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Influence of spindle material and surface texture on trash content for picking of cotton under variable conditions

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■ **ABSTRACT :** Manual picking of cotton is commonly done in India and it is not only tedious and labour consuming but also costlier than other agricultural operations. Machine picking is, therefore, considered to be viable in minimizing the drudgery involved in hand picking and reducing the cost of cotton picking.The present investigation was undertaken to study the mechanism of picking cotton by the rotating spindles. The spindles were fabricated with the materials selected for the study and they were evaluated for their performance in picking cotton from bolls under laboratory conditions. The spindles were evaluated with the help of the test rig developed for the purpose and the different parameters were recorded. The trash content in the picked cotton ranged from 0 to 74.96 per cent for the selected varieties. The trash content was observed to be minimum with hylum spindle for all the varieties. The trash content was minimum upto the speed of 2000 rpm and increased greatly with the increase in speed of rotation of 2500 rpm and higher speeds. The trash content was minimum at higher level of moisture. The surface texture of the spindles did not show any particular trend of increase or decrease of trash content. The laboratory trials of the spindles revealed that, the hylum spindle of tapered shape with grooves and knurl gave better performance as trash content in the picked cotton was minimum. The speed of rotation within the range of 1000 to 2500 rpm was found to be better in which the trash content was minimum.

■ **KEY WORDS :** Cotton picking, Picking spindles, Trash content, Spindle material

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In India harvesting of cotton is done manually by hand picking. Manual picking is not only tedious and labour consuming but also costlier than other agricultural operations. In recent years it has been observed that labour availability is scarce during peak periods of cotton harvesting. The use of mechanical picking by machine is, therefore, considered to be a viable option in minimizing the drudgery involved in hand picking (Kepner *et al.*, 1978 and Smith, 1964).

India ranks third in the world in production of cotton crop. Cotton is being cultivated in three distinct agro-climatic zones namely; North Zone comprising of Punjab, Haryana and Rajasthan, Central Zone comprising of Maharashtra, Gujarat and Madhya Pradesh and South Zone comprising of Tamil Nadu, Karnataka and Andhra Pradesh.

As per the available reports, the research on mechanical picking or cotton pickers are very meagre or no information is available in India. Consequently this area of research and development needs immediate

attention of researchers for development of suitable mechanical pickers. As the biological scientists are gearing upto develop suitable cotton varieties which are amenable to mechanical picking, it is necessary to develop/ identify a mechanical picker suitable for cotton crop cultivated in Indian conditions.

Mechanical cotton pickers are selective in picking and in this system the seed cotton is removed/picked from the open bolls, where as green and un open bolls are left on the plant itself to mature for later pickings, while strippers on the other hand are once-over machines. All bolls whether open or closed are removed from the plant in a single pass. Chemical defoliants and desiccants are usually applied to facilitate harvesting.

By keeping these factors in view, an attempt has been made to identify crop machine and operational variables which influence on the picking mechanism of the cotton pickers and to develop the picking spindles and to conduct exhaustive trials using different spindles for picking cotton under variable conditions and their suitability for different varieties grown in the region.

METHODOLOGY

The present investigation was undertaken to study the mechanism involved in picking of cotton by the rotating spindles. The biometric parameters of the selected varieties of cotton crop were noted down which are useful for development of test rig. The criteria adopted for development of spindles of different materials, development, fabrication and working of the test rig are explained. The details of the tests conducted for the measurement of performance parameters are also given.

Mechanics of picking:

The basic principle of the revolving spindle is penetrating through the cotton plant, winding the seed cotton from the open boll and retracting to a doffing zone, which is employed by all the commercial pickers now available. The rearward movement of the spindles, while in the picking zone is substantially the same as the forward movement of the machine, generally 3.2 to 5.6 km/hr, so that the spindle while in the picking zone, do not move forward or backward with respect to the cotton plant.

The spindles are carried either on bars arranged in vertical drums or on vertical slats attached to the endless chain belts. Tapered spindles are commonly employed on drum type pickers and have three to four longitudinal rows of sharp barbs or grooves for engaging the cotton. The tapered shape facilitates easy removal of the cotton (doffing) after they leave the picking zone. Spindle speeds range from 1850rpm at a forward speed of 2.9km/h to 3250rpm at 5.0km/h.

Biometric parameters of test crop:

The measurement of biometric parameters of cotton crop helps in fixing the optimum dimensions of the test rig to facilitate the movement of the spindle in horizontal, vertical and transverse directions to pick the cotton from the bolls. The details of cotton crop with respect to selection of varieties, procedure for measurement of various physical parameters are discussed in this section.

Selection of varieties:

The cotton crop presently grown by the farmers of the region are mainly Bt cotton varieties and a few hybrids. The selection of cotton crop varieties for the study was done by keeping in view the different varieties grown in the region. Three predominantly grown varieties of cotton crop were selected from within the Bt cotton and hybrid varieties grown in the region.

Size of spindles:

The dimensions of spindles were decided by considering the size of spindles available on the existing cotton pickers.

Development of test rig for evaluation of picker spindles:

A laboratory test rig was developed to facilitate for testing the performance of spindles at different peripheral speeds. The test rig developed had the provision to move the spindle in all three directions *i.e.*, horizontal, vertical and transverse directions. The test rig was fabricated by using standard fabrication techniques. Two variable speed dc motors were selected, one for rotating the spindle at different speeds and the other to move the spindle in all three directions. The test rig was mounted on a table attached to a pedestal. The test rig can be moved up and down along with the table by rotating the handle.

Selection of variables of study:

The evaluation of the picking spindles were carried out by taking into consideration the different independent variables. The working of the spindles under variable conditions influenced the different parameters, these parameters were considered as dependent variables.

Independent variables:

Material type	4 levels
– Mild steel	M_1
– Aluminum	M_2
– Nylon	M_3
– Hylum	M_4
Surface texture	3 levels
– Tapered plain	S_1
– Tapered with grooves	S_2
– Tapered with grooves and knurl	S_3
Spindle speed	5 levels
– 1000 rpm	N_1
– 1500 rpm	N_2
– 2000 rpm	N_3
– 2500 rpm	N_4
– 3000 rpm	N_5
Moisture content	3 levels
– 2.5 – 3.5 %	mc_1
– 3.5 – 4.5 %	mc_2
– 4.5 – 5.5 %	mc_3
Varieties	3 levels
– NHH-44	
– NCH-145	
– RCH-2	
Replications	3

Dependent variables

– Weight of trash, g

Measurement techniques for various parameters of study:

The spindles developed for the study were evaluated under variable conditions at College of Agricultural Engineering, Raichur, for their performance with the help of the developed test rig.

Laboratory tests were conducted to evaluate the performance of selected spindles at three levels of moisture content and five different spindle speeds. The trash content was observed and recorded during the trials. The methodology followed is as under.

Spindle speed:

The different types of spindles developed for the study were rotated by holding them in the chuck of the variable speed motor in the test rig. The spindle speed is recorded as indicated in the digital speed indicator attached to the test rig. The different speeds required for the study were obtained by regulating the speed with the help of a dimmer connected to the motor.

Moisture content of cotton:

The moisture content of cotton from each boll was measured by using a digital moisture meter. The digital moisture meter was pre calibrated by adopting the standard procedure. The cotton picked from the boll was filled in the cup and the ram was pressed against the cotton in the cup by rotating the handle for required number of revolutions. The moisture content was noted on the indicator panel.

Trash content:

The quality of seed cotton separated from the boll is an important factor from the point of commercial value of the product. The seed cotton picked by the spindle was analyzed for impurities present in it. The impurities like small sticks, parts of dried leaves were separated from the cotton picked by the spindle and termed as trash content. The trash content was calculated for each sample collected after picking by each spindle under variable conditions. The calculation was done by separating the thrash present in the cotton sample. The trash content was determined by using the following formula.

$$T = \frac{W_1}{W_2} x100 \quad \text{....(1)}$$

where,

T= Trash content, per cent

W_1= Weight of the trash separated, g

W_2= Weight of cotton, g.

■ RESULTS AND DISCUSSION

The observations on the different parameters were recorded as per the methodology discussed earlier. The spindles were fabricated with the materials selected for the study and they were evaluated for their performance under laboratory conditions for picking of cotton from the bolls. The spindles were evaluated at variable conditions with the help of the test rig developed for the

purpose and the trash content in the cotton picked by the spindles was observed.

Varieties taken for study:

Selection of cotton varieties for the study was done by keeping in view the different varieties grown in the region. Three most promising varieties of cotton crop grown in this region namely NHH-44 a hybrid variety and NCH-145 and RCH-2 from Bt cotton varieties were selected for the study.

Development of picking spindles:

The development of spindles was carried out by considering various boll parameters and the spindles were fabricated by adopting standard fabrication techniques and also by taking into consideration the shape, surface texture and size of the spindles available in the existing cotton pickers.

Selection of the materials:

The selection of the material for spindles was done by taking into consideration the machinability aspects, availability and the cost of the materials. Four types of material namely mild steel, aluminum, nylon and hylum were selected for the study.

Selection of surface texture

The shape and surface texture of the spindle were selected by considering the ease of picking, ease of doffing, machinability aspects etc. The tapered shape was commonly adopted for all the materials. Three types of surface textures namely tapered plain, tapered with grooves and tapered with grooves and knurl, were selected for study. The surface texture was formed by adopting standard fabrication techniques.

Size of spindles:

The size of spindle was determined by considering the spindles available on the existing cotton pickers. The total length of the spindle is 125 mm out of which the length of the tapered portion is 75mm. A length of 25mm on the other side of the spindle is used for holding the spindle with the chuck for rotating the spindle. The diameter of the spindle is 10mm at the larger end of the taper and is 2 mm at the smaller end of the taper.

Development of test rig for evaluation of picking of cotton by spindles:

The biometric observations of the crop were considered for the development of test rig. The test rig was fabricated by using standard fabrication techniques. Two variable speed dc motors of 0.25 hp were used, one for rotating the spindle at different speeds and the other to move the spindle. A regulator is provided to vary the speed of the motor from 0 to 3000 rpm. An electronic speed indicator is provided to display the speed of rotation

Table 1 : Percentage of trash under different variables of the study for NHH-44 variety

Material	Surface texture	1000 rpm			1500 rpm			2000 rpm			2500 rpm			3000 rpm		
		Moisture content														
		mc_1	mc_2	mc_3	mc_1	mc_2	mc_3	mc_1	mc_2	mc_3	mc_1	mc_2	mc_3	mc_1	mc_2	mc_3
M_1	S_1	4.34	0.00	0.00	0.34	0.00	0.00	5.20	1.91	0.00	3.90	2.51	1.30	21.25	21.89	20.88
	S_2	0.00	5.32	0.00	0.00	0.00	0.00	3.37	0.00	0.00	2.07	1.95	0.75	25.00	22.04	20.28
	S_3	0.00	0.00	0.00	0.53	0.00	0.00	2.01	0.29	0.00	1.63	0.84	0.12	19.19	13.79	6.62
M_2	S_1	0.00	0.00	0.00	1.55	0.00	0.00	0.00	0.00	0.00	27.45	22.29	20.94	42.14	29.73	26.82
	S_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.03	16.31	12.16	48.55	62.21	34.21
	S_3	1.37	0.00	0.00	0.00	0.00	0.00	3.12	0.00	0.00	51.52	33.63	27.94	51.31	49.93	30.97
M_3	S_1	0.00	0.00	0.00	3.50	0.00	0.00	5.16	2.05	0.00	14.53	5.42	4.00	28.67	24.00	12.54
	S_2	0.00	0.00	0.00	0.00	0.00	0.00	3.18	0.00	0.00	3.87	1.75	0.00	30.29	17.37	13.11
	S_3	0.00	0.00	0.00	0.00	0.00	0.00	2.65	0.00	0.00	14.50	11.63	1.38	21.98	18.87	16.96
M_4	S_1	0.00	0.00	0.00	2.76	0.00	0.00	0.74	0.00	0.00	7.08	6.12	3.59	13.91	7.70	3.72
	S_2	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	7.42	5.01	0.63	12.10	4.62	4.39
	S_3	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	7.30	1.89	0.72	8.03	4.48	2.10

Note: M_1 – Mild steel M_2 – Aluminum M_3 – Nylon M_4 – Hylum
S_1 – Tapered plain S_2 – Tapered with grooves S_3 – Tapered with grooves and knurl
mc_1 – Moisture content (2.5 to 3.5), % mc_2 – Moisture content (3.5 to 4.5), % mc_3 – Moisture content (4.5 to 5.5), %

of the spindle. The test rig is mounted on a table attached to a pedestal. The test rig can be moved up and down along with the table by rotating the handle. The height of the pedestal was fixed as 125 cm so that it can guide the spindle to the level of the uppermost boll. The arm of the table is pivoted to the pedestal so that it can swing at any angle required. The arm of the table can move forward upto 75 cm to facilitate the spindle to reach the boll nearest to the stem. The table can also move in the transverse directions to reach the bolls at the extreme ends of the plant.

Evaluation of picking spindles under variable conditions:

The spindles were evaluated at College of Agricultural Engineering, Raichur, for their performance

Table 2 : Percentage of trash under different variables of the study for NCH-145

Material	Surface texture	1000 rpm			1500 rpm			2000 rpm			2500 rpm			3000 rpm		
		Moisture content														
		mc_1	mc_2	mc_3	mc_1	mc_2	mc_3	mc_1	mc_2	mc_3	mc_1	mc_2	mc_3	mc_1	mc_2	mc_3
M_1	S_1	0.00	0.00	0.00	0.00	0.00	0.00	6.57	5.33	1.83	7.52	5.26	2.30	38.37	30.88	23.31
	S_2	0.00	0.00	0.00	1.91	0.71	0.00	8.58	2.54	0.00	3.47	2.89	2.39	36.35	27.77	25.19
	S_3	2.35	1.18	0.00	0.00	0.00	0.00	4.61	1.78	0.00	2.02	2.05	1.36	26.69	17.77	11.53
M_2	S_1	0.00	0.00	0.00	9.07	0.00	0.00	3.94	3.68	0.00	59.11	50.32	37.01	62.54	51.25	31.63
	S_2	0.00	0.00	0.00	0.00	0.00	0.00	4.97	0.00	0.00	38.01	32.84	27.96	69.98	59.15	51.52
	S_3	0.00	0.00	0.00	3.45	0.00	0.00	1.22	0.00	2,90	33.90	27.09	26.78	39.18	40.60	37.92
M_3	S_1	3.77	0.00	0.00	0.00	0.00	0.00	4.76	4.09	0.00	19.41	16.70	6.11	25.23	19.16	14.71
	S_2	0.00	0.00	8.76	0.00	0.00	0.00	5.01	2.03	0.00	5.08	2.51	0.87	39.04	33.73	22.73
	S_3	0.00	0.00	0.00	0.00	0.00	0.00	5.50	4.61	0.00	27.87	25.05	15.12	39.06	35.43	35.55
M_4	S_1	0.00	0.00	4.87	0.00	0.00	0.00	2.26	0.00	0.00	14.38	10.39	4.02	12.24	7.59	4.66
	S_2	0.00	0.00	0.00	0.00	7.88	0.00	2.46	0.68	0.00	14.47	10.85	5.50	30.71	26.91	25.42
	S_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.53	6.07	3.78	18.74	13.84	6.04

Note: M_1 – Mild steel M_2 – Aluminum M_3 – Nylon M_4 – Hylum
S_1 – Tapered plain S_2 – Tapered with grooves S_3 – Tapered with grooves and knurl
mc_1 – Moisture content (2.5 to 3.5), % mc_2 – Moisture content (3.5 to 4.5), % mc_3 – Moisture content (4.5 to 5.5), %

Table 3 : Percentage of trash under different variables of the study for RCH-2 variety

Material	Surface texture	1000 rpm			1500 rpm			2000 rpm			2500 rpm			3000 rpm		
		Moisture content														
		mc_1	mc_2	mc_3	mc_1	mc_2	mc_3	Mc_1	mc_2	mc_3	mc_1	mc_2	mc_3	mc_1	mc_2	mc_3
M_1	S_1	0.00	0.00	0.00	2.14	0.00	0.00	10.25	7.69	4.08	8.44	7.15	4.51	42.08	34.99	28.53
	S_2	0.00	0.00	0.00	0.00	0.00	0.00	15.80	3.67	0.00	4.67	3.16	2.37	45.41	37.54	29.47
	S_3	0.00	0.00	0.00	15.00	0.00	0.00	7.24	4.51	4.48	5.39	5.00	4.49	31.46	24.82	18.89
M_2	S_1	5.80	0.00	0.00	0.00	5.87	0.00	5.66	5.50	2.03	65.34	56.78	41.65	69.28	60.60	31.43
	S_2	0.00	0.00	0.00	0.00	0.00	0.00	6.30	4.07	0.00	46.85	34.79	27.36	74.96	68.20	58.24
	S_3	0.00	0.00	0.00	0.00	0.00	0.00	2.69	1.06	0.00	29.68	31.64	31.34	47.72	41.84	34.80
M_3	S_1	0.00	0.00	0.00	6.75	0.00	0.00	5.81	2.38	0.00	26.40	19.41	10.94	37.89	24.62	20.10
	S_2	0.00	0.00	17.55	0.00	0.00	0.00	8.67	6.57	0.00	8.60	5.68	2.79	47.30	48.86	34.34
	S_3	0.00	10.53	0.00	0.00	0.00	0.00	8.04	6.55	5.03	37.71	32.57	19.72	58.40	53.04	42.11
M_4	S_1	0.00	0.00	0.00	0.00	0.00	0.00	3.69	2.74	0.00	18.27	13.32	8.20	15.82	9.35	4.64
	S_2	0.00	0.00	0.00	11.32	0.00	0.00	0.00	0.00	0.00	3.58	2.02	0.00	18.06	12.98	11.43
	S_3	0.00	0.00	0.00	0.00	0.00	0.00	38.15	31.10	17.76	13.36	9.15	5.73	22.42	20.70	9.77

Note: M_1 – Mild steel M_2 – Aluminum M_3 – Nylon M_4 – Hylum
S_1 – Tapered plain S_2 – Tapered with grooves S_3 – Tapered with grooves and knurl
mc_1 – Moisture content (2.5 to 3.5), % mc_2 – Moisture content (3.5 to 4.5), % mc_3 – Moisture content (4.5 to 5.5), %

with the help of the test rig, under variable conditions.

The laboratory evaluation of the above spindles were carried out for three varieties of cotton namely NHH-44, NCH-145 and RCH-2, at three range of moisture contents namely 2.50 to 3.50 per cent, 3.50 to 4.50 per cent and 4.50 to 5.50 per cent and five speeds in the range of 1000 to 3000 rpm with steps of 500 rpm.

Trash content:

The trash content in the picked cotton under variable conditions is presented in Table 1 to 3. The trash content in the cotton picked under variable conditions ranged from 0 to 74.96 per cent for the selected varieties. The trash content was observed to be minimum with hylum spindle for all the varieties. The speed of rotation greatly influenced the trash content. The trash content was minimum upto the speed of 2000 rpm and increased greatly with the increase in speed of rotation of 2500rpm and higher speeds, this is because the cotton wounded up smoothly with the spindles at lower speed where as the winding of cotton with the spindles was abrupt at higher speeds due to which the adjacent trash from the burs was also picked with cotton. The moisture content also influenced the trash content particularly at higher speeds. The trash content was minimum at higher level of moisture and maximum at lower moisture levels, this is because the burs of the boll were very dry and brittle at lower moisture content and increased the trash content particularly at higher speeds due to the abrupt picking of cotton by the spindles. The surface texture of the spindles did not show any particular trend in the increase or decrease of trash content. Similar work related to the present investigation was also carried out by Corely (1966); Hesston (1962) and Prasad *et al*. (2007)

Conclusion:

The conclusion drawn from the study are; the hylum spindle tapered with grooves and knurl gave better performance as the trash content in the picked cotton were minimum. The speed of rotation below 2500 rpm was found to be better as the trash content was minimum. The study helps in getting the basic information regarding the mechanism of picking with the spindles under variable conditions of picking. This helps in building a base for further development of cotton picker indigenously and also to develop suitable varieties of cotton crop for efficient picking of cotton by machine pickers.

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