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Application of RSM to optimise single locking cotton feeder for enhancing ginning efficiency of double roller gin

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Spike cylinder single locking cotton feeder has been developed and optimized to enhance the ginning efficiency of double roller (DR) gin. The feeder is developed with an aim to unlock the cotton bolls and maintain constant feeding rate of individual locules at the ginning point of DR gin. Spike cylinder speed and cotton moisture content are optimized by using response surface methodology. Ginning efficiency of DR gin is improved with the use of developed feeder. Quadratic models for prediction of ginning output and specific energy and linear model for prediction of reduction in bulk density are generated by using response surface methodology following central composite design that show excellent agreement with the experimental values. Multiple response analysis shows the optimum level of moisture content (7.49%) and spike cylinder speed (317 rpm) with desirability of 0.904695 by maximizing the output and minimizing the specific energy. The ginning output, cleaning efficiency and reduction in bulk density are increased by 23.25%, 16% and 30.5% respectively, whereas the specific energy is decreased by 12% without any adverse effect on fibre quality. Colour grade of the cotton improves from middling to strict middling. Thus, the developed feeder would be highly useful for cotton ginneries.

Keywords: Cotton, Central composite design, Double roller ginning, Response surface methodology, Single locking feeder

1 Introduction

Double roller (DR) gins are more prevalent in Indian ginneries than saw gins. DR gins has prominent share in ginning industries across the world. About 95% of the cotton produced in India is subjected to ginning by using DR gins. As compared to saw gin and rotary knife roller gin, the ginning capacity of DR gins is very low (40–90 kg lint/h) depending on the length of gin machine. Low production capacities of DR gin is the barrier for its widespread adoption across the world, except in India and some African countries[1].

Studies have been made to improve DR gins to increase capacity and ginning efficiency. Improved models of DR gins were developed by increasing roller length from 1065 mm to 1525 mm with an increase in output from 40 kg lint/h to 90 kg lint/h. In variable speed DR gin, roller and beater drives are driven separately[2]. Self grooving rubber roller was developed as a substitute to chrome composite leather roller to increase the gin productivity & roller life, to reduce drudgery of roller grooving and to eliminate the chromium contamination[3]. These improvements increased ginning efficiency of the DR gin to some extent.

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The ginning efficiency is governed by lint output, lint quality and energy conssumption[4]. Cotton to be ginned, moisture content, roller speed, beater speed, setting and adjustments, and feeding mechanism to DR gin influence the ginning output to a great extent. Sharma[1] reported that manual feeding never offers uniform feeding which results in loss of efficiency upto 20%. Shukla *et al.*[5] observed that automatic feeding ensures minimum investment in labour and enhances the monetary returns to cotton processors and improve the quality of lint.

The conventional feeding system used in Indian ginneries comprises auto-feeder in combination with micro-feeder and screw conveyor which faces problems like non uniform feeding, feeding of cotton in bunches, frequent stoppages, falling of seed cotton outside the hopper and damage to cloth belts. It is difficult to maintain the optimum feed rate to DR gin due to erratic flow rate and entanglement of cotton bolls. Due to these problems the ginning efficiency of the DR gins gets adversely affected. Antony[6] suggested that ginning efficiency can be improved by maintaining the constant feed rate of seed cotton to an extent that ensures smooth and trouble free ginning in order to obtain optimum bale value.

It was felt necessary to modify gin feeder employed on DR gin in order to enhance its ginning efficiency. Efforts were made to develop spike cylinder type feeder employing the concept of single locking of cotton bolls for feeding seed cotton locules to DR gin. The similar concept has been adopted in saw and rotary knife roller gin extractor feeders to feed seed cotton in single locks uniformly to the gin stand at controllable rates that provide even flow of seed cotton to the knife edges of rotary gin and saw tips in saw gins[7]. Baker *et al.*[8] reported that single locking of seed cotton ensures controlled feed rate and increases the production capacity with the increased bale value.

The present study is aimed at developing a spike cylinder single locking cotton feeder for DR gin based on the concept of single locking of cotton bolls. Response surface methodology has been used to optimize the spike cylinder speed and moisture content of cotton for improving ginning efficiency in terms of ginning output, specific energy, degree of unlocking (decrease in bulk density) and fibre quality.

RSM determines how big is the effect of each parameter and the interaction between them to the response. Central composite design (CCD) generates quadratic relation between experimental factors and response. RSM not only decides the effect of independent variable on response, but also generates a mathematical model[9]. The main idea from this method is to know the effect of variables to the response and also to achieve the optimal conditions which generate the best response.

2 Materials and Methods

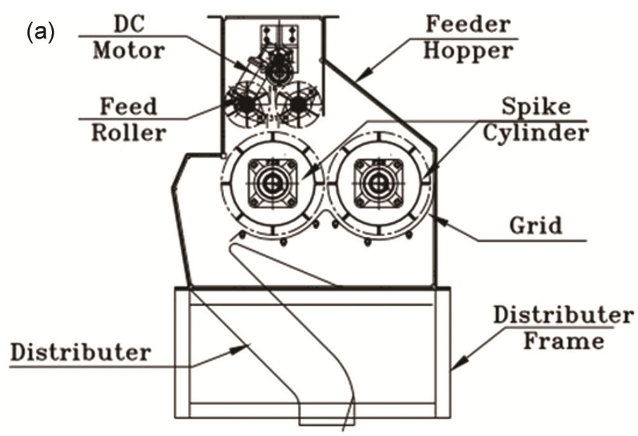
2.1 Development of Research Prototype

The research prototype of spike cylinder single locking cotton feeder (Fig.1) was designed and developed at ICAR-Central Institute for Research on Cotton Technology, Mumbai with an aim to maintain constant feeding rate of individual locules at the ginning point of double roller (DR) gin. Single locking of the cotton bolls was achieved with a mechanism comprising a pair of feed rollers, pair of spiked cylinders and grid bar housed in a feeder hopper and chute for cotton distribution on either side of the beater of DR gin. Feed roller assembly comprises a pair of counter rotating fluted rollers with roller length of 1283.5 mm. The feed rollers are driven by 30W DC motor (24 V and 1.5 A). Spike cylinder assembly consists of a pair of spiked cylinders and each cylinder comprises shaft, cylinder, spikes and centre plates. The overall diameter of the cylinder with the spikes is 279.4 mm. Altogether 200 spikes are mounted in zigzag pattern in eight rows over the periphery of cylinder. The spike cylinders are driven by 2 hp, 1440 rpm electric motor. Concave shape grid assembly with radius of 150 mm is made out of a square wire mesh of sieve size 11.2 mm and sieve wire diameter 1.6 mm. Grid assembly is mounted below the spike cylinder assembly. Feeder hopper with overall dimensions of 1300×671×739 mm is provided with suitable inlet and outlet to deliver the unlocked and cleaned seed cotton to the distributor mounted below it. The trash chamber is provided below the grid to collect the trash. Distributor chute receives the unlocked cotton from the feeder hopper outlet to convey and drop evenly along the length and on either side of the beater of DR gin. The distributor chute is attached to the outlet of the feeder hopper.

2.2 Performance Evaluation of Prototype

The performance of the developed prototype was evaluated by mounting it on the commercial DR gin with roller length of 1360 mm. The performance was

(a)



(b)

Fig. 1 — Spike cylinder single locking cotton feeder (a) schematic diagram and (b) prototype

measured in terms of degree of unlocking of cotton bolls, ginning output and specific energy consumption. The spike cylinder speed of feeder and the cotton moisture content were optimised to enhance the ginning efficiency of DR gin. Long staple cotton was used for performance testing and optimisation. The spike cylinder speed was varied with the help of a variable frequency drive. Degree of unlocking was determined by measuring change in bulk density of seed cotton before and after passing through the feeder. The effect of the developed feeder on cotton quality was assessed by measuring the fibre quality parameters on High Volume Instrument (HVI) and Advanced Fibre Information System (AFIS). The trash analyser was used to measure the trash content and thereby the cleaning efficiency of the developed prototype. The clamp on power meter (CW240; Yokogawa, Japan) was used for the measurement of energy consumption. The performance of the developed feeder was compared with the conventional system of feeding, comprising autofeeder

2.3 Experimental Design and Statistical Analysis

Central composite design (CCD) of response surface methodology (RSM) has been used to analyse and optimise two factors, namely moisture content of cotton (X_1) and spike cylinder speed of feeder (X_2) (Table 1). The ginning efficiency parameters, viz. ginning output (Y_1) and specific energy consumption (Y_2) of DR gin and degree of unlocking of cotton bolls in terms of decrease in bulk density of cotton (Y_3) were the dependent variables. A generalized linear/quadratic model with a binomial response distribution was employed, as shown in following equation:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_{12}X_1X_2 + b_{11}X_1^2 + b_{22}X_2^2 \quad \dots (1)$$

where Y is the response; X_1 and X_2, the variables; b_0, the constant; b_1 and b_2, the coefficients of the linear terms; b_{11} and b_{22}, the coefficients of the quadratic terms; and b_{12}, the coefficient of the interaction terms.

The experimental design matrix resulted by the CCD consisted of 10 runs (Table 2). The experiments were carried out by varying the parameters. All the optimum conditions were obtained from a numerical optimization procedure using the software for maximizing output and minimizing the specific energy. The target values in the range of 30.5-31.5% were set for the response decrease in bulk density to get maximum output and minimum specific energy. The variables were codified to normalize them before regression analysis and to eliminate the effect of different units and ranges in the experimental domain. It allows parameters of different magnitude to be investigated more evenly in a range between -1 and +1. The regression models of the ginning output, specific energy and decrease in bulk density were fitted based on the CCD design by using SAS software. Analysis of variance (ANOVA) was used to analyze the models for significance and the suitability of the terms for each response.

Table 1 — Independent variables and their levels for central composite design

Variable	Level		
	-1	0	+1
Cotton moisture content (X_1), %	5	7	9
Spike cylinder speed (X_2), rpm	200	300	400

3 Results and Discussion

3.1 Results of Experimental CCD Design

Ten experimental runs with two independent variables at three levels have been done at random

Table 2 — Experimental design by using CCD and actual results of dependent variables

Standard run	Random run	Coded variables		Actual variables		Actual results		
		X_1	X_2	X_1	X_2	Output (Y_1), kg/h	Specific energy (Y_2), kWh/kg	Decrease in bulk density (Y_3), %
1	5	-1	-1	5	200	70.0	0.0536	29.53
2	3	-1	0	5	300	73.0	0.0519	32.58
3	2	-1	1	5	400	71.0	0.0530	37.77
4	7	0	-1	7	200	77.0	0.0497	27.08
5	9	0	0	7	300	82.0	0.0478	30.69
6	4	0	0	7	300	81.9	0.0481	30.64
7	1	0	1	7	400	78.0	0.0492	33.12
8	10	1	-1	9	200	74.0	0.0509	25.71
9	8	1	0	9	300	78.0	0.049	29.2
10	6	1	1	9	400	76.0	0.0499	32.01

X_1 — Cotton moisture content (%), and X_2 — Spike cylinder speed (rpm).

instead of the standard runs to avoid biases during the trials, and the analysis of the data is done at standard CCD runs (Table 2). The levels of moisture content varied from 5% to 9% and spike cylinder speed form 200 rpm to 400 rpm. The ginning output, specific energy and the decrease in the bulk density for each run are measured.

The result reveals that the moisture content and spike cylinder speed play a vital role in unlocking the cotton bolls as evidenced from the decrease in bulk density. Experimental results show that the degree of unlocking in terms of decrease in bulk density varies from 25.71% to 37.77%. Single locking of cotton bolls is achieved as the spike tips are spaced closer to the feed rollers than the thickness of a lock of cotton and the spiked cylinder travel at a greater linear speed than the feed rollers, thus striking the bolls of cotton momentarily held between the feed rollers. Single locking of cotton bolls is increased with increase in spike cylinder speed and decreased with increase in cotton moisture content. It shows that spike cylinder has positive effect, whereas moisture has the negative effect on the single locking of the cotton bolls. Cotton unlocking is largely influenced by the spike cylinder speed of the feeder.

Ginning output and specific energy vary in the range of 70 - 82 kg/h and 0.0478 - 0.0536 kWh/kg of ginned lint respectively with variations in cotton moisture and cylinder speed. Ginning output is found to increase with increase in moisture content upto 7% and further increase in moisture content results in decrease in ginning output. Specific energy is found to have inverse relation with the ginning output. As the ginning output increases the specific energy decreases. The lowest ginning output is observed at 5% moisture content. This is due to the fact that as moisture content of cotton lowers the fibre becomes more brittle and relative humidity lowers; then static electricity can develop which may lead to fibres wrapping on rollers or failing to doff properly, resulting in negative impact on processing efficiency. Conversely, if relative humidity is allowed to increase too high, there are potential problems with the fibres drafting and doffing properly as well as the propensity for blockages during ginning operation.

The increase in spike cylinder speed results in higher ginning output but beyond 300 rpm any further increase in speed results in decrease in ginning output. This is observed to be the same for all the moisture levels. Higher output at increased speeds is observed mainly due to unlocking of cotton bolls. Unlocking increases the surface area of cotton, thereby more number of fibres came in contact and adhere to the ginning roller in the given time. The ginning output beyond 300 rpm is low due to excessive opening of cotton bolls at these speeds. Excessively opened locules took longer time to reach ginning point, resulting in lower ginning output and consequently higher specific energy.

3.2 Establishment of Regression Models

The results of the analysis of variance (ANOVA) and lack-of-fit (LOF) tests are generated for three responses from the experimental data (Table 3). Quadratic model is fitted for prediction of responses ginning output (Y_1) and specific energy (Y_2) whereas linear model is fitted for decrease in bulk density (Y_3) (Table 4). Large F-values of 66.66, 352.13 and 48.54 for ginning output (Y_1), specific energy (Y_2) and decrease in bulk density (Y_3) respectively and p-values <0.001 indicate that the models are extremely significant at 5% level of significance. Values of R^2 exceeding 0.9 indicate that the fitted models are in agreement with the experimental values.

Moisture content (X_1), second order term of moisture content (X_1^2) and spike cylinder speed (X_2^2) significantly influence the ginning output, whereas moisture content (X_1), spike cylinder speed (X_2), second order term of moisture content (X_1^2) and spike cylinder speed (X_2^2) significantly affect the specific energy at 5% level of significance as reflected in p-values. The degree of unlocking as shown by decrease in bulk density is influenced by the moisture content (X_1) and spike cylinder speed (X_2). Interaction effect of the variables could not significantly influence all the three responses under study. The fitted models are found to be significant as revealed by the significant p-value and non-significant LOF values showing that the model can fit any data. The predicted values of ginning output, specific energy and decrease in bulk density based on the fitted CCD model is plotted against the actual values (Fig. 2). The model is able to capture around 98.8%, 99.7% and 94.3 % of the variability in the output, specific energy and decrease in bulk density respectively as reflected in R^2 values.

The maximum output of 81.75 kg/h is predicted at critical values of moisture and speed of 7.43 % and 310 rpm respectively. The minimum specific energy of 0.0477384 kWh/kg is predicted at critical values of moisture and speed of 7.6% and 313 rpm respectively.

Table 3 — ANOVA for ginning output, specific energy and decrease in bulk density

Parameter	SS	df	MS	F- value	P-value
Ginning output					
Model	151.9	5	30. 38	66.65	0.0006*
X_1	32.666667	1	32.666667	71.673	0.0011*
X_2	2.666667	1	2.666667	5.8509	0.0729
$X_1 X_2$	0.25	1	0.25	0.5485	0.5
X_1^2	70.034405	1	70.034405	153.6604	0.0002*
X_2^2	28.234405	1	28.234405	61.9483	0.0014*
Residual	1.8231	4	0.4558		
LOF	1.8180952	3	0.606032	121.2063	0.0666
Pure error	0.005	1	0.005		
Total	153.729	9			
R^2: 0.988					
Specific energy					
Model	0.00003553	5	7.11E-06	352.1388	<0.0001*
X_1	0.00001262	1	0.00001262	625.1681	<.0001*
X_2	0.00000074	1	0.00000074	36.4248	0.0038*
$X_1 X_2$	0.00000004	1	0.00000004	1.9823	0.2319
X_1^2	0.00001392	1	0.00001392	690.0531	<.0001*
X_2^2	0.00000486	1	0.00000486	240.7316	0.0001*
Residual	0.00000008	4	2.02E-08		
LOF	3.57E-08	3	1.19E-08	0.2646	0.8529
Pure error	4.50E-08	1	4.50E-08		
Total	0.00003561	9			
R^2: 0.997					
Decrease in bulk density					
Model	100.87953	5	20.1759	48.5442	0.0011*
X_1	27.9936	1	27.9936	67.3539	0.0012*
X_2	70.5894	1	70.5894	169.8413	0.0002*
$X_1 X_2$	0.9409	1	0.9409	2.2638	0.207
X_1^2	1.335096	1	1.335096	3.2123	0.148
X_2^2	0.00263	1	0.00263	0.0063	0.94
Residual	1.66248	4	0.4156		
LOF	1.6612286	3	0.553743	442.9943	0.0349*
Pure error	0.00125	1	0.00125		
Total	102.54201	9			
R^2: 0.943					

Table 4 — Regression equations for output, specific energy and decrease in bulk density

Response value	Regression models
Ginning output (Y_1), kg	$Y_1 = + 81.46 + 2.33X_1 + 0.66X_2 + 0.25X_1 X_2 - 5.47X_1^2 - 3.47X_2^2$
Specific energy (Y_2), kWh/kg	$Y_2 = + 0.047979 - 0.00145X_1 - 0.00035X_2 - 0.0001X_1X_2 + 0.002443X_1^2 + 0.001443X_2^2$
Decrease in bulk density (Y_3), %	$Y_3 = + 30.399286 - 2.16X_1 + 3.43X_2 - 0.485X_1X_2 + 0.7564286X_1^2 - 0.033571X_2^2$

3.3 Response Surface Analysis of Parameters of Ginning Efficiency

The mutual interaction effects of the spike cylinder speed and cotton moisture content on the ginning output, specific energy and decrease in bulk density can be seen on the three-dimensional (3D) response surface plots (Fig. 3). Figure 3 (a) depicts the effects of the interaction between the spike cylinder speed and cotton moisture content on the ginning output. It is observed from curved contour lines that the ginning output increases as the speed is increased until 310 rpm. This behaviour may be attributed to the fact that higher speed increases degree of unlocking of cotton bolls, opening of lumps of cotton, removal of entanglements within the boll and individualisation of fibres adhering to the cottonseed. Unlocking increases the surface area of cotton thereby more number of fibres comes in contact and adhere to the ginning roller in the given time. The ginning output tends to decrease when speed exceeds 310 rpm. This behaviour may be attributed to the fact that excessive opening of cotton bolls make them lighter and allow to float in the ginning hopper. They take longer time to come in contact with the ginning region, thus results in reduced ginning output. The ginning output is increased as the moisture increases until ~7.5% and then decreases with further increase in moisture content. At low moisture, the output may be low due to excessive opening of cotton bolls which is undesired, as stated earlier. It could also be due to the fact that cotton with too low moisture content may stick to metal surfaces as a result of static electricity generated on the fibres and cause machinery to choke, resulting in reduced output. Less

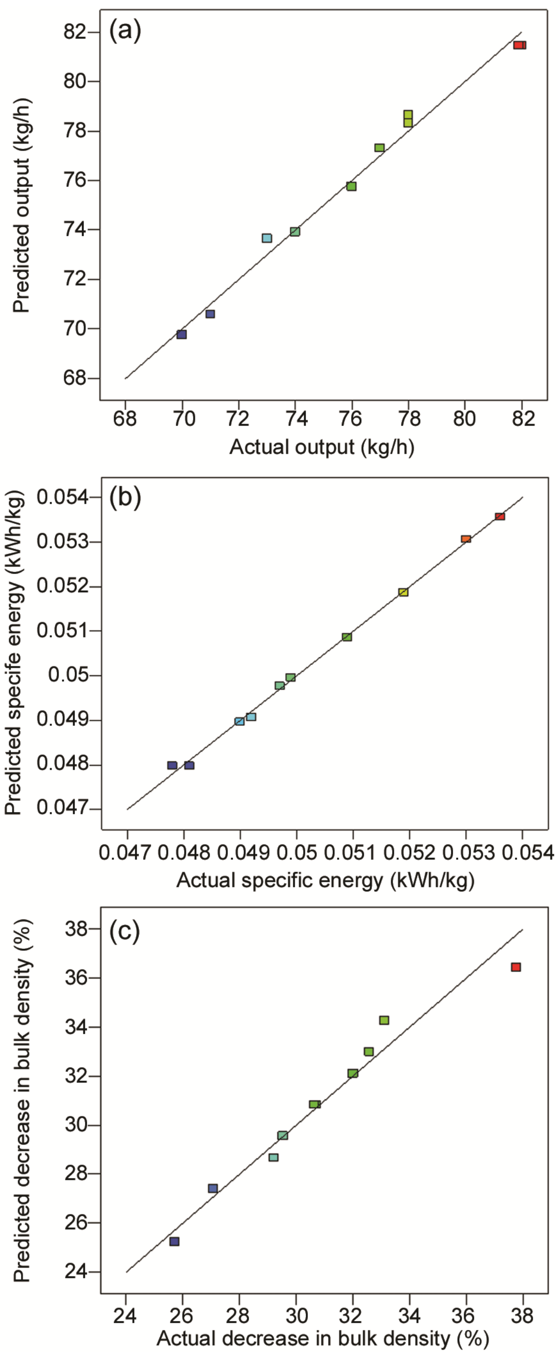


Fig. 2 — Actual and predicted values of CCD models for (a) ginning output, (b) specific energy and (c) decrease in bulk density

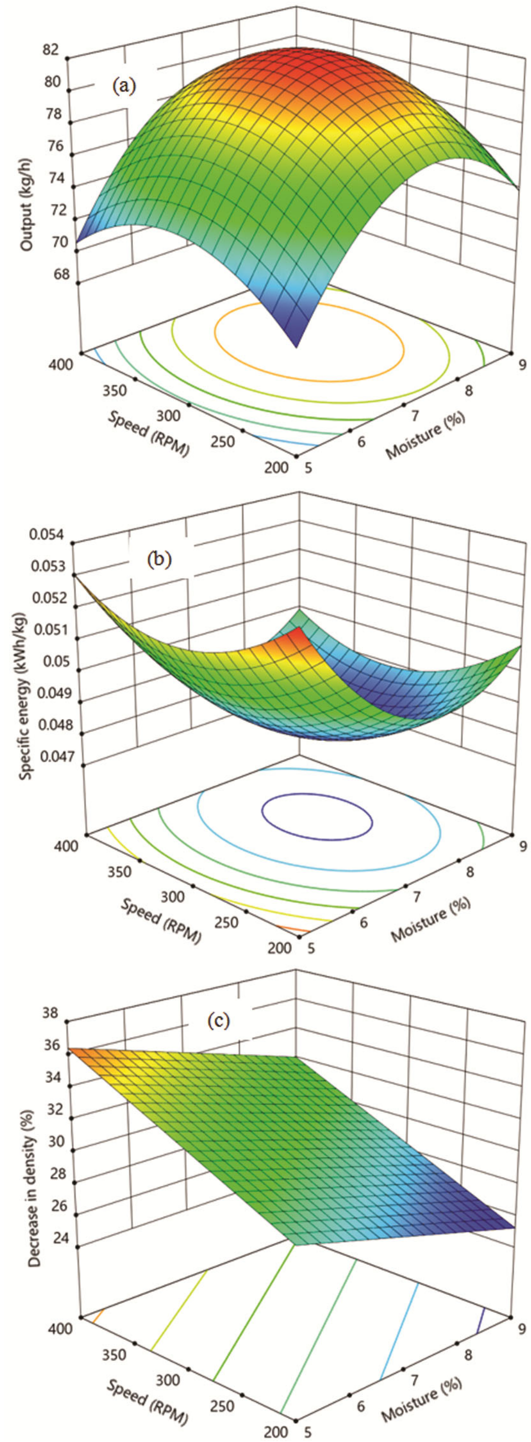


Fig. 3 — 3D surface plots showing the effect of spike cylinder speed and cotton moisture on (a) ginning output, (b) specific energy and (c) decrease in bulk density

output at higher levels of moisture may be due to less unlocking of cotton bolls and choking while ginning.

Figure 3 (b) reveals the interaction effects of speed and moisture on the specific energy consumption during ginning. It is noticed from the curved contour lines that the specific energy decreases with simultaneous increase in moisture content and speed to ~ 310 rpm and 7.5% respectively and then increases with further increase in moisture speed and moisture content. Specific energy consumption is mainly governed by the ginning output. As the ginning output increases the specific energy per kilogram of lint ginned decreases and vice versa.

The effect of spike cylinder speed and moisture content on degree of unlocking of cotton bolls in terms of reduction in bulk density is presented in Fig.3 (c). The spike cylinder speed and moisture content significantly affect the degree of unlocking of cotton bolls. Increasing the speed results in linear increase in degree of unlocking, which might be due to more agitation and aggressive opening of bolls at higher speeds. In contrast, increase in moisture results in linear reduction in degree of unlocking of cotton bolls. It may be probably due to the fact that at higher moisture, cotton locules are more compactly entangled with each other and offers more resistance for unlocking.

3.4 Optimizations of Responses and Desirability

The aim of the investigation is to find out the optimal parameters, i.e. spike cylinder speed and cotton moisture content to enhance the ginning efficiency on one hand and to reduce the specific energy on the other without affecting the fibre quality. Optimization process is conducted, by assigning the constraints 'in the range' for independent variables for maximizing output and minimizing the specific energy. In case of the response variable 'decrease in bulk density', neither maximum nor minimum could be obtained (saddle point). Since the interest is to achieve maximum output, minimum specific energy with desired unlocking of the bolls, the multiple response optimization is done, keeping the target values for the response decrease in bulk density in the range of 30.5±1%. The single optimum solution is obtained by multiple response analysis (Fig. 4), which shows ginning output 81.72 ±1.08 kg/h, specific energy 0.047748 ± 0.000232 kWh/kg and decrease in bulk density 30.50 ± 1.0355%, obtained at optimum levels of moisture content 7.49% and speed 317 rpm with desirability of 0.904695.

3.5 Comparative Assessment of Developed Feeder with Conventional System

The performance of the DR gin is evaluated with the use of developed spike cylinder single locking feeder (SCF) in comparison to the conventional system (control) having autofeeder. The designed mechanism unlocks the cotton bolls to individual locules to the desired extent and successfully opens the lumps of seed cotton and found to work satisfactorily, resulting in efficient ginning on DR gin. Single locking is evidenced by the decrease in bulk density of the cotton. Table 5 shows the mean values of the ginning performance parameters along with the fibre quality parameters of the experimental runs conducted according to CCD at spike cylinder speed of 200 rpm, 300 rpm, and 400 rpm and cotton moisture content of 5%, 7% and 9%. Significant improvement at 5% level of significance is noticed in ginning efficiency of DR gin with the use of spike cylinder single locking cotton feeder as compared to the conventional system, as evidenced from the p-values (<0.05). The developed feeder successfully removes fine trashes, leaf bits and dust resulting in the improvement in colour grade of the cotton from middling to strict middling.

The other quality parameters measured on HVI such as UHML, micronaire, tenacity, etc. remained unaffected with the use of the developed feeder. The developed feeder does not show any adverse effect on the fibre quality parameters tested by AFIS, except mean trash size. The ginning output, cleaning efficiency and reduction in bulk density are increased

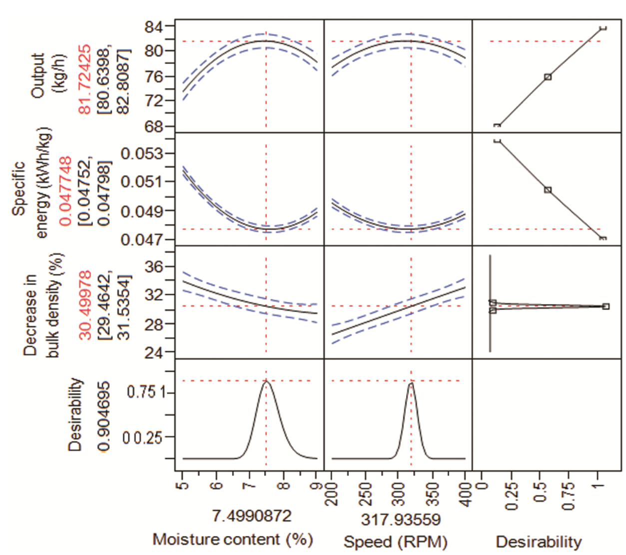


Fig. 4 — Desirability and levels of moisture and speed for multiple response optimisation

Table 5 — Effect of spike cylinder feeder on the ginning efficiency and fibre quality parameters in comparison to conventional system

Parameter	SCF	Control	F-value	P-value
Ginning performance				
Ginning output, kg/h	75.4	66.3	14.4292	0.019127
Bulk density, kg/m^3	48.68	68.6	61.50349	0.001428*
Decrease in bulk density, %	29.09	0.00	998.472	5.98E-06*
Energy, kWh	3.81	3.58	25.0968	0.007439
Specific energy, kWh/kg	0.0506	0.0540	6.7645	0.059993
Trash content, %	2.24	2.67	239.8114	0.000101*
Cleaning efficiency, %	16.19	0	240.3422	0.000101*
Fibre quality-HVI				
UHML, mm	31.0	31.1	0.6667	0.460051
UI, %	85.8	85.7	0.0625	0.814902
MIC, µg/inch	4.8	4.7	1.7500	0.256435
Tenacity, g/tex	29.3	29.3	0.0156	0.906554
Elongation, %	5.2	5.2	0.0323	0.866194
SFI, %	6.1	6.1	0.0241	0.884158
Rd, %	82.6	73.4	76.8284	0.000934*
Plus b, %	7.7	8.1	7.4483	0.052489
Fibre quality-AFIS				
L (w), mm	27.1	27.0	0.4153	0.554408
UQL (w), mm	33.2	33.1	0.0955	18.51282
SFC (w), %	6.4	6.5	0.1164	0.750178
Fibre neps, c/g	46	44	0.0860	0.783862
Fibre neps size, µm	623	614	0.2385	0.650863
Seed coat neps, c/g	31.2	30.7	0.0799	0.791492
Seed coat neps, µm	1318	1379	0.4967	0.519806
Trash, c/g	51	61	7.3890	0.053082
Mean trash size, µm	184	167	9.6163	0.036185*
Dust, c/g	486	524	0.4597	7.708647
Total trash, c/g	538	585	0.9268	0.390216
VFM, %	1.28	1.39	1.0094	0.371895

F Critical: 7.70865, *Significant 5% level of significance.

UHML – Upper half mean length; UI – Uniformity index; MIC – Micronaire; SFI- Short Fibre Index; Rd – Degree of reflectance; + b – Degree of yellowness; L(w) - Length by weight basis; UQL – Upper quartile length; SFC- Short fibre content; VFM-Visible foreign mater; HVI – High volume instrument; AFIS – Advanced fibre information system

by 23.25 %, 16% and 30.5% respectively, whereas the specific energy decreased by 12%. The increase in output may be attributed to opening of lumps of cotton, removal of entanglements within the boll and individualisation of fibres adhering to the cottonseed. Unlocking increases the surface area of cotton, thereby more number of fibres come in contact and adhere to the ginning roller in the given time.

4 Conclusion

Spike cylinder single locking cotton feeder has been developed with an aim to maintain constant feeding rate of individual locules at the ginning point of DR gin. Ginning efficiency of DR gin is improved with the use of developed feeder. Quadratic models for prediction of output and specific energy and linear model for prediction of reduction in bulk density are generated by using RSM following CCD. Optimum levels of moisture content of 7.49% and spike cylinder speed of 317 rpm with desirability of 0.904695 are obtained by using multiple response analysis. The ginning output, cleaning efficiency and reduction in bulk density are increased by 23.25 %, 16% and 30.5% respectively, whereas the specific energy is decreased by 12% without any adverse effect on fibre quality. Colour grade of the cotton improves from middling to strict middling.

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