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Comparative evaluation of energy consumption and interventions to improve energy efficiency of bale presses used in cotton ginneries

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ABSTRACT : Techno economic evaluation of fully automatic up and down packing type of bale presses with special emphasis on energy consumption was carried out to facilitate the cotton ginners' for selection of appropriate bale press. Energy consumption was found to be 2.25, 1.75 and 1.5 units/bale for down packing presses with capacity of 8, 15 and 25 bales/h, respectively. Similarly, for up packing type of bale presses was found to be 1.0 and 0.9 units/bale with capacity of 15 and 25 bales/h, respectively.Energy consumption and cost of operation was found to be higher for down packing presses as compared to up packing for different capacities. Increase in energy consumption and cost of operation was noticed with decreease in capacity. About 40 per cent less energy is required for up packing than down packing presses. About 15 per cent reduction in energy consumption was observed for bale presses with capacity of 25 bales/hr as compared to 15 bales/hr. Up packing type of presses were found to be cost effective by about 10 per cent as comapred to down packing. Interventions were suggested to improve energy efficiency of bale presses.

Key words: Bale press, energy consumption, interventions

Ginning industry in India has over 4000 ginneries (Anonymous, 2003) that processover 300 lakh bales of 170 kg each every year. Last one decade has brought out sea changes in the ginning industry by adopting new technological developments through modernisation. With the continued development in press manufacturing in India, the focus is shifted from the double stage conventional presses to fully automatic either down or up packing, oil hydraulic presses In India presently more than 1000 automatic baling presses are in use. Increased usage of these presses has resulted in reducing the contamination and improving the quality of lint. The safety of the workers is ensured by eliminating the drudgery involved in the operation of bale press (Anonymous, 2002).

Bale packaging is the final step in processing cotton at ginneries. (Antony,1994). A majority of the bale presses in India are conventional double stage type. Due to advent of modernization automatic single stage presses are becoming more popular in India. These presses are either single box or double box, up packing or down packing type, revolving and fixed, door less and door type, mechanical and hydraulic tramper, oil and water hydraulic presses etc. These presses have many advantages over the existing conventional presses. These presses also have an auto trampling facility, which reduces the requirement of labourers and avoids contamination too (Arude, *et al.,* 2008)

The pressing capacity of bale presses found to vary from 8 to 35 bales/h. The selection of the appropriate bale press has become a difficult task for the ginners due to variation in design, make, model, capacity and techno economic feasibility. The techno economic feasibility is governed by many factors such as functional suitability of the bale press, design features, initial and operating cost and after sale service by the manufacture (Sharma, 2005) Ginners don't have the necessary information with regard to technical as well as economic aspects of the bale presses. Different makes and models of presses have their own techno-economic constraints as well as advantages.

Operating cost is largely affected by the total power requirement and energy consumption per bale. (Gerald and Gergely 2009). Each component of a bale press performs a specific function. The major unit operations in bale packing are pressing, tramping, tying, cooling, lint feeding and conveying. The selection of sizes of electric motors is rather limited, so it is often difficult to match connected horse power to actual load requirements. To be on safer side many ginners have installed larger motors than actually needed throughout the gin plant.

Appropriate selection of bale press is largely governed by the energy consumption and cost of operation/bale. Hence the need was felt to evaluate energy consumption of fully automatic up and down packing type of bale presses and facilitate the cotton ginnersfor appropriate selection of a bale press and with measures for improving energy efficiency.

MATERIALS AND METHODS

The fully automatic down and up packing type bale presses were selected for the experimentation. Down and up packing type automatic presses consist of a battery condenser, lint slide, lint feeder, tramper, bale press box, hydraulic ram and cylinder, hydraulic power pack, hydraulic fittings and an electrical control panel. In down packing type presses the hydraulic ram and press box are located above the ground level and pressing is carried out by the downward movement of the hydraulic raminside the press box. While in up packing type of presses, the hydraulic ram and press box are located below the ground level and pressing is carried out by upward movement of the hydraulic ram inside the press box. The components are same for both down and up packing type of presses.

Experimental trials were carried out during the year 2011-2012 and 2012-2013 in commercial ginneries that were modernised as per norms of Technology Mission on Cotton Mini Mission IV (TMC MM IV) of Government of India.Three models of automatic down packing type bale press *viz.,* DB1, DB2 and DB3 with capacity of 15, 25 and 8 bales/h, respectively were studied. Four models of automatic up packing type bale press *viz.,* UB1, UB2, UB3 and UB4with capacity of 12, 14, 15 and 25 bales/h, respectively were studied.The characteristic features of these presses were noted.

Different unit operations involved in cotton bale pressing were studied. The power requirement and energy consumption for different unit operations was measured. The time motion study of each unit operation was carried out. The Clamp on Power Meter (CW240) manufactured by Yokogawa, Japan was used for measurement of energy consumption. The data was collected on power required, energy consumption, current, voltage, and power factor for each unit operation. Data analysis was carried out to find out the energy consumption/bale. The comparative analysis of energy consumption was carried out and interventions were suggested to improve the energy efficiency.

RESULTS AND DISCUSSION

Power requirement: The power requirement of bale presses of individual electric motors for carrying out specific unit operations was measured. Separate electric motors were used for hydraulic ram pressing, tramping, oil circulation, cooling, box tuning and tying operations. The power requirement for automatic down and up packing bale presses respectively are shown inTable 1 and 2. Power requirement was found to be comparatively more for down packing type presses than up

Table 1. Power requirement for automatic down packing type bale press

Motor/Press	Power (HP)		
	DB1	DB2	DB3
Hydraulic ram	50	75	40
Tramper	20	30	—
Oil circuit	2	5	3
Cooling	1	2	2
Turning	2	—	—
Compressor	—	3	2
Bale handling system	—	4	—
Total	**75**	**119**	**47**
Capacity (bales/h)	15	25	8

Table 2. Power requirement for automatic up packing type bale press

Motor/Press	Power (HP)			
	UB1	UB2	UB3	UB4
Hydraulic ram	40	40	50	60
Tramper	15	15	13	15
Oil circuit	1	—	—	—
Cooling	—	—	—	—
Turning	1	3	3	3
Compressor	—	—-	3	2
Total	**57**	**58**	**71**	**80**
Capacity (bales/h)	12	14	15	25

Time motion study of different unit operations: During operating cycle while baling different unit operations were performed. It includes downward and upward movement of hydraulic ram, downward and upward movement of press box, tying of bale, tramping and turning of the box. The time required to perform each unit operation and for pressing a bale was measured. The time required for each unit operation significantly affects the energy consumption and the actual capacity of bale press. The movement of hydraulic ram is controlled automatically. The time required for individual unit operations for down and up packing bale presses are depicted inTable 3 and 4.

Table 3. Time requirement for unit operations in automatic down packing type press

Operation	Time (sec)		
	DB1	DB2	DB3
Ram down	60	45	17
Box up	10	10	—
Tying	80	30	70
Box down	5	10	—
Ram up	30	20	17
Turning	15	10	—
Idle	60	19	236
Door open	—	—	10
Door close	—	—	10
Total	**260**	**144**	**360**
Capacity (bales/h)	15	15	25

Idle time is the time lag between turnings of press box till start of pressing of next bale excluding turning time. Tying time is the actual time required for strapping the bale. Time required for these operations affects the pressing capacity and energy consumption.The idle and tying time was found to vary between 20 to 30 percent of the total time/bale for different presses thus affecting the actual pressing capacity and energy consumption/bale.

Table 4. Time requirement for unit operations in automatic up packing type press

Operation	Time (sec)			
	UB1	UB2	UB3	UB4
Ram up	20	120	58	60
Door open	5	5	12	5
Tying	110	60	75	32
Door close	5	5	12	5
Ram down	20	10	22	20
Turning	15	15	8	8
Idle	140	50	71	20
Total	**315**	**265**	**258**	**150**
Capacity (bales/h)	12	14	15	25

Energy consumption: Energy consumption/bale (170 kg each) for selected presses for hydraulic ram, tramper and other motors were measured. During the process of compressing the lint to form a bale, large variations in the load was observed. Initially the load was accounted for the frictional force and for operation of the mechanical transmission system. During the pressing operation the load was found to increase non linearly. For the initial half of the travel of the hydraulic ram the load was approximately 25 per cent of the maximum load. During the last phase of compression, the load increased very steeply. The energy consumption/bale for pressing was determined by measuring the energy for one complete cycle of pressing operation right form the starting of the downward movement of hydraulic ram till the start of next pressing cycle. The parameter *viz.*, power, power factor, current and voltage were measured during the complete cycle.

Energy consumption/bale for down packing and up packingfor unit operations such as pressing, tramping and others are shown in Table 5. The average energy consumption/ bale for pressing operation of hydraulic ram for down packing press was found to be more compared to up packing type presses. The energy consumption/bale for tramping operation was measured over a period of one complete cycle to

Table5. Energy consumption for different unit operations in different types of presses

Press model	Capacity (bales/h)	Power (HP) Energy Consumption (kwh/bale)							
		Pressing		Tramping		Other		**Total**	
		HP	kwh/bale	HP	kwh/bale	HP	kwh/bale	**HP**	**kwh/bale**
DB1	15	50	1.10	20	0.45	5	0.20	**75**	**1.75**
DB2	25	75	1.005	30	0.28	14	0.20	**119**	**1.48**
DB3	8	40	0.86	40	1.20	7	0.20	**47**	**2.26**
UB1	12	40	0.85	15	0.25	2	0.10	**57**	**1.20**
UB2	14	40	0.47	15	0.35	3	0.13	**58**	**0.95**
UB3	15	50	0.620	15	0.25	6	0.15	**71**	**1.02**
UB4	25	60	0.62	15	0.25	5	0.15	**80**	**0.90**

press a bale including the idle period. The number of tramper strokes required for tramping the lint to from a bale of about 170 kg each was found to vary significantly because of non-uniform feeding to charging box of the press.

Energy consumption was found to be less for up packing than down packing type bale press. It was noticed that the hydraulic ram motor of up packing type press was running during pressing operation only and it was stopped during the rest period of baling cycle. In down packing type bale press the hydraulic ram motor was running throughout the baling cycle. It was found to be under loaded for about 50 per cent time of baling cycle. Energy consumption was found to be less for pressing operation in up packing than down packing type bale press.

The comparative assessment of capacity, power and energy consumption/ bale for different types of presses is depicted in Table 6. Energy consumption/ bale was found to be less for higher capacity presses than lower capacity presses. Among the same capacity presses the energy consumption/ bale was found to be less for up packing type of presses.

Table 6. Comparative assessment of capacity, power and energy consumption of different bale presses

Press model	Capacity (bale/h)	Power (HP)	Energy (kwh/bale)
DB1	15	75	1.75
DB2	25	119	1.50
DB3	8	47	2.25
UB1	12	57	1.20
UB2	14	58	0.95
UB3	15	71	1.02
UB4	25	80	0.9

Cost economics: Cost of operation/bale for different types of bale presses with capacity 8, 15 and 25 bales/h was calculated and comparative analysis was carried out. Cost of operation/bale was found to be Rs. 195, 170 and 246 for down packing type presses with capacity of 15, 25 and 8 bales/h. Cost of operation/bale was found to be Rs.174 and 157 for up packing presses with capacity of 15 and 25 bales/h.

Comparative analysis of energy consumption and cost of operation: The comparative analysis of energy consumption and cost of operation for presses with capacity of 15, 25 and 8 bale/h is shown in Table 7. Energy consumption and cost of operation was found to be higher for down packing type presses as compared to up packing for different capacities. Increase in energy consumption and cost of operation was noticed with decreease in capacity of bale presses. Bale presses of either down or up packing with 15 bales/h capacity were found to be more widely used in ginneries. About 40 per cent less energy is required for up packing than down packing presses. About 15 per cent reduction in energy consumption was observed for bale presses with capacity of 25 bales/h as compared to 15 bales/h. Up packing type of presses were found to be cost effective by about 10 per cent as comapred to down packing.

Interventions to improve energy efficiency of bale presses: Energy efficiency means the utilisation of energy in the most cost effective manner to carry out a process or to provide a service, whereby energy waste is minimized and the overall consumption is

Table 7. Comparative analysis of energy consumption and cost economics

Particulars	Press capacity (bales/h)		
	15	25	8
Down packing			
Power (HP)	75	119	50
Energy consumption (Unit/bale)	1.75	1.5	2.25
Fixed cost (Rs/bale)	58	470	79
Operational cost (Rs/bale)	137	123	167
Total cost of operation (Rs/bale)	**195**	**170**	**246**
Up packing	58	80	—
Energy consumption (Unit/bale)	1.0	0.9	—
Fixed cost (Rs/bale)	44	38	—
Operational cost (Rs/bale)	130	119	—
Total cost of operation (Rs/bale)	**174**	**157**	**—**

reduced. Efficiency in the utilization of energy is largely determined by selection of component, sizes and combinations of unit operations while designing bale press and by management practices during operation. Horsepower requirement can be minimized when the bale press is designed by careful selection of component, sizes and combinations of unit operations. After the installation of baling presses in ginneries nothing much could be done to change or modify the design of press to improve the energy efficiency.

Mismatching between the ginning and pressing capacity was seen in a most of the gin plant. Bale presses installed are over capacity with respect to the actual ginning capacity. Now a days trend is towards the on line ginning and pressing activities wherein ginned lint is directly transferred to the press through conveying systems. Even if the ginning and pressing capacity matches, non-uniform feeding of lint to the press is a cause of concern. This prevents the press to operate to its designed capacity. It results in decreased production and increased operating cost due to increased energy consumption. Hence uniform feeding of lint as per the recommendation of manufacturer needs to be ensured.

Hydraulic ram motor of up packing type of press stops after its upward movement while downward movement of the ram is governed by the self weight and gravitational force on the ram. But in case of down packing type of press the hydraulic ram motor runs through out the baling cycle. Motor found to be under loaded for about 50 per cent of its operating time resulting in poor power.

Energy consumption was found to be less for pressing operation in up packing than down packing type bale press. Energy efficiency of down packing press can be improved by improving the power factor of the motor employed for this operation and by minimizing time of operating cycle during which ram motor remains under loaded. It could also be achieved by providing the suitable mechanism for stopping the motor at no load condition during the operating cycle. High power factor has direct benefit of energy saving. Use of double coil and multiple motors for performing different unit operation and avoiding use of oversized motors would improve the energy efficiency.It is advisable to keep the total connected load as near actual load requirement as practicable for efficient operation.

Tramper operates through out the baling cycle except during the turning of press box. To have minimum energy consumption, tramping operation should be finished before the pressed bale is ejected out. Idle time should be avoided or minimized. Reduction in idle time will increase the pressing capacity and will reduce the energy consumption/bale. Number of tramping strokes should be kept minimum as possible and should be optimized. During idle time ram motor remains in operation hence affecting the energy consumption. For improving energy efficiency tying time needs to be reduced. Double trigger gun can be used for strapping operation. Use of automatic tying machines can reduce the tying time. Reduction in tying time will increase the capacity of bale press. The time required/bale for entire operating cycle should be as low as possible which will ensure the reduction in tramping time. However minimizing idle, tying and tramping time and ensuring uniform feeding to press box may improve the energy efficiency at least by 20 per cent.

CONCLUSIONS

1. Energy consumption and cost of operation was found to be higher for down packing presses as compared to up packing presses.
2. About 40 percent less energy is required for up packing than down packing presses. About 15 per cent reduction in energy consumption was observed for bale presses with capacity of 25 bales/h as compared to 15 bales/h.
3. Up packing type of presses were found to be cost effective by about 10 per cent as comapred to down packing
4. Efficiency in the utilization of energy is largely determined by selection of component, sizes and combinations of unit operations while designing bale press and by management practices during operation.
5. Minimizing idle, tying and tramping time and ensuring uniform feeding to press box may improve the energy efficiency by 20 per cent.
6. Energy efficiency would be improved by providing a mechanism to stop the hydraulic ram motor of down packing press after pressing operation.

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