
B	**Lint Filling Box**		
1	M.S. Box -size	1200x480x2400mm	2 No
2	Steel wheel	150x30mm	8 No
3	Rail (Steel)	30x4500mm	2 No
C	**Structure**		
1	Size 1350x600x3000mm		1
2	Mild steel plate 1200x500x10mm thick		1
D	**Platen**		
1	Flat platen 1200x500x50mm		2
2	Unitized platen of steel 500x25x140mm		16 No

CONCLUSION

a) The load necessary for compressing bale of 90 kg and of size 1200x480x470mm as established by carrying out extensive experimentation on mechanical press machine used for waste cotton was 9210kgf. The mechanical press is designed for 10000 kgf.
b) To optimize the production capacity of this press, two lint boxes are provided. The idle time of worker is utilized for filling the lint cotton in one box while cotton is being compressed in another box.
c) For getting focused compression, unitized platens are provided in press.
d) Utilizing the proposed mechanical press machine will substantially reduce the cost and space required for a composite ginnery.
e) This low cost mechanical press will make decentralization of composite ginnery a reality, which will improve the quality of lint cotton by reducing handling substantially.

NOMENCLATURE

B- Width of box mm, d - Diameter of screw mm, F_c- Force of compression kgf,
g- Acceleration due to gravity m/s^2, I_e - Equivalent moment of inertia of mechanical power transmission system kg-m^2,
I_t - Total moment of inertia of mechanical power transmission system kg-m^2,
L- Length of box mm, M- Moisture content in lint cotton %, t- Instantaneous time sec.,
T_i - Torque input at motor kgf-m, V- speed of screw m/sec., W- Weight of lint cotton kg
W_f – force in kgf, θ - Angular velocity rad/sec. α - lead angle, ϕ - friction angle

REFERENCES

1) W. S. Anthony, "Concept to reduce cotton bale packaging forces" Journal of Applied Engineering in Agriculture, Vol. 17(4), 433-440, 2001.
2) C. H. Mirani, K. S. Parmar, " Baling the White Gold" Tecoya publication, Mumbai, 1995
3) Paul H. Black et al. "Machine Design" Third Edition, McGRAW-HILL International Edition, Translation Screws, 1981.
4) J. F. Agrawal, R. D. Askhedkar, P. M. Padole, J. P. Modak, "Formulation of generalized experimental model for compressing lint cotton to form a bale with a view to generate design data for mechanical press". INCARF 2003, IIT Delhi, *Paper* No. 228, Technical Session IV B, 2003.
5) J. F. Agrawal, R. D. Askhedkar, P. M. Padole, "Optimum level of low cost automation for quality processing at ginnery", National Conference on World Class Manufacturing, Amrita Institute of Technology and Science Ettimadai, Coimbtorer, pp 234-238, 2003.

6) J. F. Agrawal et. al., Assessment of productivity of Mechanical Press Machine used for Compressing Waste Cotton and Methods of Improvement" Journal of Industrial Engineering. Under Publication