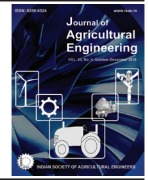
https://doi.org/10.52151/jae2019561.1674

http://www.isae.in / journal_jae.aspx

Journal of Agricultural Engineering

Vol. 56 (1): January-March, 2019



Electronic Device to Quantify Clearance and Control Feed Rate of Rubber Roll Sheller

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Article Info

Manuscript received:
October, 2017
Revised manuscript accepted:
January, 2019

Key words: Head rice, microcontroller, printed circuit board, sensor, shelling efficiency

ABSTRACT

Rice milling process refers to the removal of husk and bran layers from the paddy grain. Proper machine settings in relation to physical and engineering properties of paddy are necessary for efficient milling operations. The present research work was aimed at incorporating modifications in a rice rubber roll sheller of modern rice mill for better control on its operation. A microcontroller-based electronic device was developed to quantify the clearance between the rubber rolls and feed opening of the rubber roll sheller. The values were displayed on seven-segment display units. A mechanical system to suit automation was also developed to automatically control the feed rate of feed hopper of the rubber roll sheller. The device was designed to read from 0 - 72 mm feed opening gap with least count of 0.075 mm, and rolls clearance from 0 mm to 21 mm with least count of 0.01 mm.

Rice (Oryza sativa L.) is a major staple food for more than 70 % of the Indian population (Nisar *et al.*, 2017). India is one of the world's largest producers of white and brown rice after China, and produces 20 % of the rice production of the world.

Rice grain generally consists of 20 % rice hulls or husk, 10-12 % bran layers, and endosperm in the range of 68-72 %, (Sahay and Singh, 2001; Dhankhar, 2014). Rice milling is a process in which paddy is converted into consumable white rice by removing the outer layer (dehusking/shelling), followed by removing of brownish outer layer (whitening) (Yadav and Jindal, 2008). The milling outturn of paddy depends on many factors as variety, percentage of matured grains, moisture content, drying methods, dimensions, linear speed and milling techniques (Rajkumar *et al.*, 2004). Zare *et al.* (2002) reported that the optimum paddy moisture content for milling process is 12 % to14 % (w.b.). The major moisture-dependent physical properties of biological materials are shape, size, mass, bulk density, true density and porosity (Mohsenin, 1986; Ghasemi *et al.*, 2007). Many researchers have reported on automation of post-harvest machinery for grain processing (Grift *et al.*, 2008; Mello and Caimi, 2008; Stone *et al.*, 2008; Goday *et al.,* 2010). An increase in application of automation and informatics in the field of agricultural production and processing has been observed in recent past (Stone *et al.*, 2008; Mello and Caimi, 2008; Goday *et al.,* 2010). Data qualities in terms of accuracy, precision and resolution are considered as one of the most critical challenges related to sensors applications and networks, especially when data is used in decision making or in automated processing. Errors may be introduced in the process of data extraction, transformation, or loading.

Automation and digital techniques in rice processing have become popular in recent years. Shaw *et al.* (1993) developed a monitoring device to sense the handling process of rice post-harvest system, and connecting them with a PLC and a personal computer to solve labour problem. Yadav and Jindal (2001) monitored milling quality of rice using a digital image analysis technique. They found that two-dimensional imaging of milled rice kernels could be used for making quantitative assessment of head rice yield and degree of milling for on-line monitoring and better control of the rice milling operation. Similarly, Srinivas *et al.* (2009) developed an indigenous automated rubber roll sheller (500 kg.h^{-1} capacity) having built-in optical sensors with PC-based control system where operational parameters were continuously monitored and all the information like set gap, sensor voltages, roll movement, peripheral speed etc. were displayed on a PC.

Modern rice mills in India mostly use rubber roll sheller (Singha, 2013). Rubber roll sheller consists of two rubber rolls rotating in opposite directions. The speed ratio of the faster and slower rolls is 1.33 (Sahay and Singh, 2001). Paddy fed between these rolls is dehusked due to compressive and shear forces. Gap between these rolls is manually adjusted by judging the shelling efficiency. As there is no display device in use to see the clearance between these rolls, slight excessive pressure between rolls than the optimum pressure leads to issues like colouring in shelled rice and roll damage. Low pressure between rolls reduces shelling efficiency. Presently no device is available with rubber roll sheller that can digitally quantify the clearance between rubber rolls and feed opening. Shelling efficiency mainly depends on the skill of the operator and machine settings. Automation may be helpful to solve such kind of problems (Katariya *et al.,* 2015).

Similar type of intervention was developed for fibre processing machine with a device to set the clearance of clothing points of the two rolls, where for setting the clearance an electronic device having arrangements of an indicator, drive motor, electronic control and regulating device, electrical circuit including indicator for visually display of said signal was designed (Schlichter and Leifeld, 1995; Leinders *et al.*, 2011). Similarly, a device was developed for a textile machine for monitoring the contacts of a rotating component, in which the components were connected to an electrical power source, which are electrically isolated from each other, and only in the case of a contact between the two components a short-circuit is generated and detected by the monitoring device (Werner and Baumann, 2014). Kour and Kumar (2013) developed a proximity sensor-based seed spacing evaluation system to measure time intervals between seeds and seed spacing uniformity for mustard seeds.

The present work was thus aimed to develop an electronic device that can digitally quantify the clearance between the rubber rolls and feed opening of rubber roll sheller as well as automatically control the feed rate of feed hopper.

MATERIALS AND METHODS

Raw Material

Paddy (variety Sugandha-3; sample size: 35 kg) at moisture content 12 % (w.b.) was used in this study for carrying out experiment on shelling. A commercial rubber roll sheller (capacity: 500 kg. h^{-1} operated with 3.73 kW, 1440 rpm 3-phase induction motor) located at Agro-Processing Centre, College of Agricultural Engineering, JNKVV, Madhya Pradesh, India, was used for the experiment.

Design and Development of Electronic Device

An electronic device was developed for automatic control of feed rate, digital display of rubber roll clearance and feed opening gap of feed hopper, reduced human intervention, ease in operation, and improvement in the quality of head rice of rubber roll sheller.

The device consisted of printed circuit board (PCB), power supply unit/analog to digital converter (A/D) module, display unit, potentiometer,H-bridge, DC motor, pulley and frame. An electronic circuit on a circuit board was designed using the components like resistance, capacitor, transistor, relay, push-to-on switches, transformer, rectifier, voltage regulated IC 7805, microcontroller- PIC16F877A. Microcontroller PIC16F877A was used to process digital values for limit checking and control algorithm, directly accept digital information like on-off status of machines, generate time signals to time sequence and schedule the events, and generate output analog voltage to drive the actuator. Power supply unit consisted of a transformer to steps down high voltage AC mains to low voltage AC, a rectifier to convert AC supply to DC supply, a filter to smooth the DC voltage to a small ripple, and the regulator was used to eliminate ripple by setting DC output to a fixed desired voltage. A potentiometer was used as a sensing device at the rubber roll adjusting wheel to sense the clearance between the rubber rolls as shown in Fig. 1. The housing was mounted on a stationary reference frame. The roll clearance was maintained by rotating the adjusting wheel in clockwise or anticlockwise direction. The clockwise rotation of the wheel decreased the clearance, while the anticlockwise rotation increased the clearance. The movement of handle was sensed by the potentiometer in the form of digital signal and fed to the pin no. 5 of microcontroller PIC16F877A. The digital signal was processed by the microcontroller, and corresponding values of roll clearance was displayed on 4-digit seven segment display units as shown in Fig. 2. Software programme

Fig. 1: Potentiometer as a sensor to read roll clearance

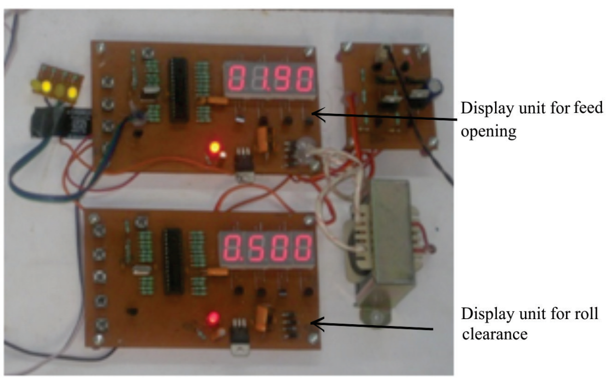

Fig. 2: Display unit for feed opener and roll clearance

was written in assembly language to function the microcontroller PIC16F877A as per requirements, and its implementation was done into the circuit. Software algorithm to display roll clearance is shown in Fig. 3.

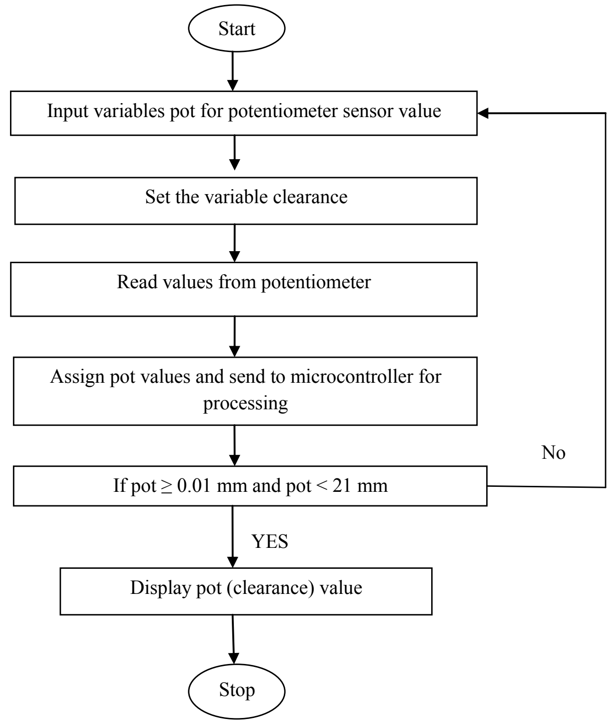

Fig. 3: Software algorithm for display of roll clearance

Fig. 4: System for feed rate control

Mechanical System to Control Feed Rate:

A mechanical system was developed and assembled at the lower portion of the feed hopper (Fig. 4) to automatically control the feed rate of feed hopper and displayed the feed opening gap on a display unit. The parameters set in the mechanical system to control feed rate were diameter of drive and driven pulley, gear ratio, and motor speed. The diameter of drive and driven pulley were 6 mm and 78 mm, respectively. The gear ratio was maintained at 7.16:1. Since the total opening of the feed hopper was 72 mm, a threaded cast iron bolt of 72 mm length and 6 mm diameter with thread pitch of 1 mm was welded on the sliding plate to move it with the threaded bolt to close or open the feed opening. A 12 V centre shaft DC motor of 30 rpm rated speed was used to move the sliding plate of the feed hopper to close/open the feed opening of hopper.

H-bridge was used in the circuit to control the motor in both forward as well as reverse direction with a processor. The software algorithm is shown in Fig. 5. Power was transferred from the motor to the threaded bolt. The rotary motion was ultimately converted into reciprocating movement to move the sliding plate. When the system was operated, the DC motor rotated the threaded bolt. With clock-wise rotation of the bolt, the sliding plate moved out to increase the feed opening. With anti clock-wise rotation, the sliding plate moved towards the hopper causing the feed opening gap to decrease. The threaded bolt required a total 72 revolutions to cover the feed opening gap. A potentiometer was attached at the pulley to sense the feed opening gap on the thread pitch.

Initially the feed hopper was kept closed. With the system put in on position, a desired value of feed opening (in mm) was manually entered using the keypad, the motor rotated the threaded bolt to move the sliding plate for the pre-defined gap. The circuit then automatically disconnected power to the motor. The movement of the sliding plate was sensed by the potentiometer on the thread pitch in the form of digital signal and fed to the microcontroller PIC16F877A for processing and corresponding values of feed opening was displayed on the 4-digit seven-segment display unit. The block diagrams of display units are shown in Fig. 6 and Fig. 7. The developed system assembled on the commercial rubber roll sheller installed at Agro Processing Centre, College of Agricultural Engineering, JNKVV, Madhya Pradesh, and its performance was evaluated with paddy variety Sugandha-3.

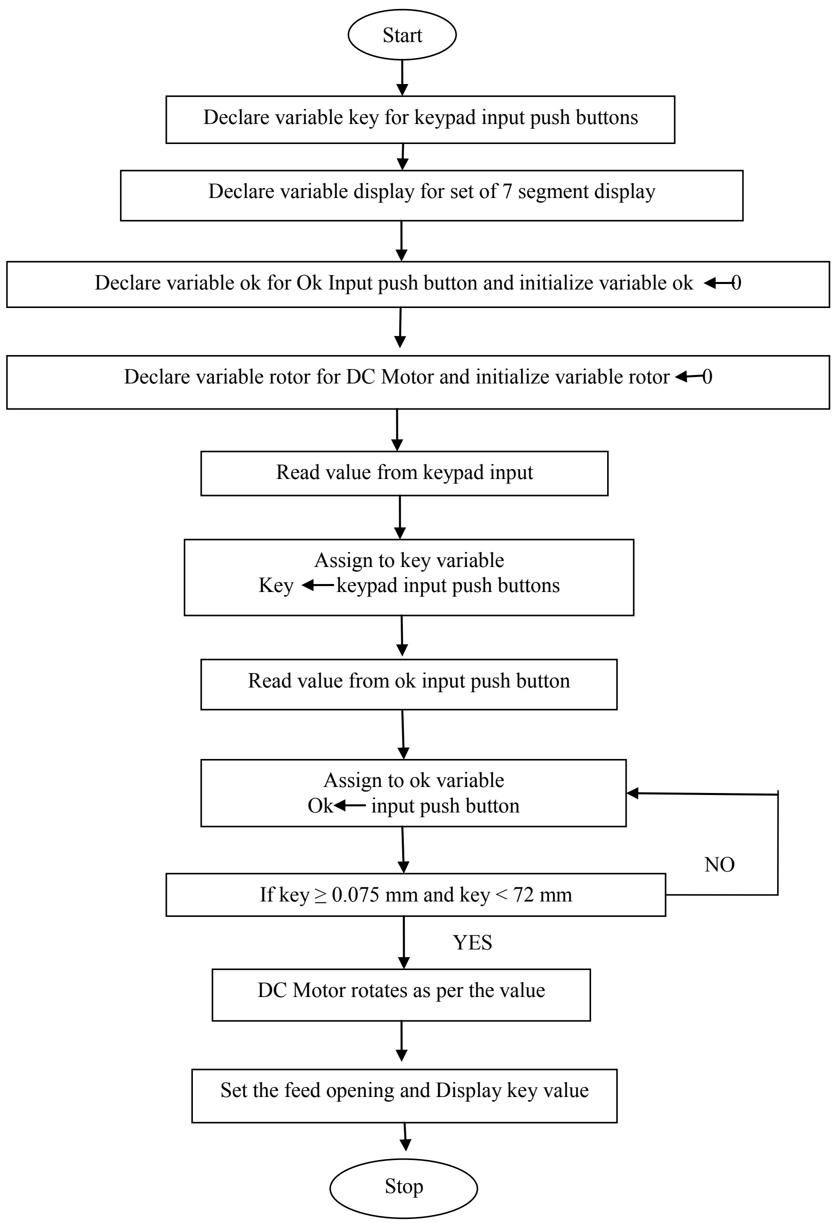

Fig. 5: Software algorithm for display of feed opening gap

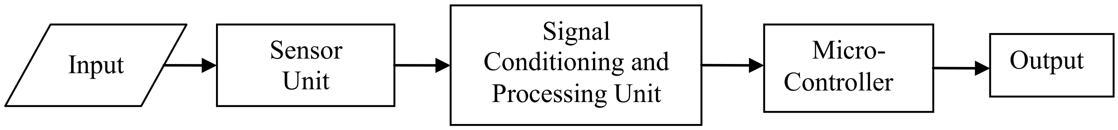

Fig. 6: Block diagram of electronic device to display roll clearance

Design of Experiment

Completely Randomized Design (CRD) was used for designing the experiments. Independent variable of one level (roll clearance range 0.25 mm, 0.30 mm, 0.35 mm, 0.40 mm, 0.45 mm and 0.50 mm) was selected while the dependent variables of four levels (head rice %, broken %, unshelled paddy % and husk %) were selected.

Each experiment was replicated three times with 35 kg paddy sample size. The average values of three replications are reported. Data was statistically analysed at 5 % level of significance.

Experimental Procedure

Paddy (variety Sugandha-3) grains were cleaned manually and moisture content of the grain (12 % wet basis) was determined using a universal moisture meter (Range: 3.5 – 40 %, consistency: ± 0.2 %, principle of measurement: resistance).

Cleaned grains were fed to the sheller at constant feed opening of 4 mm. Various roll clearances (0.25 mm, 0.30 mm, 0.35 mm, 0.40 mm, 0.45 mm and 0.50 mm) were set with the help of the electronic device and the effects of roll clearances on shelling efficiency were evaluated.

Effect of roll clearances on shelling efficiency

Shelling efficiency

It is expressed as a percentage of milled rice including broken obtained from paddy, and was determined using the following equation (Gbabo and Ndagi, 2014):

$$S = \frac{Wd \times 100}{Ws} \qquad ...(1)$$

Where,

S = Shelling efficiency, %,

Wd = Weight of dehusked rice, kg, and

Ws = Weight of sample used, kg.

Head rice percent

This is the weight of whole kernels, and expressed as following (Gbabo and Ndagi, 2014):

$$Mh = \frac{Ww}{Ws} \times 100 \qquad ...(2)$$

Where,

Mh = Head rice recovery, %,

Ww = Weight of whole kernel, kg, and

Ws = Weight of sample used, kg.

Broken per cent

Broken per cent is the kernel having less than 75 % of the average length of the whole kernel, and expressed as (Gbabo and Ndagi, 2014):

$$Mb = \frac{Wb}{Ws} \times 100 \qquad ...(3)$$

Where,

Mb = Percentage broken rice,

Wb = Weight of broken rice, kg, and

Ws = Weight of sample used, kg.

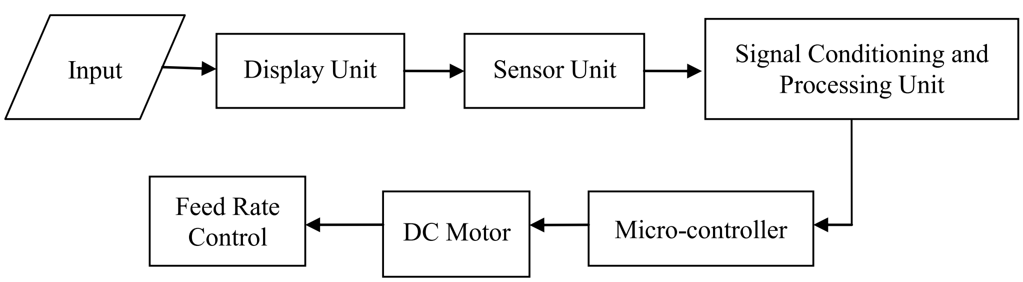

Fig. 7: Block diagram of electronic system for feed rate control

RESULTS AND DISCUSSION

Working of Electronic Device and Mechanical System

A microcontroller-based electronic device was designed to read 0 - 72 mm feed opening gap with least count of 0.075 mm, and rolls clearance from 0 mm to 21 mm with least count of 0.01 mm. The feed rate was thus automatically controlled. When both the rolls touched the outer surface, the reading displayed "0" and when rolls were fully opened the reading displayed 21 mm in the display unit, and was found correct. To calibrate the device for roll clearance, special fillers of different thicknesses were used. When the device was set for roll clearance of 0.5 mm, the fillers of thickness 0.4 mm, 0.5 mm and 0.6 mm were used to verify the actual clearance. The filler plate of 0.5 mm thickness fitted properly in between the rubber rolls, thereby verifying that the display device performed correctly. The process was replicated three times for different clearance settings, and were similarly verified. Similarly, the readings of the display device for feed opening was calibrated using a digital vernier callipers (WW-TH54A; range: 0-150 mm, resolution: 0.01 mm), and found that the measured values of feed opening were similar to the displayed values. This showed that the device worked satisfactorily in terms of measuring and displaying the clearance between rolls and gap of feed openings at display units.

Similarly, the feed opening gap was checked and found correct. This showed that the device worked satisfactorily with the rubber roll sheller in terms of measuring and displaying the clearance between rolls and gap of feed openings at display units.

Effect of Roll Clearances on Paddy Recovery

The developed device was used to set various roll clearances from 0.25 mm to 0.50 mm in order to study the effect of roll clearance on paddy recovery parameters. The results are shown in Table 1. The treatments were significant at 5 % level of significance.

The results showed that the maximum recovery of head rice (65 %) was obtained at roll clearance of 0.30 mm, while the minimum recovery of head rice (16.5 %) was obtained at 0.50 mm roll clearance. The CD value was 3.68.

In case of broken percentage, least broken percent (0.7 %) was obtained at rolls clearance of 0.50 mm, while the highest broken percent (3 %) was obtained at roll clearance of 0.25 mm. The CD value was 0.40.

The percent of unshelled paddy was lowest (8.8 %) at roll clearance of 0.30 mm, while highest unshelled paddy (67 %) was at 0.50 mm roll clearance. The CD value was 4.60.

The husk percent was highest (25 %) with roll clearance of 0.25 mm and lowest (15 %) at roll clearance of 0.50 mm. The CD value was 2.18. The findings were consistent with that obtained by Alsharifi *et al.* (2017) and Alwan *et al.,* (2018).

From the above results, it was observed that 0.3 mm roll clearance was optimum for the paddy variety. Increase in clearance above 0.3 mm (0.35 mm, 0.40 mm, 0.45 mm and 0.50 mm) decreased the pressure on the grain and led to decrease in percent of head rice, brokens and increase in percent of unshelled paddy. Decrease in roll clearance below 0.30 mm to 0.25 mm led to increase in broken percentage, decreased head rice percentage and percent of unshelled paddy.

Effect of Roll Clearances on Shelling Efficiency

The effect of roll clearances on shelling efficiency is

Table 1. Effect of roll clearances on recovery of paddy components

Sl. No.	Rolls clearance, mm	Head rice, %	Broken, %	Unshelled paddy, %	Husk, %
1.	0.25	62.0^{ab}	3.0^{a}	10.0^{e}	25^{a}
2.	0.30	65.0^{a}	1.9^{b}	8.8^{e}	24.3^{ab}
3.	0.35	59.0^{b}	1.5^{bc}	17.5^{d}	22^{bc}
4.	0.40	55.0^{c}	1.3^{cd}	23.7^{c}	20^{c}
5.	0.45	51.4^{c}	1.0^{de}	30.6^{b}	17^{d}
6.	0.50	16.5^{d}	0.7^{e}	67.8^{a}	15^{d}
	CD (0.05)	3.68	0.40	4.60	2.18

Note: Values with same superscript do not differ significantly at p=0.05.

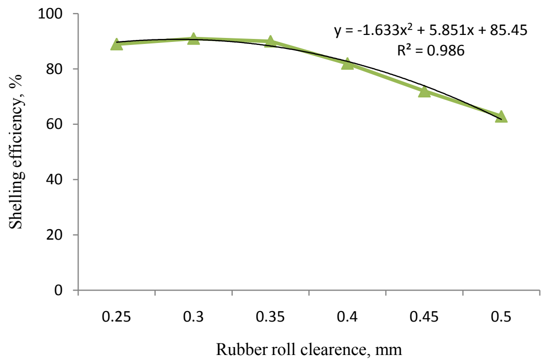

Fig. 8: Effects of roll clearance on shelling efficiency

shown in Fig. 8. Roll clearance of 0.30 mm gave highest shelling efficiency of 91 percent. Further increase in roll clearances resulted in continuing decrease in shelling efficiency till 62.9 % at 0.50 mm roll clearance. The regression equation had R^2 value of 0.99 with a negative correlation existing between roll clearances and shelling efficiency. Past research showed that the shelling efficiency of rubber roll sheller ranges from 60 % to 90 % due to the differences in roll clearances (Alizadeh and Rahmati, 2011).

Performance of the device suggested that it could be useful for low-capacity rubber roll sheller as well as other similar type of small-scale grain processing machines for wheat milling and pulse processing where feed rate is to be controlled or clearance between two adjacent layers is to be quantified. Manual control of small rice rubber roll sheller is dependent on skill of the operator. Operator set the rolls clearance based on the product quality. Slight excessive pressure between rolls than the optimum pressure leads to colouring in shelled rice and rolls damage, while low pressure reduces shelling efficiency. With the use of present device, one can digitally quantify the clearance of rolls as well as feed opening gap and feed rate can be controlled automatically.

CONCLUSIONS

A microcontroller-based electronic device was designed to automatically control feed opening of rubber roll sheller from 0 mm to 72 mm with least count of 0.075 mm, and digital display of roll clearance from 0 mm to 21 mm with least count of 0.01 mm for rubber roll sheller. Roll clearance of 0.30 mm for paddy variety Sugandha-3 was optimum, and 4 mm gap of feed opening for 70 kg.h^{-1} feed rate gave maximum shelling efficiency of 91 percent.

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