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Development of safer fodder-cutter machines: a case study from north India

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Abstract

Fodder-cutter machines are used everyday by farmers and their families in India for preparation of fodder for the livestock they own. An epidemiological study done in north India showed that all age groups sustain fodder-cutter injuries while operating the machine. More than 45 and 64% of the victims were children below 15 years of age in Phase I and II. The injuries led to a large number of limb amputations [43 cases (80%)] among the persons operating the machine or playing with the machine taking treatments in the study area hospitals. A detailed study of injuries and machine characteristics resulted in a safer fodder-cutter design. The design changes are cost effective and can be incorporated,in both existing and new fodder-cutter machines. This paper reports the process of the community-based study and the safer design features of fodder-cutter machine.

Keywords: Fodder-cutter; Agricultural injuries; Safety

1. Introduction

The population of cattle (cows) in India in 1987 is 196 million and that of buffaloes is 77 million (Singh, 1997). Out of this 34% cattle and 9% buffaloes are used for draught work for field operations. Fodder-cutting machines are used for chopping fodder for draft animals and domestic cattle. These can be operated manually or can

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be power driven using electric motors or diesel engines. The number of fodder-cutting machines was estimated to be 0.62 million in 1986–1987 (Singh, 1997). This number would be much higher now. The mechanization of agricultural practices has resulted in increased agricultural productivity in India but at the same time the incidence of traumatic injuries among agricultural workers seem to have increased also. It is estimated that every year in Haryana, Punjab and Uttar Pradesh (three states of northern India) alone there may be 5000–10,000 deaths, 15,000–20,000 amputations and 150,000–200,000 serious injuries due to agricultural related activities (Mohan and Patel, 1992). Another study from Madya Pradesh, India (Tiwari et al., 2002) reports an overall injury incidence rate of 1.25/1000 workers/year. Of all incidents, 77.6% were due to farm machinery, 11.8% were due to hand tools, and the remaining 10.6% were due to other factors. It was estimated that in the year 2000 there would have been about 17,480 agricultural incidents in Madhya Pradesh (population 60 million) causing death to about 2050 workers and injuries to about 16,770 workers, including amputations of limbs, burns, cuts, etc. Total monetary loss due to agricultural injuries in the state of Madhya Pradesh has been estimated as US $27 million/year.

World over, fatality rate for agricultural industry workers are higher than all-other industry workers (Singleton et al., 1981; Injury facts, 1985; Franklin et al., 2001; Horsburgh et al., 2001; Rautiainen and Reynolds, 2002). Biomechanics and ergonomics principles have been used to control injuries in road accidents, industry and sports, but their applications in agriculture have been limited. Agricultural machine related injuries involved all age groups. Farmers, unlike industrial workers, work as long as they can along with their family members irrespective of age (Hansen, 1986; Steuland et al., 1990). In older age groups, various reasons have been reported for injuries. These include economic necessity, slow reflexes, carelessness with increased experience, physiological impairments and other age related reasons (Hansen, 1986; Goodman et al., 1985). Injuries among children are prevalent in farm activities unlike other professions because of easy access to machines at farm and in the home. The involvement of children are also reported by Muckala (1967), DeMuri and Purschwitz (2000)%in and Reed and Claunch (2000) in agricultural, Mohan and Patel (1992) show that in north India children below 14 years of age were involved in 16% of all agricultural injuries. 30% of the equipment related injuries among 0–14 year old children were caused by fodder-cutting machines, and in the 0–4 year age group, 50% of the injuries resulted from these machines.

Agricultural workers in low-income countries (LICs) are neither covered by insurance nor do they have adequate infrastructure for medical facilities. In LICs safety standards and their enforcement are also not adequate enough to protect farmers from injuries. The International Labour Organization published a manual for safety in agriculture as far back as 1969 (Guide to Safety in Agriculture, 1969), which was useful in high-income countries (HICs) but had little impact in LICs. In addition, a large number of safety standards have been drawn up for agricultural activities which cover safety standards for agricultural equipment, operator control, alert systems, brake testing systems, roll over, protection, glazing materials (e.g.

ASAE standards). In India, it is only in the past few years that standards have been promulgated on fodder cutters (BIS 7898, 1981). A Dangerous Machine (Regulation) Bill was passed by Indian Houses of Parliament in 1983, which regulates trade and commerce in, and production, supply and distribution and use of dangerous machines and for payment of compensation to injured workers. This bill was initiated in the Indian Parliament because of the large number of severe injuries sustained annually due to threshing operations in agriculture. However, its important is not the same in every state of the country as agriculture is a state subject regulated locally. This paper reports the results of an epidemiological study, which resulted in safer design fodder-cutter machine.

2. Objectives

The objectives of this study were (1) to assess the magnitude of fodder-cutter-related injuries among farming communities (2) to conduct an ergonomic evaluation of the factors influencing the fodder-cutter machine injuries (3) to develop safer designs fodder-cutter machine

3. Methodology

3.1. Agriculture injuries survey

The study was done in two phases. In the first phase data on agricultural-related injuries was collected from nine contiguous villages of District Sonipat of the state of Haryana in 1987–1988. In the second phase of study 21 more villages were added, nine from District Baraut of state of Uttar Pardesh and 12 from Rai Block of Sonepat District of the state of Haryana in 1990–1991. These villages were selected for high agricultural activities and use of modern technology. These three areas are predominantly wheat, sugarcane and rice growing. In Phase-I, survey workers were trained to collect injury data from household surveys. These workers visited every house once every 2 weeks and obtained epidemiological information on all injury-related events for a period of 1 year in the first phase. In the Phase-II, informers were selected in each study village to report cases of all agriculture-related injuries over a 1-year period. For every injury case reported, a trained investigator visited the home of the victim and obtained all injury and equipment-related information (Tables 1–4).

Injuries from fodder-cutter machines are the unintentional consequence of action either during operation of the machine or while children playing with it. Abbreviated Injury Scale (AIS) defines separate AIS scores for typical injuries to seven major body areas (The Abbreviated Injury Scale, 1990). AIS classifies injuries as AIS scores ranging from AIS 1 (minor injury) to AIS 5 with AIS 2 as moderate, AIS 3 as serious not life threatening, AIS 4 as severe life threatening, survival probable and AIS 5 as critical, survival uncertain.

Table 1
Distribution of injuries by type of agricultural implement used and severity of injury (Phase I)

Implements	Severity of injury					Total (%)
	AIS 1	AIS 2	AIS 3	AIS 6	Unknown	
Manual fodder cutter	31	6	–	–	–	37 (6)
Powered fodder cutter	20	4	2	1	–	27 (5)
Thresher	7	2	1	–	–	10 (2)
Tractor	14	11	1	–	1	27 (5)
Trolley	4	4	–	–	–	8 (1)
Cultivator	2	1	–	–	–	3 (∼)
Harrow	8	3	–	–	–	11 (2)
Leveler	1	1	–	–	–	2 (∼)
Engine	23	3	1	–	–	27 (5)
Flour mill	1	1	–	–	–	2 (∼)
Manual plough	6	2	–	–	–	8 (1)
Seed drill	4	1	–	–	–	5 (1)
Tube well	7	3	–	–	–	10 (2)
Tonga	1	2	–	–	–	3 (∼)
Bullock cart	24	6	3	–	–	33 (6)
Spade	133	3	–	–	–	136 (24)
Sickle	130	1	–	–	–	131 (23)
Others	86	9	–	–	1	96 (17)
Total (%)	502 (87)	63 (11)	8 (1)	1(∼)	2 (∼)	576 (100)

(∼%) = less than 1%.

Table 2
Distribution of injuries by type of agricultural implement used and severity of injury (Phase II)

Implements	Severity of injury					Total (%)
	AIS 1	AIS 2	AIS 3	AIS 5	AIS 6	
Manual fodder cutter	25	28	1	–	–	54 (19)
Powered fodder cutter	15	14	4	–	–	33 (12)
Thresher	6	3	–	–	–	9 (3)
Tractor	15	15	1	1	1	33 (12)
Trolley	1	3	–	–	–	4 (1)
Cultivator	4	1	1	–	–	6 (2)
Harrow	6	3	–	–	–	9 (3)
Leveler	2	–	–	–	–	2 (1)
Engine	–	3	1	–	–	4 (2)
Seed drill	3	–	–	–	–	3 (1)
Tube well	4	4	1	–	–	9 (3)
Bullock cart	21	16	3	1	1	42 (15)
Hand tools	49	4	1	–	–	54 (19)
Others	8	9	1	–	2	20 (7)
Total	159 (56)	103 (37)	14 (5)	2 (1)	4 (1)	282 (100)

Table 3
Distribution of injuries by type of agricultural implement used and age of victim (Phase I)

Implement	Age (years)						Total (%)
	0–4	5–14	15–24	24–54	55–64	>64	
Manual fodder cutter	5	18	3	11	–	–	37 (6)
Powered fodder cutter	1	5	6	10	3	2	27 (5)
Thresher	1	2	3	4	–	–	10 (2)
Tractor	–	2	6	16	1	2	27 (5)
Trolley	–	2	1	4	1	–	8 (1)
Cultivator	–	1	2	–	–	–	3 (~)
Harrow	–	4	3	3	–	1	11 (2)
Leveller	–	–	1	1	–	–	2 (~)
Engine	1	1	12	13	–	–	27 (5)
Flour mill	–	–	–	–	–	2	2 (~)
Manual plough	1	1	3	1	1	1	8 (1)
Seed drill	–	–	2	3	–	–	5 (1)
Tubewell	–	1	6	2	1	–	10 (2)
Tonga	–	1	1	–		1	3 (~)
Bullock cart	1	7	13	6	2	4	33 (6)
Spade	1	10	77	42	4	2	136 (24)
Sickle	1	15	44	59	7	5	131 (23)
Others	2	13	30	41	6	4	96 (17)
Total (%)	14 (2)	83 (14)	213 (37)	216 (38)	26 (5)	24 (4)	576 (100)

Table 4
Distribution of injuries by type of agricultural implement used and age of victim (Phase II)

Implement	Age (years)						Total (%)
	0–4	5–14	15–24	24–54	55–64	>64	
Manual fodder cutter	11	30	4	7	2	–	54 (19)
Powered fodder cutter	5	9	4	12	1	2	33 (12)
Thresher	–	1	4	3	–	1	9 (3)
Tractor	2	1	9	14	2	5	33 (12)
Trolley	–	1	1	2	–	–	4 (1)
Cultivator	1	–	1	4	–	–	6 (2)
Harrow	–	4	1	3	–	1	9 (3)
Leveller	1	–	–	1	–	–	2 (1)
Engine	–	–	1	2	–	1	4 (1)
Seed drill	–	1	–	1	–	1	3 (1)
Tubewell	1	1	1	5	1	–	9 (3)
Bullock cart	5	6	7	11	5	8	42 (15)
Hand tools	2	8	23	20	–	1	54 (19)
Others	3	2	1	12	–	2	20 (7)
Total (%)	31(11)	64(23)	57(20)	97(34)	11(4)	22(8)	282 (100)

3.2. Fodder-cutter injury survey of the victims taking treatment in the hospitals of the study area

Visits were made to neighbourhood villages where fodder-cutter machines were involved in injury and victims have taken treatment in the study area hospitals. A total of 52 fodder-cutter injuries were investigated in detail. Details regarding the event, injuries, and risk factors were obtained. Detailed investigation of occurrence of event, type of injury sustained and risk factors associated were obtained. The details of victim, body part injured and machine parts associated with injury were also obtained (Table 5).

3.3. Engineering interventions for fodder-cutter injuries prevention

Based on the information on factors associated with injuries (fodder-cutter machine part involved in the injury and mode of operation while occurrence of incidence) engineering design interventions were developed that were suitable for retrofitting in the existing machines and for incorporation in new fodder-cutter machines.

4. Results

Phase-I was a baseline study in which we obtained records of all injuries that disabled victims for 1 day or more in a total population of 19,723 persons. However, in Phase-II we expected the informer to report "serious" injury cases only which occurred in the village. This study was conducted with the intention to obtain a larger sample of AIS $\geqslant 2$ (The Abbreviated Injury Scale, 1990) injuries to obtain a better epidemiological understanding of the factors involved. The total population of all households covered in Phase-II was 78,890. The first phase gives a better idea of all injuries where as the second phase gives a bigger sample of more severe injuries but it was is not representative of all injuries sustained by the population.

4.1. Injury magnitude

A total of 576 and 282 injuries were reported in Phase-I and Phase-II, respectively (Tables 1 and 2). Fodder-cutters accounted for 64 (11%) and 87 (31%) of total agricultural injuries in the two study phases, respectively. This is the only machine which is used daily for chopping fodder for livestock. The usage is at least once or twice every day and duration depends on the number of animals owned by the family. On an average the fodder cutter machine is operated for about 1 h daily. In the study area of nine villages of Phase-I there were total of 815 powered fodder cutters and 1186 manual cutters.

4.1.1. Injuries recorded in Phase-I

In this study, 13 (20%) injuries of AIS 2 and above were due to fodder cutting machines. Children below 15 years of age were involved in 29 (45%) of cases.

Children (0–14 years) playing with fodder cutters resulted in 21 (70%) injuries. In most of the cases the children's fingers were cut by the blade when another child rotated the flywheel while they were playing with the equipment. In three cases the fingers were amputated by the blades. Eighteen cases involved deep cuts on the back of fingers due to slips while sharpening blades. All these injuries however were of AIS 1 severity. Injuries in other cases (7) were sustained while cleaning the fodder cutter, removing grass from the gears or because of entanglement of clothes. There was one death involving a powered fodder cutter. The victim, a woman, was found dead with her long scarf entangled in the uncovered gears of the machine. It is suspected that she died of strangulation or head injury. The exact medical reason is not known, as an autopsy was not conducted.

The incidence of AIS 2 and more severe injuries was 5.1 per thousand of manual fodder cutters and 8.6 of powered fodder-cutter machines.

4.2. Injuries recorded in Phase-II

In the second Phase, 47 (48%) injuries of AIS 2 and above were caused because of fodder cutting machines. Children below 15 years of age were involved in 55 (64%) cases and 50 (90%) of them got injured while playing with the fodder-cutter machine and rest while working with the machine.

4.2.1. Injuries recorded for the victims taking treatment in the hospitals of the study area

In addition to the cases reported from our study villages we interviewed all fodder cutter injury victims ($N = 52$) with serious cuts or amputations taking treatment in nearby hospitals. Table 5 gives detail of the victims, body part injured and machine part involved in injury.

Out of 52 cases interviewed, 11 were children below 15 years of age. Out of 11 children eight got injured while playing with the machine. All of them had either their fingers or hand amputated from the cutting blade. Total cases of amputations were 43 (83%).

4.3. Machine parts involved in fodder-cutter injuries

Details of the machines associated with injuries obtained from the victims under treatment in different hospitals are presented in Fig. 1. In case of victims 15 years of age or younger, 8 (73%) of the injuries were from the cutting blade and while playing.

The fodder is fed into the cutting wheel by feed rollers, and at times along with the fodder, the fingers get trapped in the feeding rollers. The hand is further fed into the rotating blades by the roller, and as a result, the fingers and the hands get crushed between the rollers first and then get cut by the blades on the flywheel. In electric motor or diesel engine powered fodder cutters the rotational speed is very high and it is almost impossible for a person to take any protective measure once a hand is caught in the feeding rollers. The situation in which injuries are common are (1) a

Table 5
Details of fodder–cutter machine injured victims

Case No.	Age (years)	Sex	Body part	Injury	Machine part involved
1	5	Male	Left hand fore arm	Amputation	Blades
2	52	Female	Head	Scalp avulsion	Power transmission shaft
3	32	Female	Left hand all fingers	Amputation	Roller
4	8	Female	Right hand two fingers	Amputation	Blades
5	17	Female	Right hand wrist	Amputation	Roller
6	65	Male	Left hand	Amputation	Roller
7	16	Female	Head	Scalp avulsion	Gears
8	66	Male	Right hand	Amputation	Roller
9	14	Male	Left hand wrist	Amputation	Roller
10	46	Male	Left hand	Amputation	Roller
11	27	Male	Left hand	Amputation	Roller
12	13	Female	Left hand	Deep cut	Roller
13	75	Male	Right hand fingers	Fracture	Gears
14	25	Female	Right hand fingers	Amputation	Roller
15	16	Female	Right hand	Amputation	Roller
16	62	Male	Left hand	Amputation	Roller
17	17	Male	Right hand	Amputation	Roller
18	18	Female	Both hands	Amputation	Roller
19	7	Female	Right hand	Amputation	Blades
20	30	Female	Left hand	Amputation	Roller
21	70	Male	Right hand	Amputation	Roller
22	60	Male	Right hand	Amputation	Roller
23	75	Male	Right hand	Amputation	Roller
24	40	Female	Left hand	Amputation	Roller
25	38	Female	Right hand	Amputation	Roller
26	16	Male	Left hand	Amputation	Roller
27	52	Male	Right hand	Amputation	Blades
28	45	Male	Right hand	Amputation	Roller
29	23	Male	Right hand	Amputation	Roller
30	38	Male	Left hand two fingers	Amputation	Roller
31	52	Male	Left hand	Amputation	Roller
32	42	Male	Left hand	Amputation	Roller
33	26	Female	Right hand	Amputation	Roller
34	68	Male	Right hand	Amputation	Roller
35	20	Male	Right hand	Amputation	Roller
36	38	Male	Right hand	Amputation	Roller
37	3	Female	Right hand two fingers	Amputation	Blades
38	55	Male	Right hand	Amputation	Roller
39	70	Male	Death case	Head injury	Roller/Blades
40	65	Male	Left hand	Amputation	Roller
41	26	Male	Right hand	Amputation	Roller
42	40	Male	Right hand	Amputation	Roller
43	11	Male	Left hand	Amputation	Roller
44	33	Male	Left hand three fingers	Amputation	Blades
45	3	Female	Right hand fingers	Deep cut/laceration	Blades
46	7	Female	Right hand fingers	Fracture/laceration	Blades
47	68	Male	Both hands	Amputation	Roller
48	23	Male	Left hand fingers	Fracture/laceration	Blades
49	18	Male	Left hand	Amputation	Roller
50	45	Female	Right hand	Amputation	Roller
51	6	Female	Right hand	Amputation	Blades
52	10	Female	Right hand fingers.	Amputation	Blades

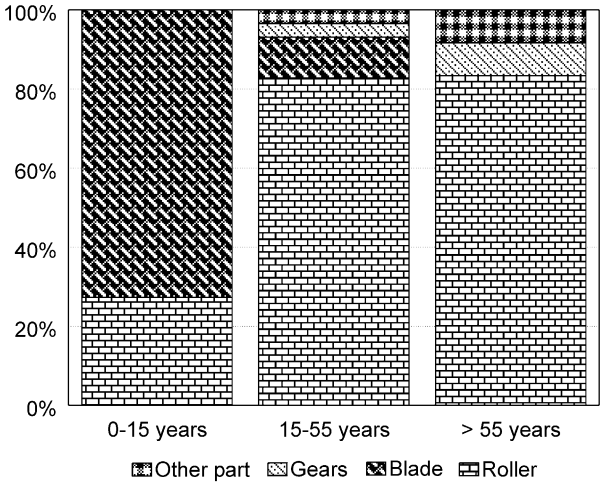

Fig. 1. Fodder-cutter machine parts associated with injuries ($N = 52$).

person attempts to feed small pieces of fodder into the roller; (2) the feeding chute is small; (3) children operate the machine and are unable to observe safe posture and operating methods; (4) very young children play with the machine and inadvertently get their hands/fingers cut by blades on the rotating flywheel; (5) loose garments get caught in the rotating parts; and (6) while sharpening the blades they cut the back of their fingers if the sharpening file slips and the hand hits the blade.

Crush injuries caused by hand/fingers getting trapped in feed rollers were 3 (27%) in 15 years or younger age group, 24 (83%) in the 15–55 age group and 10 (84%) among the older than 55 years. Of these, most of them resulted in amputation of fingers and hands and others involved deep cuts, and laceration.

Only 3 (11%) cases were reported for injury from blades and one each from gears and other part of fodder cutting machine in 15–54 years of age group. In the older age group of 55 years and above no injury was reported from blade and only one injury each from gear and other part of the fodder-cutting machine was observed.

5. Engineering interventions

5.1. Safer design of fodder-cutter machines

Based on the analysis of Phase I and Phase II injuries revealed that fodder-cutter injuries are prevalent in all ages (11 and 31%, respectively) and more than 45% are in children of age group less than 15 years in Phase I and 60% in Phase II. The analysis of 52 cases under treatment in hospitals, studied in detail, clearly showed that both feeding (rollers) and as well as cutting system (blades) are dangerous to adults and children. The safety interventions should be so designed that it prevents injuries from both feeding and cutting side and should be easily introduced to new

and existing fodder-cutter machines. Following interventions were developed to make the fodder-cutter machine safer.

5.1.1. Warning roller

A roller of metal or wood can be installed before the feed roller as a warning device, which warns the operator that the hand has gone in the dangerous area (Fig. 2a). Its upward movement is controlled by the cam, which lifts the roller when the straw is pushed into the feeding mouth of the fodder cutter. When the chute is empty, the roller comes down with help of springs provided for the purpose. While feeding the fodder, the operator's finger touches the roller, which acts as a pre-warning of the impending danger to the fingers. In non-operating mode, this roller prevents children from putting their hand near the feeding rollers because of its resistance to lifting.

5.1.2. Blade safety guard

The blade safety guard is made out of mild steel rods of 9 mm diameter which is given a similar curvature as the fodder-cutter blade shaped into holes at two ends for fitment in the fodder cutter with the blade mounting bolts (Fig. 2b). The device precedes the blades in the direction of motion and prevents injuries to the limbs as it pushes the limbs away and acts as a warning signal before the blades hit the limb. This safety device can be fitted on each blade of the fodder cutter.

5.1.3. Gear cover

The safety gear cover is made out of mild steel sheet, which covers the open gear system available on the fodder cutter (Fig. 2c). It can be fitted with the help of two nuts to the body of the fodder cutter. On the sides, the plates have been bent to cover gears from the sides. At the top, the centre hole has been provided for facilitating the lubrication of gears.

5.1.4. Flywheel locking pin

The safety device is a linch pin with chain to lock the fodder-cutter flywheel, when it is not requited to be operated (Fig. 2d). This can be fixed on the flywheel main gear shaft at the end so as to restrict the movement of the system. This is specially needed to lock the movement of fodder-cutter blades in order to avoid injuries when fodder cutter is not in use. The linch pin can be fastened to body of fodder cutter with the help of chain.

5.1.5. Finger guard

A finger guard installed on the sharpening file (Fig. 2e). This would prevent cuts even if the file slips while sharpening blades.

All these safety accessories can be fitted on existing as well as new machines (Fig. 2) and can be easily fabricated by village level technicians and artisans. The proposed retrofitting will increase fodder-cutter cost by Rs 150–Rs 200 (3$–5$). This is not very significant compared with the cost of the fodder-cutter machine (Rs 2000 or 40$).

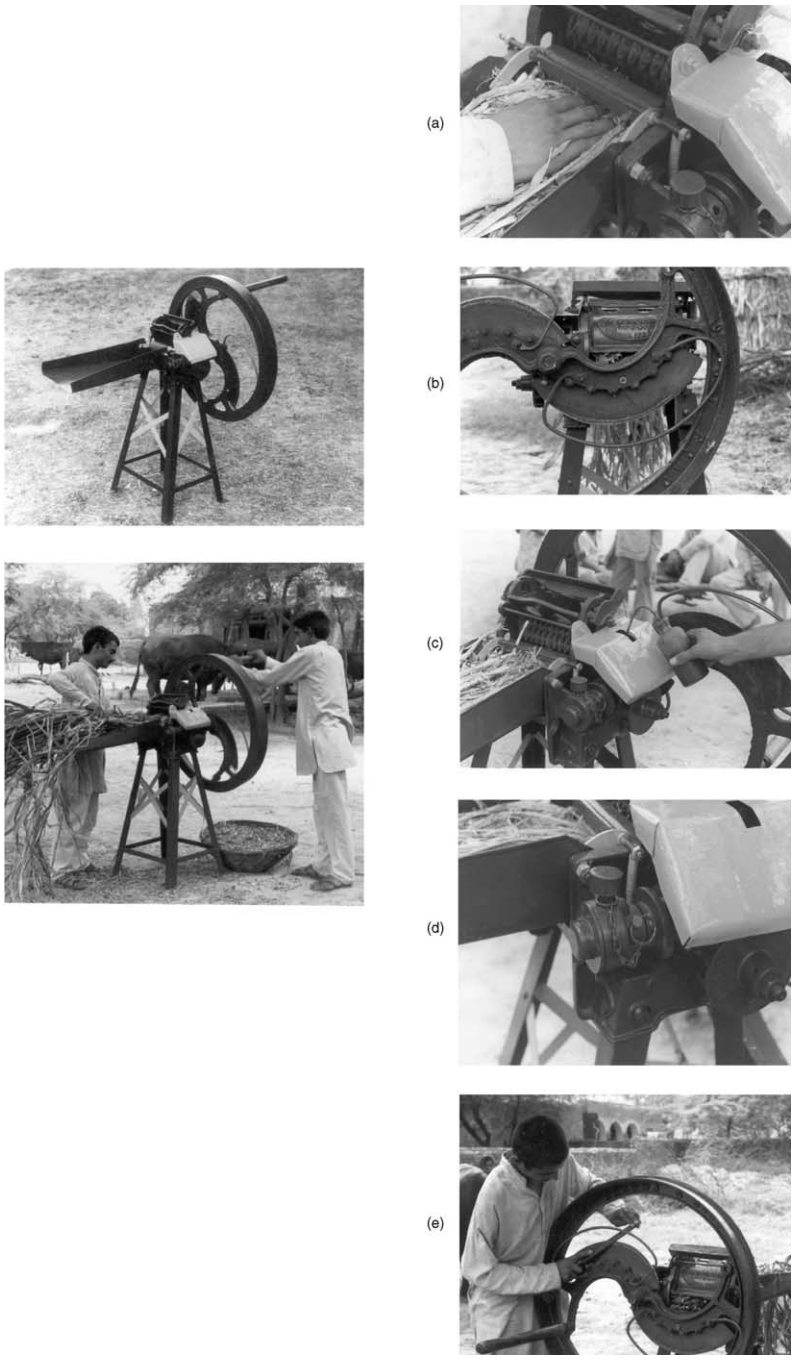

Fig. 2. Safer design of fodder-cutter machine (a) warning roller; (b) blade safety guard; (c) gear cover; (d) flywheel locking pin; (e) finger guard.

5.2. Evaluation and feedback on safer design

One-hundred fodder cutters were retrofitted with safety accessories developed by us and monitored thereafter. Some users experienced feeding difficulties and this feedback was used to improve the design of the warning roller. Their suggestions were also incorporated to improve the design of locking pin and gear cover. Local manufacturers were also consulted for simplifying the design to suit local technology.

The final design was exhibited in three farmer's fairs in India to reach a larger spectrum of farming community. The final design interventions have received a very favorable response from the users. These were evaluated at the ''Farm Machinery Training and Testing Institute, Hissar, Haryana , India. For wider dissemination of the information on this design, leaflets have been printed in a style and language easily understood by the villagers and local workshop owners. These specifications are being incorporated in Bureau of Indian Standards, Manually Operated Fodder-Cutter Specification (BIS 7898) and in a proposed standard on ''Safety Requirements for Power Chaff Cutter''.

6. Concluding remarks

Fodder cutting machines are major cause of serious injuries to the hands of both adults and children in the villages of northern India. Among agricultural machine related injuries fodder cutter machine constitute a significant proportion (11% and 31% in Phase I and II) of all injuries.

The severe injuries (AIS $\geqslant$ 2) were 20 and 48% in Phase I and II, respectively. More than 45% victims injured were children below the age of 15 years. The mechanism of injury in the two groups, however, is different. In the adults, injuries occur from feeding side while feeding the fodder to the machine while children get injured while playing with the machine. It was possible to design simple but effective engineering interventions to prevent injuries. These features could be easily introduced at the time of manufacturing or retrofitted in the existing machines by local artisans/technicians.

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