Axial Flow Pre-Cleaner for on Farm Cleaning of Cotton

by
V. G. Arude
Scientist (Sr. Scale) (FMP),
Central Institute for Research on Cotton Technology,
ICAR, Mumbai-400019
INDIA

T. S. Manojkumar
Program Coordinator (KVK)
and Scientist (Sr. Scale) (ASPE),
Central Plantation Crops Research Institute,
ICAR, Kasargod,
INDIA

S. K. Shukla
Scientist (Sr. Scale) (Mech. Engg.),
Ginning Training Centre of Central Institute for Research on Cotton Technology,
ICAR, Nagpur-440023,
NDIA

Abstract

A single cylinder cotton pre-cleaner based on axial flow principle was designed and developed. The developed axial flow pre-cleaner consists of different assembly's viz. cylinder, grid bar, top cover, feeder, and mainframe and power drive assembly. The pre-cleaner of 1,200 mm cylinder length and overall peripheral cylinder diameter of 443.4 mm was fabricated. It was observed that the principle of axial flow could be effectively used for pre-cleaning of cotton. The machine was found to remove effectively the large trash particles, sand, dust, kawadi etc. The capacity of the machine was found to be 650 kg/h. The cylinder with diameter of 203.2 mm and spike length of 114.6 mm was found optimum. The better cleaning efficiency and optimum output was observed at cylinder speed of 225 rpm. The cleaning efficiency of the machine was found between 30-40 %. The machine found to bring down the trash content by about 0.8-1.5 %. The fibre quality parameters viz. fibre length, uniformity ratio, micronaire and strength were unaffected by the axial flow pre- cleaner. The improvement in the colour grade of the cotton was observed. The cost of operation per hour and per tonne was observed to be Rs. 44 and Rs. 67.5 respectively. Additional income to farmer per tonne was found to be Rs. 540. It was observed that axial flow pre-cleaner could be effectively used for on farm cleaning of cotton to enhance farm income.

Introduction

The Indian cotton are considered to be trashy despite being hand picked and being contaminated by wide range of impurities gathered during post harvest handling till it reaches the spinning mills. In the process of picking, laborers pick the cotton with large amount of trash such as leaves, stems, bracts and immature and unopened bolls. The cotton is sold in the market based on its grade. The market value of cotton is decided by the quality and purity of its fibres. The trash content in the cotton is the predominant parameter in deciding the value of the cotton. Thus fetching good price in the market, the baled cotton should contain minimal trash and be free from contamination (Patil *et al.*, 2006). Due to high trash content in the cotton farmer fetches lower prices. The farmers may realize high prices for their cotton, if they clean it and sell it into the market. But the suitable pre-cleaner which can be used by the farmers is not available.

If pre-cleaning is not done trash particles are made to adhere to the fibres during the high pressure baling process. Subsequent removal of trash in the blow room at spinning mills becomes difficult, expensive and detrimental to fibre quality. Pre-cleaning is necessary to improve gin stand performance and lint quality. Cylinder cleaners are used for removing finely divided particles and for opening and preparing the seed cotton for the drying and extraction processes (Mayfield et. al., 1983). The spiked cylinder pre-cleaners works on the principle of feeding the cotton longitudinally i.e. along the length of the cylinder. The cleaning efficiency of cylinder pre-cleaner mainly depends on the number of cylinder employed. Use

of pre-cleaners in Indian ginning industry is increasing day by day.

Cylinder cleaners are either inclined cleaners or horizontal cleaners depending on the arrangement of the cylinder. Inclined pre-cleaners are currently manufactured in widths of 1.2-2.4 m with rated capacities of 3.5-6.0 tonne seed cotton/h. Inclined pre-cleaners are employed with 4 to 6 cylinders depending on the cleaning efficiency required. They are of high capacity, costlier and require more power. These are not affordable to farmers.

The trash removal efficiency of cylinder cleaners is generally low. However they are not used alone but are used in combination with other machines. Studies using both machine picked and machine stripped cotton have shown that the total trash removal efficiency of a six cylinder inclined cleaner with grid rods generally ranges from 10-40 % (Cocke, 1972; Read, 1972; Baker *et al.*, 1982). These efficiencies, however, were based on the test cotton's total trash content. Fine trash removal efficiencies as high as 50-55 % has been reported for both grid –rod and screen type inclined cleaners when processing stripped and picked cotton (Laird *et al.*, 1984, Anthony 1990). Efficiencies are highest for high trash content cottons (Franks and Shaw. 1959).

Cleaning machinery is subjected to considerable wear from the large volumes of trash and soil particles contained in the seed cotton. Also seed cotton occasionally contains rocks, scrap metal, large woody debris or other foreign objects that can damage various machine components. The removal of trash reduces wear and tear of gin parts (Baker *et al.*, 1994). Fibre quality remains unaffected by the use of pre-cleaner (Shukla *et al.*, 2006).

These present pre-cleaners which are bigger in size and more in capacity are not feasible for the on farm use. The farmers need compact pre-cleaners with much lesser output and with reduced energy consumption. The pre-cleaning machine can be made more compact and suitable to farm use with lesser power requirement by employing the principle of axial flow feeding of cotton to the cylinder. Therefore a single cylinder cotton pre-cleaner based on axial flow principle for the use of farmers was developed.

Materials and Methods

A single cylinder cotton pre-cleaner based on axial flow principle was designed and developed at the Ginning Training Centre of Central Institute for Research on Cotton Technology (CIRCOT), Nagpur. The three dimensional drawings and two dimensional draftings of each machine component, subassemblies and whole machine were prepared. The single cylinder axial flow pre-cleaner was fabricated and tested. The performance of the machine was evaluated to find out the applicability of the principle of axial flow for pre-cleaning of cotton. The developed machine was tested at different cylinder speeds and cottons. The cylinder speed was maintained between 175-400 rpm with the help of variable frequency drive. The output capacity, trash removal efficiency, reduction in trash content and effect on cotton fibre quality was studied. The cotton samples were tested on High Volume Instrument (HVI-900) for measurement of fibre quality parameters. The techno-economic feasibility of the developed machine was studied. The experimental trials were carried out to optimize the machine parameters as well their effect on cotton quality.

Independent Variables

The independent variables studied were as follows.

1) Grid size

Two grids were selected (1) Grid bar spacing 12 mm, (2) Grid bar spacing 10 mm.

Spacing between grid bars and spike tip: (1) 25 mm (2) 35 mm (3) 45 mm

2) Cylinder speed

Seven cylinder speed were selected: 175, 200, 225, 250, 300, 350 and 400 rpm.

3) Cottons

Three cotton varieties were selected: Cotton A, Cotton B and Cotton C.

4) Cylinder configuration

Three cylinder configurations were selected and named as C_1, C_2 and C_3 (**Table 1**).

Dependent Variables

The independent variables studied were output capacity, trash removal rate, cleaning efficiency, fibre quality and energy consumption.

Design and Fabrication

A prototype of cylinder type cotton pre-cleaner based on axial flow principle was designed and developed. The developed axial flow pre-cleaner consists of different assembly's viz. cylinder, grid bar, top cover, feeder and mainframe and power drive assembly. The pre-cleaner of 1,200 mm cylinder length and overall peripheral cylinder diameter

Table 1 Specifications of cylinder configurations

Parameter	C_1	C_2	C_3
Cylinder diameter (mm)	152.4	203.2	250.4
Spike length (mm)	140	114.6	89.2
Number of rows of spikes	6	8	10
Spikes on each cylinder	93	124	155
Spacing between spikes (mm)	75	75	75
Overall cylinder diameter (mm)	443.6	443.6	443.6
Cylinder length (mm)	1,200	1,200	1,200

of 443.4 mm was fabricated. Main components of a cylinder assembly were cylinder made out of a seamless pipe, cylinder shaft and spikes. Spikes were inserted in holes made on the periphery of the cylinder and welded from inside of the cylinder. The angular distance between each row was maintained properly. The adjustable semicircular grid made up of grid bars spaced at specified distance between the two grid bars was provided underneath the cylinder. Proper clearance was maintained between the tip of the spikes and the grid bars. The top cover assembly was developed and was provided with suitable inlets and outlets. Guide plates were fabricated and mounted at an inclination on the inside surface of the top cover to guide the movement of the seed cotton along the axis of the cylinder. Proper clearance was maintained between the tips of the spikes to the outer face of the guide plates. The feeder assembly consisting of counter rotating flighted roller was designed and developed for controlled feeding of the seed cotton. Main frame of the machine was fabricated out of channels and angles. The suitable drive arrangement was provided to drive the spiked cylinder and the feeder. The trash chamber was provided below the grid to collect the separated trash. Doors were provided on either side of the chamber for easy disposal of the trash. Schematic diagram of the developed axial flow cotton pre-cleaner is shown in **Fig. 1**. a pictorial view of the developed machine under testing is shown in **Fig. 2**.

Principle of Operation

Seed cotton was fed at one end of the spiked cylinder through feeder. It moved axially along the length of the cylinder as it rotated. The rotational motion of the cylinder draws the cotton inside and agitates it across the grid surfaces. The movement of the seed cotton along the axis of the cylinder was controlled by mounting specially designed guide plates on inside surface of top cover. These plates were mounted at a certain inclination to the axis at a certain distance such that it forms an open chamber. Seed cotton enters the machine at one end and moves from one to the other chamber along the axis of the same cylinder and gets discharged at the other end after cleaning. Foreign matter gets dislodged from the cotton by the agitating and scrubbing action of the cylinders and falls through grid bars provided underneath the spiked cylinder. The trash gets accumulated in the trash chamber. In case of axial flow cotton pre-cleaner if four guide plates are mounted on the machine, the seed cotton moves in a spiral path around and between the spiked cylinder and grid surfaces four times. It implies that in axial flow single cylinder pre-cleaner, cleaning efficiency would be equivalent to that of the four cylinder cleaner which employs the principle of feeding along the length of the cylinder.

Results and Discussion

Testing of the developed machine was carried out at Ginning Training Centre of Central Institute for Research on Cotton Technology, Nagpur. It was found working satisfactorily. It was observed that the principle of axial flow could be effectively used for pre-cleaning of cotton.

Optimization of Crop-Machine Parameters

The experimental trials were carried out to optimize the machine parameters as well their effect on cotton quality.

Optimizations of Grid Size

Spacing between grid bar and spike tip

Cleaning trials were conducted with different spacing between grid bar and spike tip. It was observed that at spacing of 35 and 45 mm, the cotton was getting accumulated under the cylinder which was found affecting the trash removal. The spacing of 25 mm was found to be optimum as cotton was not getting accumulated under the cylinder and trash removal was smooth. Therefore spacing of 25 mm between grid bars and spike tip was selected for further trials.

Spacing between Grid Bars

For optimiza-

Fig. 1 Schematic diagram of axial flow cotton pre-cleaner

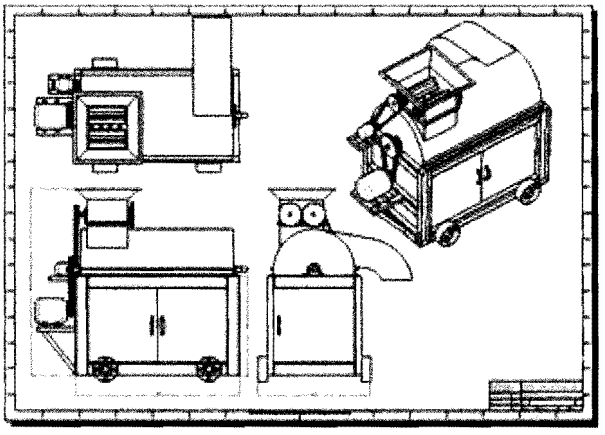


Fig. 2 A pictorial view while testing of axial flow pre-cleaner

tion of grid bar to bar spacing, spacing between grid bar and spike tip was maintained at 25 mm. The grid bar diameter was 10 mm. Three different types of grids were used. The 12 mm grid size observed to be oversized as the good cotton was passing through it along with the kawadi (immature and insect affected cotton) and trash. Another grid made up of a combination of 10 mm and 12 mm grid spacing was used. The grid with 10 mm spacing was used under first half portion of the machine and grid with 12 mm spacing was used under second half portion of machine from inlet to outlet respectively. In this grid also some good cotton was observed to pass through along with the trash. The 10 mm grid size was observed to remove the kawadi and trash effectively without allowing good cotton to pass through it. Therefore the spacing of 10 mm between the grids bars was selected for the further trials.

Table 2 Effect of cylinder speed on fibre quality parameters

Cylinder Speed, rpm	Fibre Length, mm	Uniformity Ratio, %	Fineness, Mic	Strength, g/tex
	Un-cleaned/ Cleaned			
175	29.5/29.4	46/46	3.4/3.4	20.9/21.4
200	28.4/28.1	47/47	3.3/3.2	20.8/20.2
225	29.6/29.8	46/46	3.2/3.4	23.0/22.8
250	28.9/29.6	46/45	3.7/3.6	23.0/23.4
300	28.6/29.9	46/47	3.7/3.7	21.0/21.5
350	27.6/28.9	47/46	3.5/3.5	21.1/22.2
400	29.2/30.4	48/47	3.6/3.5	23.7/23.6

Optimization of Cylinder Configuration

Three cylinder configurations were selected and named as C_1, C_2 and C_3. The output capacity, trash removal rate and cleaning efficiency was found out .The effect of cylinder configuration on fibre quality was determined. Three cottons as Cotton A, Cotton B and Cotton C and seven cylinder speeds were used.

Effect of Cylinder Speed on Output Capacity of Machine

The output capacity of the machine was found to increase with the increase in cylinder speed for all three cottons (**Fig. 3**, **Fig. 4** and **Fig. 5**). The output capacity was found to vary with cylinder configuration. Output capacity of the machine was observed better for cylinder C_2 compared to C_1 and C_3 (**Fig. 6**). Output capacity of machine with cylinder C_2 and for cotton C was observed to vary from 615 to 1,075 kg/h for the cylinder speed between 175-400 rpm. Similarly output capacity of machine with cylinder C_2 for cotton A and B was observed to vary from 655 to 1,029 kg/h. and from 600 to 1,108 kg/h respectively. The cylinder C_2 was found to be optimum in terms of output capacity of the machine. At cylinder speed of 225 rpm the output capacity of the machine was found between 650-758 kg/h for different cottons.

Fig. 3 Effect of cylinder (C_1) speed on output capacity

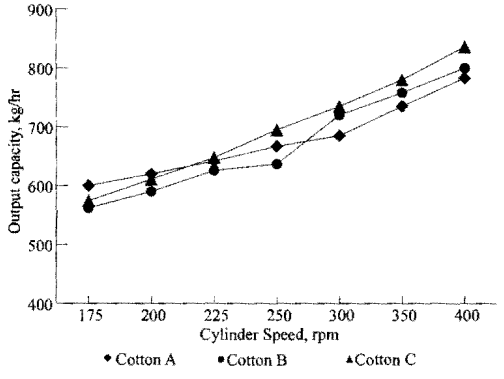


Fig. 4 Effect of cylinder (C_2) speed on output capacity

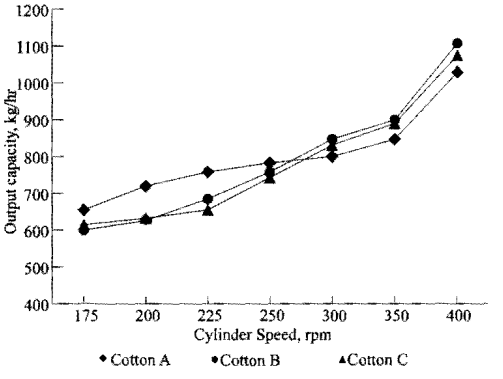


Fig. 5 Effect of cylinder (C_3) speed on output capacity

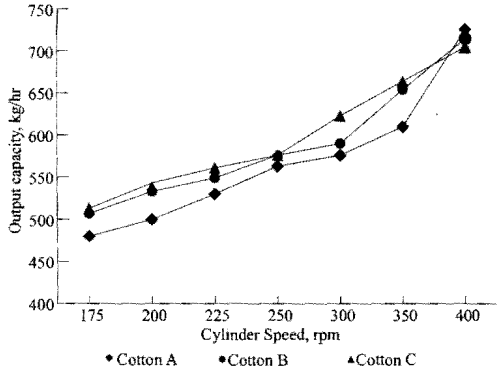
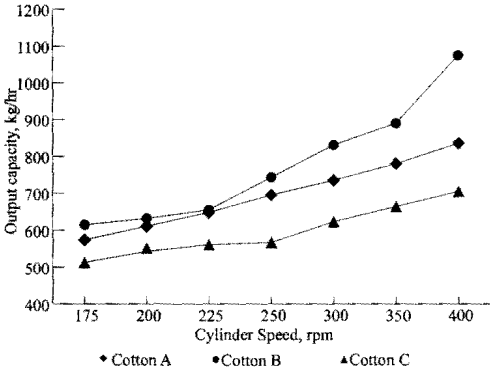


Fig. 6 Effect of cylinder speed and configuration on output capacity for cotton C



Effect of Cylinder Speed on Trash Removal

The machine

Table 3 Effect of cylinder speed on short fibre content and colour grade

Cylinder speed (rpm)	SFI (%)	Rd	+b
	Un-cleaned/Cleaned		
175	8.6/7.8	84.1/84.6	9.17.9
200	9.6/7.8	84.2/85.3	8.4/6.8
225	8.3/7.8	83.0/84.6	8.9/7.9
250	7.6/7.4	84.6/84.8	9.4/8.1
300	8.6/6.7	82.1/84.0	9.4/8.6
350	9.6/7.5	83.5/84.2	9.0/8.6
400	7.1/7.0	82.3/82.7	8.2/7.5

was found to remove effectively the large trash particles, sand, dust, kawadi etc Trash removal was observed to decrease with increase in cylinder speed for all cylinders. Trash removal was observed higher for cylinder C_2 compared to C_1 and C_3 (**Fig. 7**). **Fig. 8** shows the effect of cylinder speed on trash removal for cylinder configuration C_2. The trash removal rate was observed to be higher at lower cylinder speed for all the cylinders. The initial trash content for cotton A, cotton B, and cotton C was 2.5 %, 3.0 % and 4.0 % respectively. The machine was found to bring down the trash content by 0.8-1.5 %.for different cottons for cylinder C_2 at 225 rpm. The cleaning efficiency of the developed pre-cleaner was found between 30-40 %. A pictorial view of cleaned cotton obtained from axial flow pre-cleaner is shown in **Fig. 9**.

Fig. 7 Effect of cylinder speed and configuration on trash removal for cotton C

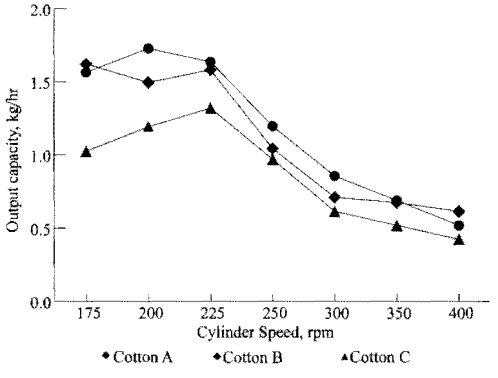
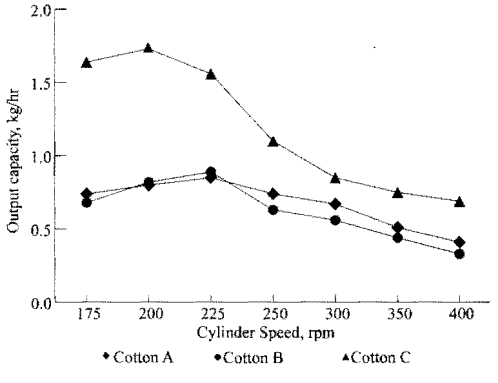


Fig. 8 Effect of cylinder (C_2) speed on trash removal for different cottons

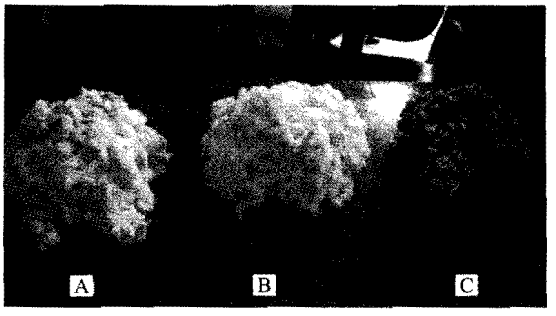


Effect of Axial Flow Pre-Cleaner on Fibre Quality Parameters

Fibre quality parameters such as fibre length, uniformity ratio, micronaire and strength were found unaffected by the use of developed pre-cleaner (**Table 2**). The entanglement of fibres after cleaning was observed at cylinder speeds of 250 rpm and above for all three cylinder configurations. The entanglement of fibres was not observed at cylinder speed below 225 rpm for all three cylinders. The entanglement of fibres results in nep formation which is undesirable. The degree whiteness of the cleaned cotton was found to be improved considerably and yellowness found to be deceased. The short fibre content was found to be lesser in cleaned cotton compared to un-cleaned cotton (**Table. 3**). The overall improvement in visual grade and appearance of the cleaned cotton was noticed.

The cylinder C_2 was observed to be optimum in term of output capacity and trash removal as compared to cylinder C_1 and C_3. Hence based on output capacity, trash removal and fibre quality parameters, the overall performance of the cylinder C_2 at 225 rpm speed was observed to be better compared to other cylinders and other speeds. The optimum output capacity of the machine was found to be 650 kg/h. The machine found to bring down the trash content by about 0.8-1.5 % depending on the initial trash content. The cleaning efficiency of the machine was found to be 30-40 %. Therefore developed machine with cylinder configuration C_2 was recommended with a cylinder speed of 225 rpm.

Fig. 9 A view of cleaned cotton from accia flow pre-cleaner, A-Un-cleaned cotton, B-Cleaned cotton, C-Trash



Energy Consumptions

The axial flow pre-cleaner was provided with 2 hp 3 phase motor for driving cylinder and 0.5 hp motor for driving feeder. The energy required for operating the machine was found to be 1kw/h at cylinder speed of 225 rpm.

Cost Economics of Axial Flow Pre-Cleaner

The assessment of techno-economic feasibility was carried out based on the findings and some basic assumptions. The cost of the machine calculated to be Rs. 75,000/-.

Premium on sale of cleaned cotton of Rs. 1000 per tonne was expected. The cost of operation per hour and per tonne was observed to be Rs. 44 and Rs. 67.5 respectively. Additional income to farmer per tonne was found to be Rs. 540. The rate of hiring of machine per tonne of cotton was assumed to be Rs. 100 per tonne. The custom hiring charges was calculated to be about Rs. 109 per hour (**Table 4**).

Conclusions

The single cylinder axial flow cotton pre-cleaner was designed and developed. The overall performance of the machine was found to be satisfactory. It was found that the principle of axial flow could be effectively used for pre-cleaning of cotton. Cylinder configuration (C_2) of 203.2 mm cylinder diameter and spike length of 114.6 mm was found optimum. The optimum cylinder speed was found to be 225 rpm. The capacity of the machine was found to be 650 kg/h. The machine was found to remove effectively the large trash particles, sand, dust, kawadi etc. The machine found to bring down the trash content by about 0.8-1.5 % depending on the initial trash content. The cleaning efficiency of the machine was found to be 30-40 %. The developed machine was not found to affect the fibre qulity parameters such as fibre length, strength and fineness. The degree of whiteness of lint was improved considerably resulting in grade improvement. The cost of operation per hour and per tonne was observed to be Rs.44 and Rs. 67.5 respectively. Additional income to farmer per tonne was found to be Rs. 540. It was observed that axial flow pre-cleaner could be effectively used for on farm cleaning of cotton to enhance farm income.

Table 4 Cost economic of axial flow pre-cleaner

Particulars	Values (Rs.)
Initial cost of machine	75,000/-
Cost of operation per h	44
Cost of operation per tonne of cotton	67.5
Monetary loss per tonne after pre-cleaning due to trash removal	390
Expenditure per tonne after pre-cleaning	460
Premium for cleaned cotton per tonne	1,000
Profit per tonne of cleaned cotton	540
Profit per hour of machine operation	351
Custom hiring of machine	
Rate of hiring of machine per tonne of cotton	100
Rate of hiring per hour	109
Returns per hour to farmer after hiring	242
Earning of machine owner per hour	65
Earning of machine owner per day (8 hours)	520

REFERENCES

Anthony, W. S. 1990. Performance characteristics of cotton ginning machinery. Transactions of the ASAE, 33, 1089-1098.

Baker, R. V., P. A. Boving, and J. W. Laird. 1982. Effects of processing rate on the performance of seed cotton cleaning equipment. Transactions of the ASAE, 25, 187-192.

Baker, R. V., W. S. Antony, and R. M. Sutton. 1994. Seed cotton cleaning and extracting. Cotton Ginners Handbook. U.S. Department of Agriculture. Agricultural Research Service, Agricultural Handbook Number, 503, 69-90.

Cocke, J. B. 1972. Effect of processing rates and speeds of cylinder type pre-cleaners on ginning performance and cotton quality. U.S. Department of Agriculture. Agricultural Research Service; ARS, 42, 199.

Franks, G. N. and C. S. Shaw. 1959. Stick remover for cotton gins. U.S. Department of Agriculture; Marketing Research report 852, 30.

Garner, W. E. and R. V. Baker. 1996. Cleaning and extracting. Cotton Ginners Handbook, Department of Agriculture, USDA publication, 18-19.

Laird, J. W., R. V. Baker, and R. E. Childers. 1984. Screen and Grid dimensions and feeding method effects on performance of a cylinder cleaner at the gin. Proceedings of the Beltwide Cotton Production Research Conference, Atlanta, National Cotton Council, Memphis. Book of papers, 159-160.

Mayfield, W., R. V. Baker, S. E. Hughs, and A. C. Griffin. 1983. Ginning cotton to preserve quality.

U.S. Department of Agriculture, Extension Service, Program Aid. 1323, 11.

Patil, P. G., V. G. Arude, and G. R. Anap. 2006. Design and development of cylinder type cotton precleaner. Journal of Agricultural Mechnisation in Asia, Africa and Latin America (AMA), 37(3): 46-51.

Read, K. H. 1972. Cylinder cleaner speed influences cleaner efficiency. Cotton Gin and Oil Mill Press, 73, 6-7.

Shukla, S. K., P. G. Patil, and V. G. Arude. 2006. Design development and performance evaluation of a saw cylinder cleaner for mechanically picked cotton. Journal of Agricultural Mechanization in Asia, Africa and Latin America (AMA), 37(1): 25-29.

■■