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DEVELOPMENT AND INSTALLATION OF SAFETY FEATURES IN FODDER CHOPPER TO MAKE ITS OPERATION RELIABLE AND HAZARD FREE

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ABSTRACT

Current study was carried out during the year 2019-20 at Agricultural Engineering (Research) AMRI division Faisalabad, Paksitan. A power cut-off/Limit switch was installed in the electric chopper to stop in dangerous conditions. A second protective feature was the trigger/belt deflector system which was worked by pressing a paddle to stop both engine and motor-driven choppers. Front shield grill, belt cover, gears cover, wooden foundation and protection barrier plates were the other novel features that were used as protective measures. These safety features were tested on alfalfa, sorghum and sugarcane crops. A rubber pipe was used as a testing tool material and feed through to check the reliability of the safety gadgets. The distance between feed rollers and blades was measured at 17 cm. When the electric motor was switch off by a cutoff switch mechanism then the rubber pipe moved 8.1 cm while the testing crop was sugarcane and 13 cm while the testing crop was berseem. When the belt was removed from the flywheel by paddle mechanism then the rubber pipe moved 9.5 cm while the testing crop was sugarcane and 13.5 cm while the testing crop was berseem, all these values were less than 17 cm which falls under the safe limit and prevents the human from any danger which makes its operation reliable and hazard-free. Hence, the cutoff switch was more reliable because in that case, the rubber pipe moves to less displacement in the cutting head. The average theoretical capacity was calculated as 1.44 ton/h, while the average actual capacity of the machine was measured 1.18 ton/h and the average efficiency of the machine was found 84.5%. All these novel safety gadgets were merely costed 4,500 PKR and research results showed that the operation of traditional Toka was safer in operation when augumented with these safety gadgets.

KEYWORDS: Fodder chopper; protection rollers; limit switch; blade safety guard; belt deflector; trigger system; safety grill; gear cover; Pakistan

INTRODUCTION

Pakistan is an agro-based country and most of its industry is directly or indirectly linked with agriculture. Livestock is another allied identity of this industry and in recent decades its importance has gained popularity throughout the country in terms of lactating animals. For animal keeping, fodder as a feed is a basic need of the day. For one or more animals, even for modern livestock farms, different kinds of fodders in different forms are being fed for productive growth and better milk production (Yadav *et al.,* 2010). The fodder crop is grown over agricultural land and it is harvested, chopped and fed to the animals. In the whole scenario, manual or mechanized operation, from sowing to chopping and even feeding of fodder involves some implications. Among all the operations, chopping off fodder either manual or mechanized is of the great debatable issue by accidental point of view (Pawlak *et al.*, 2015). No doubt, fodder chopping with a hand tool (Gundasa) is a part of the mechanized fodder chopper (Toka) for posing a similar threat to the hand injury. But gradually increasing accidents with the power-operated chopper (Toka) is a matter of great concern as 65% of total accidents associated with agricultural machinery have been reported only by the fodder chopper. The causes of accidents must be necessarily addressed with some innovative modifications in the existing fodder Chopper (Toka) design to protect the worker from small injury, upper limb amputation to permanent disability or even loss of life (Ahmad *et al.,* 2018).

The fodder is placed in a fodder chute and then pushed forward to the grip rollers for its forced forward movement to the cutting blades. The feeding action of the operator depends upon the fodder length and age

of the grip rollers (Zakiuddin *et al.*, 2010). The other reason is the wooden chute that offers' resistance in the fodder forward movement due to its stationary base and sides. In some cases, the fodder is directly pushed to the grip rollers as a wooden chute was not available. In case feeding of short length fodder, poor grip of rollers and resistance offered by the chute or absence of feeding chute, operators use their fingers to push the crop to the grip rollers. In this situation, the fingers are got stuck in grip rollers which moves the hands towards the blades of chopper and causes loss of fingers or fist. In power operated fodder cutters due to the absence of any safety system, it is not possible to get a hand out if the hand is sucked between feeding rollers (Kumar *et al.,* 2013). The fodder chopper accidents may be caused due to careless feeding, untrained chopper operator, exhausted grip rollers of the chopper, direct approach of hand to the grip rollers, non-availability/poor feed chute, shorter length of fodder crop, loose clothing, child labour, unawareness about the consequences, unawareness about the safety precautions, try to over feed the chopper and careless behavior of the operator (Haque *et al.,* 2008). In a retrospective observational study conducted at Surgical Unit-I, Allied Hospital, Faisalabad from October 01, 2013, to April 30, 2015, sixty-nine consecutive patients, both male and female, injured with agricultural machine were admitted to surgical emergency Allied Hospital Faisalabad. Among them about 91.3% were male and 8.9% were female. The study revealed that 65% of cases were due to Fodder chopper (toka) and 43.5 % of cases were related to upper limb injuries. Upper limb and perineal injuries were mostly caused by fodder chopper (Lodhi *et al.,* 2015).

Toka-associated injuries was also studied out on 74 patients in Jinnah Hospital, Lahore patients belonging from 4 - 45 years age group. It was observed that the 47 patients needed micro hand surgical treatment (Rabbani *et al.,* 2012). Another similar study was carried out on injuries that occurred due to fodder cutting machine at the Allama Iqbal Memorial Teaching Hospital in Sialkot region. There, 196 cases were reported during three years period from August 2015 to August, 2018 of which 129 were males and 71 were females. Various kinds of injuries were received from the Toka machine and a higher percentage of male victims (13.26%) belonged from the age group 31-40 years while a higher percentaged of female victims (8.6%) belonged from 1-10 years (Ahmad *et al.,* 2018). To inquire the essential factor which causes injuries during the operation of the chopper. In a research study, it was found that the maximum injuries were caused during feeding fodder into the chute and children playing with the machine. Further, investigations were done by fabricators to get the best dimensions of the chopper by incorporating safety features (Kumar *et al.*, 2013) to overcome the above problems through new fabrication and was tested the machine for fodder chopping with safety measures.

In agricultural implement-related injuries, human factors were involved in 73% of cases of Punjab. Which was included the wearing of loose-fitting clothes, carelessness, physical inability and overburden (Rawal, 1984). Accidents caused by the chaff cutter about 7.8%. The injuries related to the hand tools (8% of the overall accidents) were non-deadly in nature. Due to the lack of practical capability of the local technician, adhering to safety and design standards is unworkable for the implements made up in the rural areas. The analysis stress that efficient safety and health management. A safer fodder cutter was designed by a detailed study of machine characteristics and injuries. The design parameters were changed which was found cost-efficient and included, in both new as well as existing fodder cutter machines (Mohan *et al.,* 2004). A manually operated fodder cutter was standardized to get best results. The following three components are the main factors which affect the efficiency of chopper viz; flywheel, gears, and chaff cutters or blade (Khope and Modak, 2013). In this research, a safety mechanism was designed for local fodder chopper to make its operation more reliable and hazardous-free. Various safety gadgets were installed viz; Power cutoff switch, spring-loaded belt deflector arm, trigger system, gear cover, front shield grill, belt cover, warning roller and barrier plate.

MATERIALS AND METHODS

It was cheerless to mention here that thousands of people had faced a different level of disability like hand injury, upper limb amputation, and even casualty. This alarming situation demand a foolproof solution to address the fodder chopper concerning accidents. According to PAMIMA source, at present more than 2 million fodder choppers were working in the province in which 80% was driven by electric power and the remaining were operated with peter engine, animal draft and manual force (GoP, 2020). However, keeping in view the power source, precautionary measures were adopted and following engineering intervention were incorporated by AMRI division Faisalabad, Pakistan during the year 2019-20 in Fodder Chopper (Fig. 1,2,3).



Fig. 1. Traditional fodder chopper (Toka) as under field operation



Fig. 2. AMRI fodder chopper with safety measures



Fig. 3. Traumatic amputation fo lower limb by fodder chopper

Power cutoff/limit switch

The power cutoff switch was also known as a limit switch. This electro-mechanical device consistd of an actuator which was further mechanically linked with a warning roller. When an operator touch with warning roller the actuator worked and supply of current brok in electric motor. In this machine, it was used for switch off the electric motor to prevent the worker from any accident (Fig. 4).

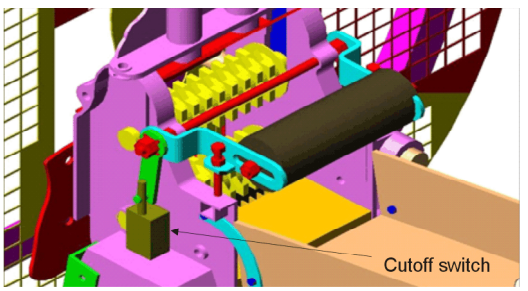


Fig. 4. Power cut off/limit switch installed on chopper

Blades safety guard

Safeguard was made of MS (mild steel) rods with a diameter of 9 mm and provided with a curve-shaped fodder cutter. The machine preceded the blade as it moved and safed from injury to the hands as it averted the hands away. This safety device was attached to each forage cutter.

Gear cover

To cover the open gear system available on the fodder cutter, a safety gear cover was made out of cast iron/ MS sheet. The cover sheet was fixed with the help of two nut bolts on the frame of the fodder chopper. A center hole had been slotted at the top for enabling the lubrication of gears (Fig. 5).

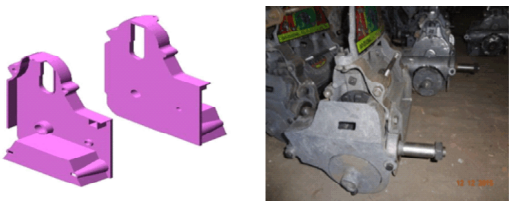


Fig. 5. Gear cover plates are designed in AutoCAD and installed on chopper

Finger guard

Finger guard which was also known as protection barrier plate which was installed on the front of feed rollers. It protects the fingers from entering the feed roller and alarms the operator to get its handoff from this limit. The width of this guard plate was 210 mm and the height was 94 mm (Fig. 6).

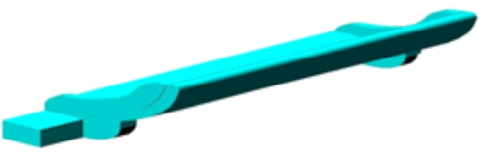


Fig. 6. Protection barrier in front feed roller

Coverage/front shield

The flywheel cover was made up of an iron sheet and mounted on the front of the fodder chopper for safe working. It also provided the shield cover from blades. Cover on flywheel and blades helped avoid accidents especially when worker crossing the moving parts. To cover the flywheel, wire mesh had been selected considering the optimum finger size of the worker. The size of the mesh was taken as 10x10 mm. To cover the whole flywheel round shaped wire mesh was used, which was fitted in the flywheel with the help of nuts and bolts.

Feeding chute

A rectangular chute was attached on the rear side of the shear plate. Fodder was fed into the cutting section

through the feeding chute which kept the fodder in a parallel position for its efficient cutting. The chute was detachable provision for changing the angle of placement of the chute. At the rear side of the chute a support should be provided. The total length, width and height of the chute was a minimum of 720 mm, 210 mm and 94 mm, respectively.

Belt deflector/trigger system

A spring-loaded iron arm was used as a belt deflector which was assisted for the prevention of operator from wounds during the chopper operation. It functions with help of a paddle which was used to deflect the belt and removed it off from the flywheel of the chopper to guard the operator from any hazard/accident. It consisted of a pedal having length 260 mm, iron wire of length 750mm, two V-shaped small pulleys of diameter 500 mm, one rod of length 420 mm and diameter 20 mm and one spring of length 140 mm and one U-shape plate attached at the end near the belt with the dimension 100 mm bottom plate and 70 mm side plate, ruler of length 100 mm and bolt of length 120 mm for fixing the ruler in U-shape plate which was moveable and used to deflect the belt (Fig. 7).

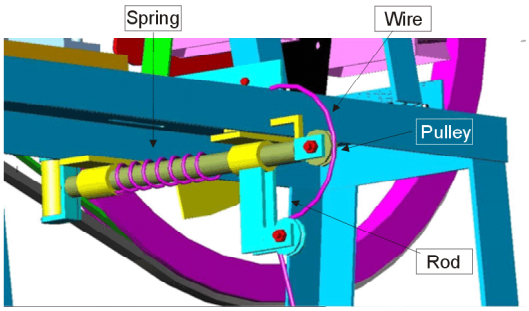


Fig. 7. Belt deflector system associated with paddle

Warning roller

Warning roller gave warning to the operator when a hand reached near the cutting blade. A warning roller was provided in the machine at arms reach a distance of 80 mm. Warning roller was made up of wood material diameter of roller was 55 mm and length 200 mm, which was fixed to the head of the chaff cuter with the iron road of 430 mm and diameter 15 mm plates to hold the wood ruler of length 160 mm, plate at ninety degrees to hold the wood roller was of length 70 mm and plate attached with the head was of length 50 mm. Two adjusting bolt of length 80 mm and diameter 13 mm were used to adjust the height of the warning roller. The rod of length 430 mm and diameter 15 mm was used to mount the whole warning roller assembly on the head of the machine (Fig. 8).

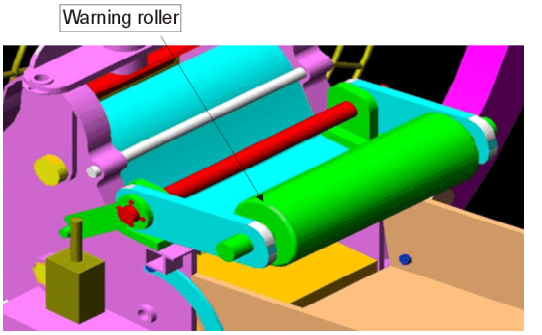


Fig. 8. Warning roller

Data collection procedure

To check the performance of the safety measures the following steps were performed. (i) all the necessary materials before testing the forage chopper machine were gathered including all important tools needed in case of any adjustment to avoid failure in the operation, (ii) the machine was run for a minute before feeding the fodder to check the functionality of the machine and its parts, (iii) a specific amount of fodder was fed at the hopper for chopping (iv) the rubber pipe was placed on the fodder in the feed chute (v) the machine was stopped by warning ruler and cutoff switch mechanism, (vi) the length of the rubber pipe moved in the cutting section was measured (vii) the time to stop the machine after switching off the motor was noted.

Theoretical capacity

Theoretical capacity or designed capacity of chopper to measure the amount of chopped fodder in ton per hour was calculated through the formula (Karunya *et al.,* 2016);

$$\text{Theoretical capacity(ton/h)} = K \times \rho \times W \times H \times L \times n \times N_f$$

ρ = Density of the crop (kg/m^3)
W = Width of chopper throat (m)
H = Height of chopper throat (m)
L = Length of cut (m)
n = Number of blades
N_f = speed of cutting head (rpm)
K = constant (60×10^{-3})

Actual capacity

The actual capacity was measured by weighing chopped crop output over period of time. The time required for chopping the sample of fodder was recorded. The actual field capacity of chopper remained less than therocitical capacity due to different variables viz; time, feed rate and density of crop were not under control due to human variations. Actual capacity was expressed in terms of ton/h by formula;

$$\text{Actual capacity (ton/h)} = \frac{\text{Weight of fodder (output)}}{\text{Time required for chopping fodder}}$$

Machine efficiency

Chopping efficiency was computed based on the ratio of the actual capacity of the chopper to the theoretical capacity of the chopper. The results were articulated in percentage by following formula:-

$$\text{Machine efficiency (ton/h)} \frac{\text{Actual capacity}}{\text{Theoretical capacity}} \times 100$$

Performance of safety measures

The performance of the safety measures was tested by placing the rubber pipe (as a testing tool) along with the fodder into the feeding chute and the motor by using one of the safety measures was stopped such as cutoff switch or paddle mechanism and then the displacement moved by the rubber pipe in the cutting head was measured and was compared with the total displacement between feed rulers and blades (Fig. 9).



Fig. 9. Fodder chopper with safety measures under testing

RESULTS AND DISCUSSION

The performance of the safety measures was checked by chopping the sugarcane and berseem with three replications. Only one type of blade was used in this experiment. The procedures for getting the data were that the test crop was fed into the machine's hopper and rubber pipe placed along with the test crops and the machine was stopped by using safety measures and recorded the length of the pipe moved in the cutting head and time to stop the machine after switching off the motor or removal of the belt by paddle mechanism. The data gathered during the experiment are given in table 1 to 4.

Performance of safety measures

The performance of safety measures was checked by feeding two different freshly harvested crops such as sugarcane and berseem into the chaff cutter machine. The total displacement between feed roller and blade was measured equal to 17 cm (Table 3).

The data (Table 1) showed that the average value of the displacement moved by the rubber pipe which was placed in the feeding chute along with the berseem was 13 cm when the motor was switched off by using the cutoff switch. It was less than the total displacement (13cm<17cm) between the feed roller and blade. Hence, the arm fingers remained in the safer zone with the engaging of cutoff/limit switch. Similarly, the intelligent sensor was used in the aeroponic system (Lakhiar *et al.,* 2018).

Data (Table 2) show that the average value of the displacement moved by the rubber pipe which was placed in the feeding chute along with the berseem was 13.5 cm when the belt was removed from the flywheel by using the paddle mechanism. It was less than the total displacement (13.5cm<17cm) between the feed ruler and blade. Hence, the arm fingers were in the safer zone by engaging belt deflector paddle. In operation of this safety gadget, a spring-loaded deflector arm removed the running belt and the flywheel of the chopper was stopped due to the resistance offered by the bulk of fodder in the throat of the chopper. Similar results were shown in the case of flywheel-powered chaff cutter by humans as an energy source (Khope and Modak, 2013).

Data (Table 3) show that the average value of the displacement moved by the rubber pipe which was placed in the feeding chute along with the sugarcane was 9.5 cm when the motor was switched off by using the cutoff switch. It was less than the total displacement (9.5cm<17cm) between feed roller and blade. Hence, the fingers remained safe by engaging of belt deflector paddle. Similar results were shown in case of flywheel

Table 1. The data gathered during the experiment with cutoff/limit switch (test crop berseem)

Replication	Length of pipe moved in cutting head (cm)	Time (sec)	Average length (cm)	Average time (sec)	Total distance from feed ruler to blade (cm)	Comparison
R1	13.5	2.33	13	2.56	17	13<17
R2	12.3	2.56				
R3	13.3	2.81				

Table 2. The data gathered during the experiment with belt deflector paddle (test crop berseem)

Replication	Length of pipe moved in Cutting head (cm)	Time (sec)	Average length (cm)	Average time (sec)	Total distance from feed roller to blade (cm)	Comparison
R1	12.7	2.60	13.5	3	17	13.5<17
R2	14.1	3.76				
R3	13.8	2.86				

Table 3. Output performance of chopper with belt deflector paddle during chopping the sugarcane stalk

Replication	Length of pipe moved in Cutting head (cm)	Time (sec)	Average length (cm)	Average time (sec)	Total distance from feed roller to blade (cm)	Comparison
R1	10.5	1.77	9.5	1.69	17	9.5<17
R2	10	1.99				
R3	8.1	1.31				

Table 4. Experimental treatments and operational conditions of the chopper during the experiment

Replication	Length of pipe moved in cutting head (cm)	Time (sec)	Average length (cm)	Average time (sec)	Total distance from feed roller to blade (cm)	Comparison
R1	7.1	1.12	8.1	1.38	17	8.1<17
R2	8.5	1.9				
R3	8.8	1.14				

powered chaff cutter by human as energy source (Khope and Modak, 2013).

Data (Table 4) show that the average value of the displacement moved by the rubber pipe which was placed in the feeding chute along with the berseem was 8.1 cm when the motor was by using the paddle mechanism. It was less than the total displacement (13cm<17cm) between the feed ruler and the blade. Same as in the case of the intelligent sensor was used in the aeroponic system (Lakhiar *et al.,* 2018). In all the experiments the rubber pipe moved the less displacement in the case of a cutoff switch (8.1 and 13 cm) because there was friction between the belt and pulleys therefore the flywheel stop in minimum time as compared to the paddle mechanism in this case the belt was deflected and removed from flywheel the flywheel free to move therefore the rubber pipe moved greater displacement (13.5 and 9.5 cm) than the cutoff switch case. The hand of the worker was remained to safe from the blade in both cases but the cutoff switch mechanism was found more reliable than the paddle mechanism. The safety of the worker also depends on the type of fodder that was chopping by the chaff cutter machine. Because some of the types of the fodder have a hard stem and some have soft stem such as sugarcane, maize, sorghum and oat, berseem and barely, respectively.

Theoretical capacity

The theoretical capacity refers to the following parameter of the machine. The density of the crop that was chopped by the machine, Area of the throat of the machine, No. of knives on the cutting head, length of cut, speed of the cutting head and value of the constant. This was the designed capacity of chopper to measure the amount of chopped fodder in ton per hour through formula (Karunya *et al.,* 2016). Table 5 shows the theoretical capacity of the chaff cutter machine by feed freshly harvest sugarcane with three replications. The average theoretical capacity of the machine was 1.44 ton/h.

Actual capacity

The capacity of fodder chopper in real time under working conditions measured in ton per hours (Beerge *et al.,* 2021). The actual field capacity of chopper always remained less than therocitical capacity due to different variables viz; time, feed rate and density of crop that are not under control due to human variations. The actual capacity of the machine was checked by chopping the sugarcane with three replications. Only one type of blade was used in the experiment. The test crops were fed into the machine's feeding chute and was chopped. The chopping time and the output were then recorded. The outputs were labeled according to the order of their replications. These processes were repeated three times. Data (Table 6) show the actual capacity of the chaff cutter machine. The average actual capacity was 1.18 ton/h.

Machine efficiency

Machine efficiency was the fraction of the actual capacity of chopper and theoretical capacity of

chopper which was expressed in percentage. This value predicts that how much efficiently this chopper was worked during testing. Data (Table 7) showed the Machine average efficiency of the chaff cutter by feeding freshly harvested sugarcane with three replications. The average efficiency of the machine was recorded as 84.48%. Similar results were reported by Beerge *et al.* (2021).

CONCLUSION

It was concluded that the cutoff switch was more reliable because in that case, the rubber pipe moves less displacement in the cutting head. When the electric motor was switched off by a cutoff switch mechanism then the rubber pipe moved 8.1 cm while the testing crop was sugarcane and 13 cm while the testing crop was berseem. When the belt was removed from the flywheel by paddle mechanism the rubber pipe moved 9.5 cm while the testing crop was sugarcane and 13.5 cm while the testing crop was berseem. Machine efficiency of the chopper was calculated by the relation of actual chopping capacity and theoretical chopping capacity which was expressed in percentage. The average theoretical capacity was found to be 1.44 ton/h and the average actual capacity of the machine was measured as 1.18 ton/h. The average efficiency of the machine was calculated as 84.48 %. All these novel safety gadgets merely costed 4,500 PKR and the operation of traditional toka became safer in operation after the accumulation of safety gadgets.

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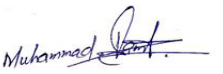
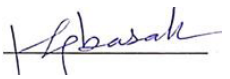
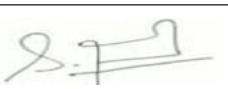
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Sr. No.	Author's name	Contribution	Signature
1.	Muhammad Usama Yaseen	Conducted the research and wrote-up the mansucript	
2.	Ghulam Saddique	Superisor	
3.	Muhammad Iqbal Sabar	Checked the design, safety features and test report	
4.	Muhammad Ashraf	Designed and developed the safety gadgets	
5.	Shahzad Ahmad	Assisted in designing and development of novel machine	
6.	Maqsood Ahmad	Assisted in testing of hazard free toka machine	