TITLE: 1610 Techno-economic Feasibility of a Mini Cotton Ginnery for developing countries like India

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ABBREVIATIONS:

ANN (Artificial Neural Network)
HVI (High Volume Instrument)
RPM (Revolutions Per Minute)

ABSTRACT

Cotton from time immemorial has held the highest place amongst the family of fibers - natural or man made. Owing to the several rich and exceptional properties it has (including comfort and drape), cotton is also known as the King of Fibers and will continue to hold this place for centuries to come. Fabric made of cotton fiber is best suited to skin under Indian climatic conditions. Indian ginneries present a dismal picture in terms of using outdated technology. There are about 3342 ginneries, which includes conventional ginneries (the majority), having outdated machines while modern ginneries are few in number. Most ginneries in India, being in unorganized sector, are not aware of modern technology. The ginning industry in the country can be said to be still backward. The geographical location of ginneries and unavailability of lint cotton packaging machines and spinning mills causes the ginning industry to transport low density voluminous lint cotton package over far distances. The principal function of the cotton gin is to separate lint from seed, but the gin must also be equipped to remove a large percentage of any foreign material from cotton. If the foreign material is not removed, it would significantly reduce the value of the ginned lint. It is in this respect of trash removal that cotton ginning plays a very important role in the preservation of the quality of cotton. But in India, trash removal during ginning is largely neglected. The objective of the present research work being reported is to establish techno-economic feasibility of producing contamination free lint cotton in the form of low to medium density bales at a mini cotton ginnery. This mini cotton ginnery would be installed in cotton growing areas.

KEYWORDS

Ginning, Pressing, Mini Cotton Ginnery, Lint Quality, Techno-economic Feasibility

INTRODUCTION

Cotton from time immemorial has held the highest place amongst the family of fibers - natural or man made. Owing to the several rich and exceptional properties it has (including comfort and drape), cotton is also known as the King of Fibers [1,2] and will continue to hold this place for centuries to come. Fabric made of cotton fiber is best suited to skin comfort under Indian climatic conditions.

Continuous improvements have been emerging in the textile spinning and weaving machinery sector. The development of high-speed automatic looms requiring high quality yarn is going to revolutionize the weaving industry. New weaving techniques necessitates special spinning techniques for the production of high quality yarns, and needless to say, such high quality yarns can be spun only from contamination-free lint of the best quality that is obtained by proper ginning.

Cotton ginning is the separation of cotton fibers (known as cotton lint or simply cotton) from seed cotton. Seed cotton is harvested manually or mechanically [3] from the bolls on the cotton plant. Most of the cotton (lint) is destined for the textile industry in the form of bales, while cottonseed goes to the oil extraction industry.

The machinery used in a typical gin in India is the ginning machine, the lint opener and the bale press**.** The bale press machine in India is a single box type (with two stage packaging – one at half press and then at full press). All the presses are hydraulically operated [5]. An electric motor of 100 hp is used to operate 12 pumps to achieve a pressed bale density of 580- 640-kg/cubic m.

The critical analysis of present-capacity [4] available shows that out of the total 3342 ginning and pressing factories in India, ginning factories (where only ginning operations are performed) are 69 % while pressing (where only lint packaging operations are performed) are only 4 % and composite (where both ginning and lint packaging operations are performed) is 27 %. There is marginal increase in composite units from the year 1993-94 to 2001-02, while pressing and ginning units have decreased negligibly. The non-availability of composite units causes extra expenditure on transportation of lint cotton from ginning to press machine and that amounts to INR 1150 millions (US $ 29 millions).

The variable cost per bale declines as the level of mechanization/automation increases while the initial capital cost rises tremendously. Out of 3342 factories only 207 factories (i.e. 6 %) are automated (having ginning and pressing capability with mechanized handling facility) [12]. The remaining factories (up to 42 %) can be modernized, if ginning equipment of higher production capacity is available.

In India, the present ginnery can be categorized into three major groups [12]

a) **Conventional Ginnery -** In conventional ginnery, ginning, pressing or both operations are carried out but the handling of seed cotton, lint, cottonseed and bales are done manually.
b) **Semi automatic Ginnery -** This is a composite unit where all the unit operations of material handling except
    1) Unloading and heap making of seed cotton
    2) Feeding of seed cotton to the gins from central platform
    3) Feeding of lint to press box and handling of bales in the press house are done automatically.
c) **Automatic Ginnery -** It is either a composite unit or an integrated unit, where all the unit operations are done automatically except
    1) Seed cotton unloading and heap making
    2) Feeding to suction system and
    3) Unloading of bales.

The composite unit is one where both ginning and pressing activities are carried out within one premises. The integrated ginning and pressing factory is one in which ginned lint is directly transferred to the press without storing or conditioning in pala house.

Traditionally a small size gin (having 12 or less than 12 DR gins), with or without press machine is 52 % of 3342 ginneries and could be an obstacle to the successful establishment and operation of semi-automatic/automatic ginnery because such ginnery needs 24 DR gin machines and lint cotton packaging bale press with mechanized handling. Further analysis using a break-even chart shows that a fully automatic ginnery is economical [12] if its production is more than 50,000 bales/year. Conventional and semiautomatic ginneries are economical [12] if the volume of production is less than 15,000 bales and equal to 15 to 20 thousand bales in a season respectively.

The quality [4] of lint cotton is affected by methods of handling of cotton prior to the gin then the lint from the gin to the press machine and finally the bale handling after pressing. About 80 % of all cotton is handled manually. In the analysis, it was found that the period of operation of about 50 % of the gin is more than six months. The extended period ranges from 7-9 months and in some cases it even extends beyond 9 months. This extended working period decreases moisture, which makes the fibers more brittle and reduces fiber length during ginning.

The maintenance of optimum cotton fiber moisture level of around 7-8 % in the cotton is important during ginning and pressing. Presently the moisture is maintained by hand in 17.4 % of the gins, by atomizer in 12.3 % of the gins of the gins and is not maintained in 70.3 % of the gins. Indian cotton has a relatively high level of contamination of about 6-8 % despite being handpicked from the farm. Moreover, a majority of the ginneries in India does not have adequate pre-cleaning arrangement. The lint with high trash content has to be subjected to proper cleaning before packaging on bale press. At an average level of 6 %, the total trash component in the present volume of Indian cotton at 27 million bales comes to about 0.3 million tonnes. This huge quantity is transported over thousands of kilometers every year at heavy cost on freight to be ultimately removed by the spinners in textile mill incurring further cost there on [6]. There is wide range of contaminants that includes over 20 types. The types of contaminants [6] are leaves, strings, feather, paper, inorganic matter like sand, dust, oily substances and chemicals like grease/oil etc. The contaminations are added at different stages of processing of the cotton [4] at the ginnery. Cotton is contaminated during pre-ginning 46 % of the time, during ginning 44 % of the time, and during pressing about 10 % of the time.

It was found through experimentation [14] that about 55 to 60 percent of the total energy required by the ginnery was consumed by the packaging system and it was also found that cotton of lower moisture content consumed 30 to 50 percent more electrical energy per kg of seed cotton processed than wetter cottons.

A review of the literature [7, 8, 23] indicates that other cotton growing countries in the world like China are compressing their lint cotton into low-medium weight and low –medium density for their domestic consumption and high-density bales for overseas consumption. In India, domestic cotton consumption has increased and cotton export is minimal, but still high-density bales are used. This may be due to the fact that the textile industries in India are located far away from the cotton growing areas and ginneries and therefore these bales are required to be transported over long distances through rail/road transport. It was found that high-density lint cotton affects further processing in textile mills [13]. Spinning test results on three density (low, medium and high density) bales indicate a tendency for manufacturing waste to increase and yarn strength to decrease with the increases of density. The raw cotton stock-dyeing test was performed on different density of cotton bales. It was found that the lint cotton from low density dyed more uniformly than that of medium to high-density cotton bales [13]. Further if bales are stored for a longer period of time, the quality of fiber deteriorates [14]. Apart from this, press machines in ginneries are costly, (high initial operating cost and maintenance cost), labor intensive and unsafe for operation as feeding in underground lint box is performed manually.

A large majority of the bale presses in India are around seven to eight decades old. Only a small percentage of the existing units are of recent origin and of modern design. The old presses have generally undergone minor modification and quite frequent reconditioning.

Consequently, a ginnery often produces bales of irregular or improper shape, uneven density and large variation in bale weights. It was also observed that to meet the capacity of modern press machines, ginning capacity must be increased or the pressing machine will be underutilized.

Decentralization of the Cotton Ginnery: An Appropriate Technology

Looking into the overall picture of the cotton industry in India, it can be concluded that packaging of Indian cotton has never been entirely satisfactory from the standpoint of fiber quality, protection against loss and damage or economy of packaging and handling.

Earlier researchers [5, 6, 10] have conflicting opinions regarding the feasibility of the cotton ginnery. Research work carried out in the last 10-15 years has revealed that the quality of lint cotton can be improved either by modernization of the cotton ginnery or through the addition of appropriate technology. Modernization of cotton ginnery means that the technology developed in advanced countries like USA where ginning and pressing operations are being performed in the same premises of a ginnery. In addition, pre-cleaner, post cleaner, drier and on line humidification system for moisture control are installed with mechanized handling of cotton, lint and seed. Appropriate technology, for Indian ginnery, meant addition of facility which would be conducive to the proper storage (like covered shed), handling of materials through conveyors, trolley etc. in order to minimize contamination through reduced human involvement and other means. Replacement/addition/modification of equipment which has outlived their utility/life and is beyond economic repairs. Addition of equipment like pre cleaner and post cleaner to bring about the needed improvement in the quality of lint cotton. The best option for the cotton ginnery in India would be to go for appropriate technology [5, 10], which will be an optimum blend of the modern with the traditional from the techno-economic point of view.

At present, however there are a number of obstacles in the way of accomplishing the adoption of various improved methods of cotton handling and processing practices, particularly related with packaging. The improvement of the ginnery is possible [5, 6, 10] only if the initial cost of the press is substantially reduced. This reduction can be achieved by pressing low-medium density bales [5, 10] on mechanical screw type presses.

This means the decentralization of the cotton ginnery using low-medium density bales made on a mechanical screw type press can be thought of as an appropriate technology. Ginneries that currently have only a ginning facility without a press can utilize this bale-making machine, which can be designed and installed to arrive at a balance between capital investment and entailment of transportation cost. This may also balance the production at the ginnery and the direct delivery of bales to mills in nearby regions.

The objective of the research work reported here is to produce contamination free lint cotton in the form of low to medium density bales at mini cotton ginnery, to establish its techno-economic feasibility, and be able to build this mini-cotton ginnery in cotton growing areas. The goal of this investigation was to determine the force required for compressing lint cotton by varying all physical quantities encountered in the process of compression of lint cotton over the widest possible range.

MATERIALS AND METHODS

The process of compressing lint cotton to form a bale is a very complex phenomenon. The independent variables in the process [17] 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 moment when the platen makes contact with the upper surface of the lint cotton, the platen starts compressing lint cotton. For the initial almost 50 % of the travel, the load is likely to be approx. 25 % of the maximum load. Subsequently the load is likely to rise non-linearly. During the last phase of compression, the load raise is most likely to be very steep. The details of the experimental findings will establish the load versus time graph. The steep rise in the load during the last phase of compression will provide very useful data for optimally designing the press. This is going to ascertain the shock likely to take place on the mechanical power transmission system of the press. The approach proposed by Schenck [15] is used for planning and execution of experimentation on a scaled model of a screw type bale-making machine.

Design of Experimentation:

The independent variables of the process are length of box-L, width of box-B, moisture content in lint cotton-M, weight of lint cotton-W, speed of screw-V, acceleration due to gravity-g, total moment of inertia of mechanical power transmission system-I, instantaneous time-t, etc. The dependent variables are, force of compression-F, energy required for compression-E, density of the compressed sample-ρ, time of compression-T, and displacement of platen during compression-S etc. The extraneous variables are the voltage fluctuations during the test, small errors in kinematic travel of the platen because of the wear in mechanical power transmission elements, error of instrumentation because of heating of electric motor and so on. As per Schenck [15] unless all independent variables are varied over widest possible range during experimentation, the developed model is not a generalized one. Some of these independent variables could not be varied during the experimentation because of limitations of time and cost of experiment. Hence some of the independent parameters remains constant like length of box, width of box, total moment of inertia of mechanical power transmission system and acceleration due to gravity during planned experimentation and models arrived at are approximate generalized models.

Dimensional Analysis

The dimensionless equations obtained by dimensional analysis [15] are

$\mathbf{F/W} = K[(B/L)^b, M^c, (g,L/V^2)^f, (V^2 I / L^3 W)^g ,(tV/L)^h]$ ------------------------(1)

$\mathbf{E/LW} = K[(B/L)^b, M^c, (g,L/V^2)^f, (V^2 I / L^3 W)^g ,(tV/L)^h]$ ----------------------- (2)

$\mathbf{S/L} = K[(B/L)^b, M^c, (g,L/V^2)^f, (V^2 I / L^3 W)^g ,(tV/L)^h]$ ----------------------- (3)

$\boldsymbol{\rho} \mathbf{L^2 V^2/W} = K[(B/L)^b, M^c, (g,L/V^2)^f, (V^2 I / L^3 W)^g , (tV/L)^h]$ -------------- (4)

$$\mathbf{TV/L} = K[\,(B/L)^b, M^c, (g,L/V^2)^f, (V^2 I / L^3 W)^g, (tV/L)^h\,] \text{ ---------------------(5)}$$

Test planning:

The test envelop, test point and test sequence [16] are decided on the basis of some of the known ranges of variation of some of the independent variables, in view of the availability of lint cotton, availability of press, availability of instrumentation and are as shown in Table 1.

Conduct of experiment:

The experimentation was conducted as per test plan. Sample of different weights 50, 60, 70, 80, and 90 kg are prepared. As per test planning, moisture in the lint cotton is increased by adding known quantity of water. The computer monitor displays rise in load during compaction in a graphical form as shown in Figure 2. The extensive experimentation has been carried out as per the classical plan of experimentation in which only one independent variable is varied at a time over its test range and simultaneously keeping other variables at their constant values. The possible range of variation of the independent variables involved in the lint cotton compression process is given in Table 1. Figure 1 shows observations being taken during the experiment.

Observations and calculations:

The power measuring system records power values in milliseconds. All the data is checked and unnecessary data is rejected. Speed versus torque characteristics curves are used for calculations of speed variation of electric motor of similar specifications. Power versus time relations is plotted for calculation of energy and force. The area under this curve gives energy.

The following equation (6) is used [3] for compressive force estimation:

$$T_i - I_e\, d^2\theta/dt^2 - W_f\, d/2x \tan(\alpha+\phi) \times 1/G \times 1.2 = 0 \text{ ------(6)}$$

T_i - Torque input at motor kgf-m

I_e - Equivalent moment of inertia of mechanical power transmission system kgf-m^2

W_f – force in kgf,

θ - Angular velocity rad/sec

d – Average diameter of screw, cm

α - lead angle;

ϕ - friction angle

G – Transmission ratio

The displacement of platen is calculated from linear velocity versus time during compression. Density of compressed bale is calculated from platen separation recorded during experimentation, length and width of box and weight of sample. All the calculated and observed values are tabulated. Table 2 shows sample observations and resultant parameters.

Observations and calculation

The experimental data was collected, as shown in Table 2 (sample). Using the collected data and equations (1-5), the exponents and constant are evaluated for each equation. The mean value of the exponents and the constant were used to establish the experimental model for each equation.

Formulation of Generalized Experimental Model

The following experimental models were developed with the help of MATLAB & ANN [17, 18] and are given in equations 1-5.

F/W = $1.1259 \times 10^{13} [(B/L)^{-28.018} M^{-0.2196} (g,L/V^2)^{-5.5875} (V^2 I / L^3 W)^{-0.5771} (tV/L)^{0.0739}]$ -------(1)

E/LW = $1.46 \times 10^{6} [(B/L)^{8.3099} M^{-1.3747} (g,L/V^2)^{-1.0731} (V^2 I / L^3 W)^{-0.8179} (tV/L)^{0.4169}]$ --------(2)

S/L = $2.116 \times 10^{71} [(B/L)^{15.5729} M^{0.7497} (g,L/V^2)^{-14.8408} (V^2 I / L^3 W)^{-0.3622} (tV/L)^{0.73}]$ ----------(3)

$\boldsymbol{\rho L^2 V^2/W}$ = $1.159 \times 10^{-80} [(B/L)^{-12.88} M^{0.0232} (g,L/V^2)^{15.9922} (V^2 I / L^3 W)^{0.2177} (tV/L)^{-0.0454}]$ -----(4)

TV/L = $4.9125 \times 10^{3} [(B/L)^{-7.8616} M^{-0.4371} (g,L/V^2)^{-1.6827} (V^2 I / L^3 W)^{-0.2256} (tV/L)^{0.8806}]$ ------(5)

The mean force of compression obtained by the MATLAB and ANN models are given in Table 3.

Selection of optimum Processing Parameters for Compression of Lint Cotton

As seen from Table 4, the compressive force does not increase linearly but is non-linear. The only conclusion could be drawn from this phenomenon is that a 60 to 80 kg bale should be compressed to achieve a gain in force and energy. However, 60 kg and 70 kg bale would be too small to achieve an economy in transportation, hence 80 kg bale would be chosen for a mini cotton ginnery. The optimum values of the selected variables [7, 17] for compression of lint cotton are given in Table 4.

Some of the primary design considerations for improved bale press moisture content of the lint cotton, production capacity of the gin, cost of operation and the desired size and weight of the bale.

The design of the various elements of an improved mechanical press machine is based on the compressive force calculated from experimental data.

The maximum compressive force exerted on the screw and other elements of press during the test was 9210 kgf for compressing a 90 kg bale of lint cotton containing 5 % moisture. The corresponding model value from MATLAB and ANN were 9143 and 9224 kgf respectively. Therefore, a value of 10,000 kgf was used in designing the elements of the experimental press.

Fabrication of Mechanical Press Machine for Mini Cotton Ginnery

The main components designed for the mechanical press were: 1) a mechanical power transmission system, 2) lint filling box, 3) structure of the press, and 4) press platen.

The mechanical power transmission system 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. Apart from the fabrication of various special elements, standard components that were used for the assembly of transmission system included the electric motor, bearings, pulleys, belts and pedestals. The size of the lint filling box is 1175 x 475 x 2400 mm. Steel wheels, which roll on rails are provided on either side of the box, at the bottom of the box (see Figure 3). The structures overall size was 1350 x 600 x 3000 mm, and was made up of standard steel channel, angles and sheet metal. The platen was fabricated as a flat plate and supported at two points, where it was connected to the power screws. The platen had dimensions of 1200 x 500 x 50 mm with nine wooden blocks with 25 mm wide by 40 mm deep slots spaced across the width of the platens that allow placement of bale restraining ties.

Specially configured inserts were affixed inside the existing slots in the platen and protruding beyond the platen surface by about 100 mm were unitized in platen for tie insertion. The inserts were shaped like an inverted, hollow and truncated V with a 25mm hole in the center for tie insertion.

Table 5 gives the general specifications of the mechanical press. The complete assembly of press machine is as shown in Figure 3.

Test of the fabricated mechanical press for mini cotton ginnery:

Test trials on the fabricated mechanical press machine for mini cotton ginnery were conducted for a 70 kg bale. The initial trial was done on a 20 kg bale and the machine worked satisfactorily. Lint cotton with the appropriate moisture level of 7.2 % was put in the filling box. The upper platen, attached to the two power screws, compressed the lint cotton in the box. Limit switches stopped the travel of platen at the proper time. The dimensions of the bale measured in compressed condition between the platens was 1175 x 475 x 450 mm. Jute covering was used to cover the bale and 3.5mm diameter galvanized iron wire was inserted through the platen for tying of bale. When the bale was tied and removed from the machine, the dimensions of bale were found to be 1200 x 550 x 500 mm. The completed bale is as shown in Figure 4. The specifications of the compressed test bale are shown in Table 6.

RESULTS AND DISCUSSION

Design and construction features of mini cotton ginnery system

i) Plant capacity, location and layout- The required input of seed cotton per day for a mini system would be 15 tons and assuming 125 to 150 working days in a season; the mini cotton ginnery would need 2,000 tons of seed cotton for operation. The numbers of bales produced by this proposed ginnery in a season would be about 6000 bales of 90 kg each.

A number of important factors like procurement of cotton, manpower and market are to be considered before constructing a new gin plant or locating an existing plant [5, 10]. It is proposed that low cost handling equipments [20] such as trolley for handling of seed cotton and baled cotton, belt conveyor for transport of lint cotton from gin machine to lint storage house should be utilized at small size ginnery.

ii) Selection of equipments: The following equipment is proposed for a new mini cotton ginnery:

a) Cottonseed pre cleaner – 1 unit
b) Roller ginning machine – 10 units
c) Mechanical bale making machine – 1 unit
d) Lint Cleaner – 1 unit

Figure 5 indicates that to balance the mini-ginning system process, 10 ginning machines (at a cost of INR 0.1 million per machine – US $ 2500) are required, which will produce a bale approximately every 10.4 minutes, which will balance the output of mechanical press machine (at a cost of INR 0.3 million per machine – US $ 7500) which can produce an 80 kg bale approximately every 10 minutes [19].

The level of cotton moisture considered optimum during ginning is 6.5 to 8 percent. The mini cotton ginnery will operate for 100-150 days during Oct/Nov - March/April. The mini cotton ginnery will produce less contaminated (free from jute strings, leaves, dust, sand, human hair, plastic pouch) lint cotton because of a reduction in handling at the ginnery and by using appropriate methods of handling. The level of contamination further gets reduced by selecting pre and post cleaner of cotton. The theoretical estimation of trash percentage in the pressed bale could be around 2 %, which would result in getting a premium price for the bale.

Economics of Mini Cotton Ginnery

The total capital required [5, 9, 10, 11] for a mini cotton ginnery is estimated to be INR 5.6 million (US $ 0.14 million). The operating cost was estimated on the basis of a full season capacity. The costs for different utilization levels (90, 80, 70, 60, 50 and 40 %) were also calculated. The improved economics of size in the ginnery become evident as plant utilization increases. At full rated seasonal capacities (100 %), the estimated total cost per bale is INR 270.37 (US $ 6.8) as compared to 40 % utilization total cost INR 397.67 (US $ 10) as shown in Table 7.

Break-even point: Two major concern of cotton ginnery are the cost relationship of (1) capacity utilization and (2) total cost of ginnery. Figure 6 shows that at different utilization level fixed cost increases with decrease in utilization, while variable cost decreases with lower utilization level. The total cost curve shows that cost increases with decrease in utilization level. The curve developed for 150 days as maximum working required for 100% utilization. The total cost curve reveals that economics results when mini cotton ginnery operates above the break even point, which is at 70 % capacity utilization level.

Profitability of Mini-Cotton Ginnery

a) Income - The mini cotton ginnery will receive ginning and pressing charges after processing the cotton. The ginnery can charge a higher rate of processing charges for production of a better quality of lint. The assumption of charges and premiums were made on the basis of historical data [6, 11, 12]. The total income for 100 % and 40 % utilization level works out to be at INR 2.7 and 1.6 million (US $ 0.07 and 0.04 million) respectively.

b) Expenses

1) The variable expenses were estimated to increase by 5 % every year.
2) The interest payable on the bank loan was estimated to be 9 %. These rates are subject to change.

c) Economic performance analysis – The profitability and economic performance analysis of mini cotton ginnery was carried out for different interest rates ranging from 9% to 14 % for calculation of the debt/service ratio and a return on investment [11, 21, 22]. The repayment period of the bank loan works out to be 10 years since repayment was considered from the third year of the commencement of ginnery operation. It is found that debt/service ratio varies in the range of 1-3, while rate of return increases gradually from third year at 13 % to 25 % on tenth year of ginnery operation.

CONCLUSIONS

A bale press for a mini-cotton ginnery was designed and tested to study the economic feasibility and operating cost of a complete mini-cotton ginnery at various estimated utilization levels.

The following conclusions have been arrived at:

1) The literature review indicates that
   i) The period of operation of ginnery is estimated to be a total of 150 days in a season ranging from October to April.
   ii) The bales can be pressed with a density of 300 kg/cubic meter for local domestic consumption.
   iii) The desired cotton moisture content for ginning and pressing should be 7.5%.
   iv) The quality of cotton can be better maintained by minimizing the transportation of cotton, and limiting storage time of cotton.
   v) A composite ginnery (having all functions of cotton ginning and bale pressing) should be located in cotton growing areas.
2) The development of mini cotton ginnery is essential for solving the current economic problems related to cotton ginning, pressing, transportation and storage.
3) The non-availability of a low cost, low capacity bale making machine is the main hurdle in developing mini cotton ginnery.
4) The present research work optimizes the parameters and working environment for the pressing operation in a mini cotton ginnery.
5) The literature review indicates that there is no analytical model currently available to predict accurately the force of compression in cotton bale formation. Experiments were planned and executed.
6) The MATLAB and ANN were used to develop model to fit the experimental data. It was observed that the ANN model gives a more accurate and reliable estimation of compressive force.
7) The selected optimal value of the force of compression for an 80 kg, 291 kg/cu.m density bale compressed at 7% moisture level was 5456 kgf.
8) On the basis of optimal value of force of compression, a screw type lint cotton bale making machine was designed and developed. It was found that the press produces a bale of 70 kg weight and of good quality with a density 200 kg/cum. The cost of the experimental press machine was estimated to INR 0.3 million (US $ 7500).
9) The mini cotton ginnery is designed and proposed. The estimated capital investment for a mini cotton ginnery was about INR 6.0 million (US $ 0.15 million) and its profitability and the economic performance is checked. The capacity of the proposed mini cotton ginnery at full utilization level is estimated to be 6000 bales in a season of 150 days utilizing one 8 hour shift per day. This mini cotton ginnery can be located near cotton growing areas.
10) To study the economic feasibility, the plant was designed and its operating cost estimated at various utilization levels. The break-even point was at 70 % utilization. The debt service ratio is about 2 and rate of return is about 20 %.

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Figure 1 Observation being taken during experiment

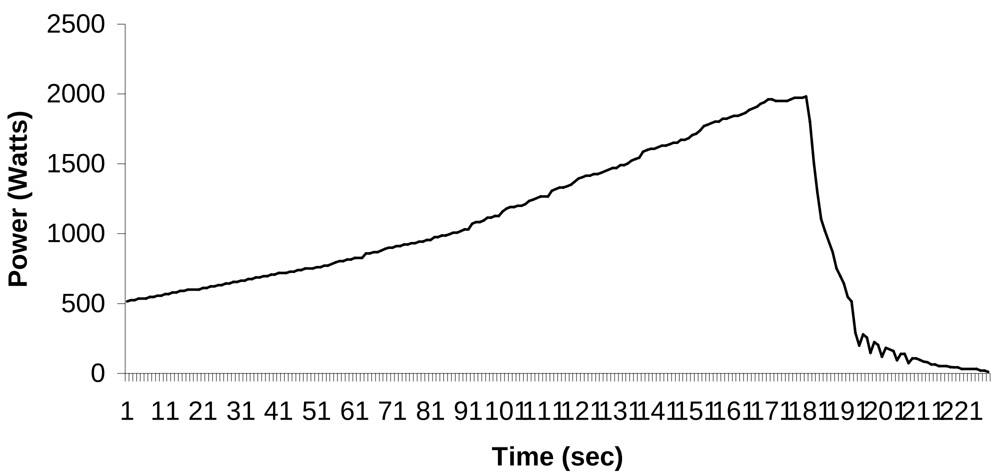

Figure 2 Experimental graph of power vs. time

Figure 3 Mechanical press for a mini cotton ginnery

Figure 4 Compressed bale from the mechanical press

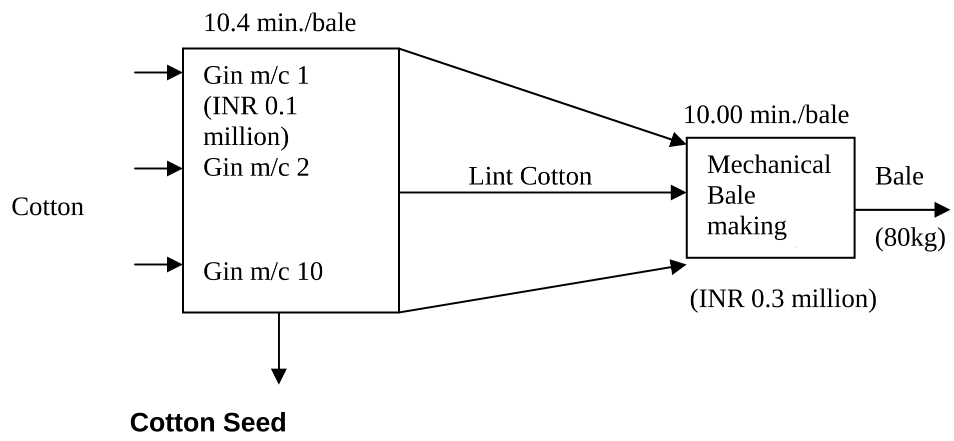

Figure 5 Balanced Process line of Mini Cotton Ginnery

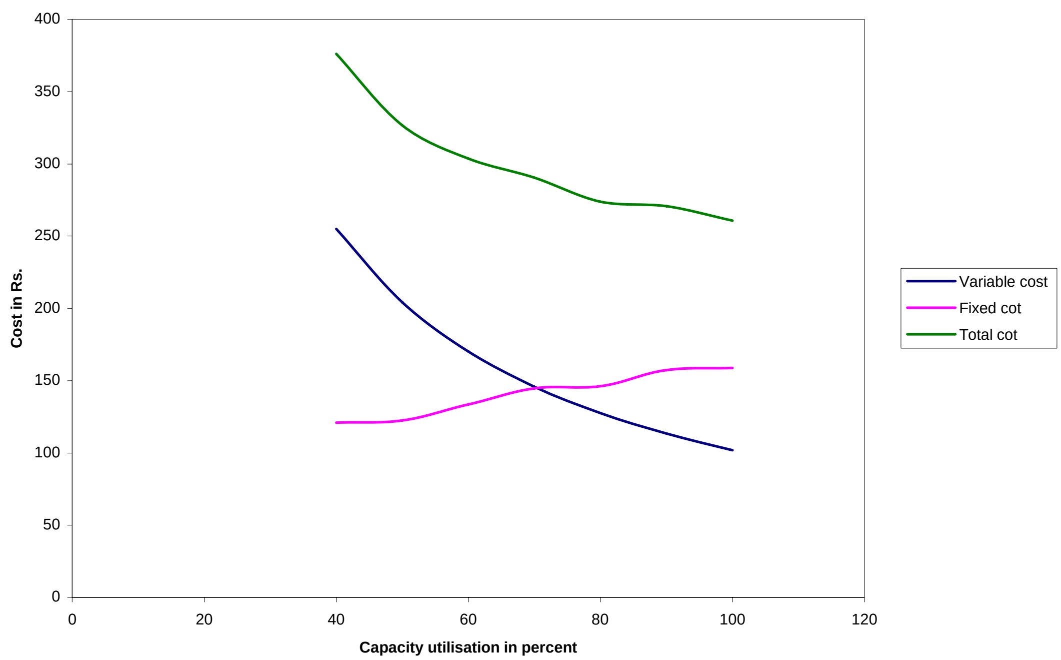

Figure 6 Estimated total cost by capacity utilization

Table 1 Test Range, Test Points and Test Sequence

Sr, No	Dimensionless Ratio (π- Term)	Independent Variable	Test Envelope	Test Points	Test Sequence
1	$\pi_1 = B/L$	Size of box	Constant	Constant	Constant
2	$\pi_2 = M$	Moisture	5%to 9%	5,6,7,8,9	4,2,5,3,1
3	$\pi_3 = gL/V^2$	Speed of screw	Constant	Constant	Constant
4	$\pi_4 = V^2I/L^3W$	Weight of lint cotton	4.63E-07 to 8.34E-07	4.63E-07, 5.21E-07, 5.96E-07 6.95E-07, 8.34E-07.	4,2,5,3,1
5	$\pi_5 = tV/L$	Instantaneous time of compression	Constant	Constant	Constant

Table 2 The experimental data (sample)

WEIGHT	kg. (W)	90	80	70	60	50
Moisture	% (M)	5	7	8	6	9
Vel. of screw	M/sec(V)	0.01745	.01757	0.01755	0.01759	0.01765
Inst. Time	sec. (t)	7.665	3.055	4.275	2.7	0.055
Force	kgf (F)	9210	5511	4401	3528	2346
Energy	kgf-m (E)	4974	1687	1950	1127	23
Density	kg/m3 (ρ)	332	281	246	222	187
Platen travel	cm (S)	27	10.73	15.00	9.50	0.194
Comp. time	sec (T)	15.33	6.11	8.55	5.4	0.11

Table 3 Mean Force of Compression

Mean Force of Compression, kgf				
Weight	Av. Density	EXPT	MATLAB	ANN
50	192	2521.9	2507.2	2527.2
60	225	3151.7	3549.1	3151.4
70	253	4281.75	4235.2	4282.6
80	291	5456.3	4922.4	5456.35
90	325	8514.1	8542.9	8514.1

Table 4 Summary of selected optimum variables for compression of lint cotton

S. No.	Type of Variable	Variable	Optimum vale
1	Independent	Size of bale in mm	1175x480x475
2	Independent	Weight of bale in kg	80
3	Independent	Moisture content in lint cotton, %	7
4	Dependent	Average Force of compression - 80 kg bale in kgf	5578
5	Dependent	Average energy of compression for 80 kg bale in kg-m	1672
6	Dependent	Average density of compressed 80 kg bale in kg/cubic meter	290

Table 5 Specifications of a mechanical press machine

S. No.	Particular	Specification
1	Dimensions of Machine	1.35 x 0.6 x 3.0m
2	Lint filling box size	1.2 x 0.48 x 2.4m
3	Weight of bale	70-90 kg
4	Size of bale	1.2 x 0.50 x 0.60m

Table 6 Specification of Compressed bale

S. No.	Particulars	Specifications
1	Size of bale	1200 x 550 x 500mm
2	Weight	70kg
3	Moisture content	7.2%
4	Density	200kg/cu.m

Table 7 Estimated annual operating cost for a mini cotton ginnery by capacity utilization

Cost Item	Capacity Utilization in percent						
	100	90	80	70	60	50	40
	Estimated cost per bale in INR (US $)						
Total fixed cost	110.06 (2.75)	122.29 (3.05)	137.59 (3.44)	157.23 (3.93)	183.45 (4.58)	220.14 (5.50)	275.16 (6.88)
Total Variable cost	160.31 (4.01)	158.81 (3.96)	147.71 (3.69)	146.21 (3.65)	135.11 (3.37)	124.01 (3.10)	122.51 (3.06)
Total all cost	270.37 (6.76)	281.10 (7.01)	285.30 (7.13)	303.44 (7.58)	318.56 (7.95)	344.15 (8.60)	397.67 (9.94)
Seasonal volume in bales	6000	5400	4800	4200	3600	3000	2400