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MATERIALS SCIENCE AND MECHANICS OF MACHINES

DESIGN FEATURES OF SHREDDING MACHINES FOR FEEDING MACHINES

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Abstract

The article presents the results of the study of design features of harvesters` shredding machines used on farms in Ukraine. It has been established that most highly efficient harvesters, more than 75% use a drum shredder, which is closed and open, two-section with a V-shaped arrangement of knives. The design of disk, rotor and combined shredders has been analyzed. Their design features, advantages and disadvantages in work have been mentioned. It has been discovered that the energy consumption of the technological process of grinding-transporting the mass is reduced, and the reliability of the apparatus is increased by using bitumen-knife grinders, which perform multi-plane cutting at the speed of 4-8 m/s. The main parameters of the working bodies are systematized and the technical characteristics of the roll and pack balers that contain the shredding machine of multiplanar cutting.

Keywords: forage harvesting unit, shredding machine, cutting drum, disk machine, rotor, cutting, stem forage.

Formulation of the problem. All types of stem fodder are used on farms of agro-industrial complex of Ukraine: hay, haylage, silage, green fodder, which form almost 60% of the cost of livestock products [1]. The choice of existing feed procurement technologies for the cattle`s needs depends on the crop grown, the required type of fodder, the method of harvesting and the available amount of energy and machinery on the farm.

The analysis of technologies of stalk forages preparation allows to state that realization of the most widespread of them leads to losses of 40% of nutrients available in plants, and the most protein-rich component - leaf fraction is lost. Deficiency of protein in the diet of 35-40% leads to overexpenditure of fodder by 40%, shortage of livestock products [2].

The bulk of fodder (haylage, silage) for cattle is harvested using forage harvesters and combines. Their work should provide high-quality grinding of fodder for their further compaction during storage, which ultimately leads to better assimilation of it by animals and, accordingly, to increase productivity.

At present, there is a large percentage of forage harvesting equipment in Ukraine is occupied by machines that are obsolete (for example, KPI-2.4; KSK-100), do not meet the requirements for shredding the stem mass and are practically no longer produced. Analyzing the market of agricultural machinery in Ukraine, we see that there are also no self-propelled domestic forage harvesters, which allow to store fodder of good quality. This niche is occupied by forage harvesters of foreign manufacturers, which significantly affects both the price of forage harvesters and employment creation.

The variety of designs, availability of combines of different productivity, strengthening of requirements to indicators of quality of crushing, economic requirements concerning prime cost of harvesting of stalk forages cause necessity and validity both technological schemes of combines, and new design decisions of their main working bodies, including the shredding machine.

Analysis of the researches and publications. Harvesting of natural and sown grasses, grain legumes, tall crops (corn, sunflower, etc.) of entire, drill or square-nest sowing for green fodder, haylage, silage, grass meal, pellets, briquettes consists of mowing operations with simultaneous grinding and loading into vehicles with pull-type mowers-shredders, pull-type forage harvesters, self-propelled forage harvesters, semi-mounted combines, which are aggregated with energy means, etc. The crushed mass is transported by trailers, trucks to the farm for direct feeding to animals or for processing or storage.

The main theories of processes performed by forage harvesters are set out in the works of N.E. Reznik [3, 4] and the works of other researchers [5-9]. As a result of the development of stem forage harvesting technologies, some elements of the combine were changed too, working bodies and units were improved, which led to the improvement of the combine design as a whole [10-14]. Thus, forage harvesters intended for harvesting of silage from thick-stemmed crops disap-

peared from the market, and they were replaced by forage harvesters, which are adapted both for harvesting forage from thick-stemmed crops and from herbage and swaths.

The shredder is the main and rather energy-consuming working unit of the forage harvester. Its design determines the technological scheme of the combine and the location of the main components.

Two types of shredders are used in forage harvesters - drum (cylindrical) and disk. Simultaneously with cutting, they perform the function of mass transportation. These are precision cutting devices, as there is a dependence between the feed rate of the feed rollers and the cutting length.

At present, Ukraine produces small forage harvesters (up to 100 kW) and middle machine batches (100-150 kW). Among them there are are combines KRP-F-2, KPI-F-2,4A, KPF-30 (LLC SPE "BILOTSERKIVMAZ"), as well as KKZ-150 "Olympus" (OJSC "Olympus") and KZK-4,2 (LLC "Borex "), which are made only by request. Imported forage harvesters with a capacity of 305-600 kW produced in Germany, Belarus, Russia, USA are also widely used.

Formulation of the goals of the article. The purpose of the article is to highlight the results of the analysis of technical solutions for the shredding machines of forage harvesters, the design features of their main working bodies and to determine trends in their development.

Presentation of the main research material. Most highly efficient forage harvesters (over 75%) use a drum shredder, which includes a cutting drum covered by a casing, an anti-cutting plate and feed rollers.

The drum of the shredding machine is structurally made as a shaft with disks mounted on it, to which knives are attached (Fig. 1). It can be single-section, when the knives are located along the entire length of the drum, or several sectional. The main measurements of the drum shredder are diameter and width. In combines of small and medium productivity the diameter of a drum is within 400-800 mm, width - 400-700 mm, frequency of rotation - 800-1100 rpm. The cutting speed is 28-40 m/s. Drums with a diameter of 406 to 800 mm and a width of 520 to 800 mm are installed on modern foreign forage harvesters. Increasing its width allows to increase the cross-sectional area of the receiving neck, and thus increase the productivity of combines. However, it should be noted that the energy consumption for the transportation of fodder by these shredders is from 30 to 50% of the total [15].

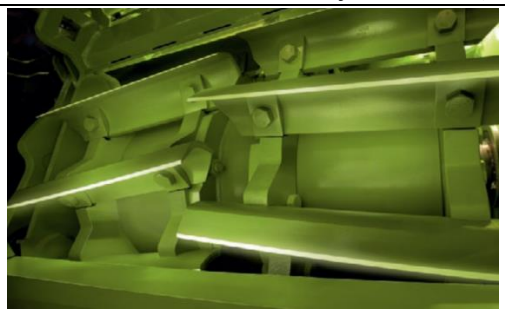
All modern models of shredding machines are equipped with an automatic knife sharpening system and an electro-hydraulic system for adjusting the gap between the drum blades and the anti-cutting plate.

Most drums (Fig. 1) of closed and open forage harvesters (Krone, Claas, John Deere, New Holland, Rostselmash, etc.) are two-section with a V-shaped arrangement of knives, which provides an effective oblique cut and high cutting frequency and smooths dynamic loads while cutting [10-14]. In this case, the crushed mass is directed to the centre of the drum, which allows to form its flow, reduce friction on the side walls of the silo and energy consumption for transportation. Closed drums are stiffer, which explains the transition of some companies to this design.

The advantage of drum shredders is a large moment of inertia, and thus a relatively high stability of the working process and increased throughput. The disadvantages include the high energy consumption of grinding and overexpenditure while creating a powerful air flow.

In addition to drum shredders, manufacturers produce machines with a disk cutting device (Fig. 2). Such devices are installed mainly on pull-type and semi-mounted forage harvesters, as well as machines that are aggregated with universal energy means, their use is due to the design of the combine as a whole. Examples of such machines are combines of Kemper model, KPK 3000 of K-G-6 complex "Polissya-250" and KDP-3000 of "Gomsilmash" production. The cutting device consists of a rotating disk with knives rigidly fixed on it, a loading mouth (window) and a cylindrical casing with a branch pipe (unloading neck). The blade of the knife is mostly rectilinear and located on a radial line or with an inclination relative to it in one direction or another. Radially mounted throwing blades are fixed on the disk next to the knives.

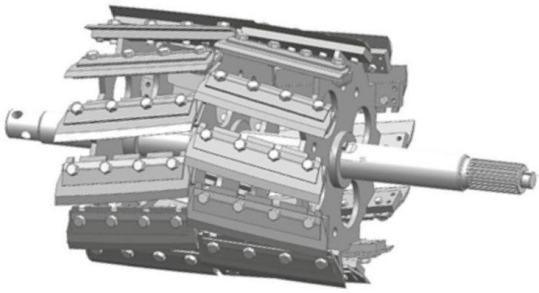
Krone, BIG X 500, 650, 800, 1000



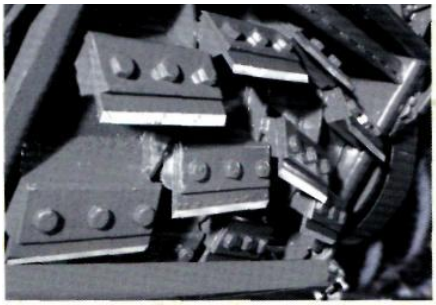
Claas, "Jaguar" V-Max 930-980

John Deere, Dura-Drum

New Holland FR 9000



Rostselmash, RSM 1701 and Don 680M



Gomselmash, "Palesse" FS8060

Fig. 1. General view of grinding drums

The diameter of the disk, at the end points of the knives, varies from 670 to 1200 mm, the speed of the most distant points of the knives from the axis of rotation - 35-52 m/s, the minimum cutting speed - 8-12 m/s.

The disadvantages of disk shredders include the limitation of the width of the loading neck of the device with the radius of the disk, which does not allow its use on highly efficient machines and the uneven load on the disk shaft. Studies of the shape of the knife line revealed the shortcomings of a flat knife with a straight blade, the main of which is the uneven load on the disk shaft. However, in practice, such knives are mainly used, given the simplicity of their production.

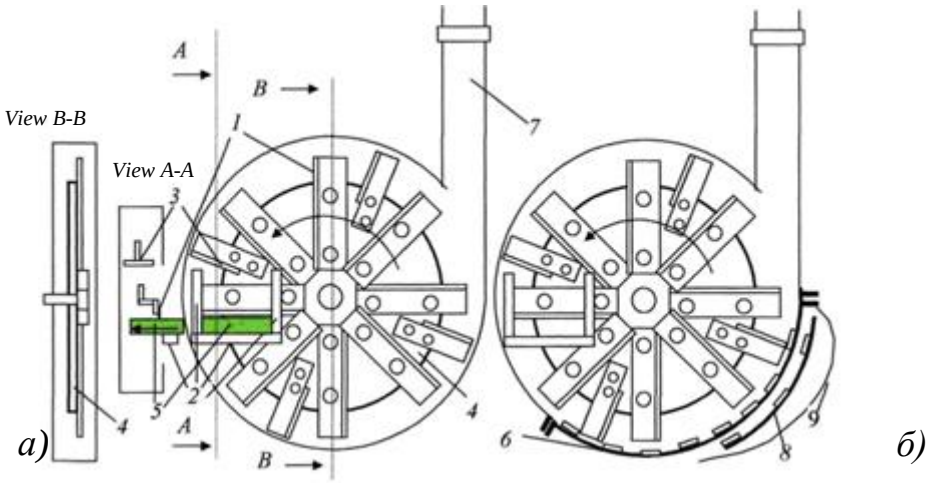


Fig. 2. Disc shredding-throwing machine with a smooth (a) and corrugated (b) bottom: 1 - knife blade; 2 - anti-cutting plate; 3 - transporting shovel; 4 - disk; 5 - layer of plants; 6 - corrugated reactor; 7 - silo pipeline; 8 - replaceable corrugated reactor; 9 - replaceable pallet

The rotary grinding apparatus consists of a rotor having a horizontal axis of rotation, on which knives with or without transport blades, an anti-cutting plate and a casing with an unloading branch pipe are hinged (Fig. 3). The diameter of the rotor with knives varies from 500 to 820 mm in width up to 2.0 m. The rotor speed varies from 1100 to 1600 rpm, the blade speed - from 36 to 60 m / s. The blades of the knives are usually parallel to the axis of rotation of the rotor and provide chopping during the process.

Along with such advantages as simplicity, reliability and universality, the disadvantage is the significant energy consumption (up to 8 MJ / t), low productivity (up to 1.5 ha / h) and low cutting quality (torn stem cut) [4, 15].

To improve the quality of grinding, a drum or disk shredder is installed in series with the rotary shredder (Fig. 4, a, b). In this case, the rotary shredder performs the function of the working bodies of the harvester: cuts the plants at the roots with knives without transporting blades and transports them into the shredder chamber.

However, such schemes are not used in modern forage harvesters.

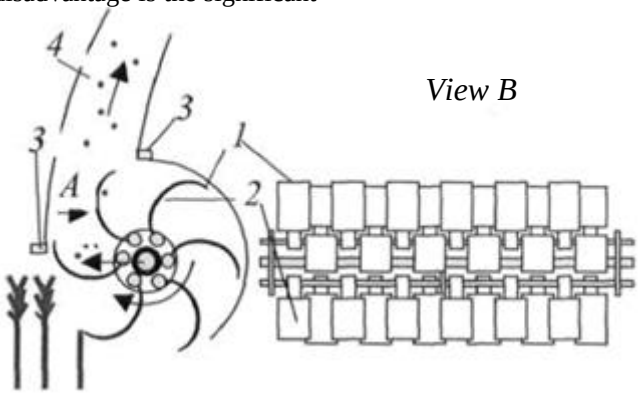
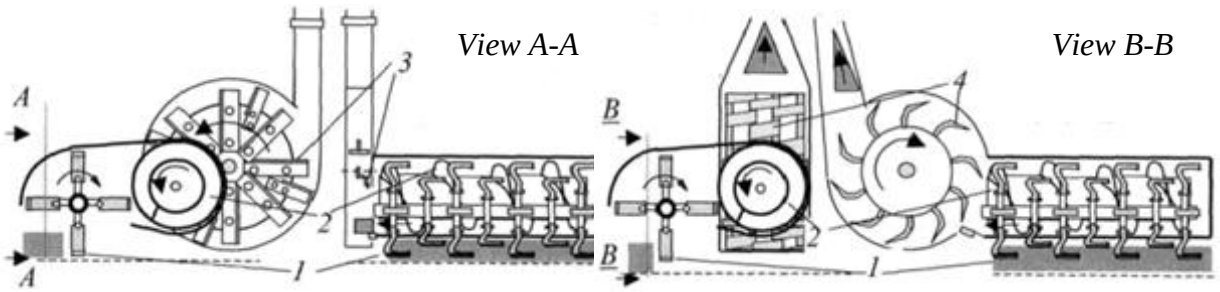


Fig. 3. Rotary shredding machine with hinged knives: 1 - knife blade; 2 - throwing blade of the knife; 3 - anti-cutting plate; 4 - unloading branch pipe



а) *б)*

Fig. 4. Shredding machine of double grinding with disk (a) and drum (b) shredding-throwing apparatus: 1 - rotor knife; 2 - transverse auger; 3 - a knife of a disk; 4 - knife drum

The energy consumption of the technological process of grinding-transporting the mass is reduced, the reliability of the device is increased by using bitterskill grinders, which perform multi-plane cutting at a speed of 4-8 m/s. Such devices are used in construction and technological schemes of balers of such well-known foreign firms as: Pottinger, Mengele, Taarup (Denmark), Far, Claas, Krone, Deutz Fahr (Germany), New Holland, Case, John Deere (USA) and others.

Technical characteristics of roll and pack balers containing a multi-plane cutting crusher are given in tables 1 and 2. Characteristics of balers are given in table 3.

Table 1

Technical characteristics of roll balers with a grinding device

Firm (country)	Model	Width and diameter of rolls, m	Pick-up width, m	Feeding rotor (number of teeth)	Length and diameter of the rotor, m	Number of knives	Theoretical cutting length, mm	Required power, kW / hp
Claas (Germany)	**Variant**							
	380 RC	1,2x0,9-1,8	2,10	RotoCut, 4		14	70	
	385 RC	1,2x0,9-1,8	2,10	RotoCut, 4		14	70	
	360 RC	1,2x0,9-1,55	2,10	RotoCut, 4		14	70	
	365 RC	1,2x0,9-1,55	2,10	RotoCut, 4		14	70	
	Rollant							
	350 RC	1,2x1,25	2,10	RotoCut, 4		14	70	
	354 RC	1,2x1,25	1,85/2,10	RotoCut, 4		16	-	
	355 RC Comfort	1,2x1,25	2,10	RotoRevers, 4		16	-	
	355 RC Uniwrap	1,2x1,25	2,10	RotoRevers, 4		16	-	
Krone (Germany)	**Round Pack**							
	1250	1,2x1,25	1,95	Multi-Cut, 3	1,2 / 0,41	17	64	36 / 50
	1550	1,2x1,55	1,95	Multi-Cut, 3	1,2 / 0,41	17	64	40 / 55
	Combi Pack							
	1250	1,2x1,25	1,95	Multi-Cut, 3	1,2 / 0,41	17	64	43 / 60
	1500	1,2x1,5	1,95	Multi-Cut, 3	1,2 / 0,41	17	64	51 / 70
	Vario Pack							
	1500	1,2x1,0-1,5	1,95	Multi-Cut, 3	1,2 / 0,41	17	64	36 / 50
	1800	1,2x1,0-1,8	1,95	Multi-Cut, 3	1,2 / 0,41	17	64	40 / 55
	Comprima							
	F 125 XC	1,2x1,25	2,15	X-Cut, 3	1,2 / 0,53	17 / 0,8,9,17,26	64 / 42	36 / 50
	F 155 XC	1,2x1,25-1,5	2,15	X-Cut, 3	1,2 / 0,53	17 / 0,8,9,17,26	64 / 42	40 / 55
	V 150 VC	1,2x0,9-1,5	2,15	X-Cut, 3	1,2 / 0,53	17 / 0,8,9,17,26	64 / 42	36 / 50
	V 180 XC	1,2x0,9-1,8	2,15	X-Cut, 3	1,2 / 0,53	17 / 0,8,9,17,26	64 / 42	40 / 55
	CV 150 XC	1,2x0,9-1,5	2,15	X-Cut, 3	1,2 / 0,53	17 / 0,8,9,17,26	64 / 42	51 / 70
	CF 155 XC	1,2x1,25-1,5	2,15	X-Cut, 3	1,2 / 0,55	17 / 0,8,9,17,26	64 / 42	51 / 70
Pottinger (Austria)	**Rollprofi**							
	3200 L SC	1,2x1,25	2,0	Proficut, 2		0, 14	70	44 / 60
	3300 L SC	1,2x1,25	2,20	Proficut, 2		0, 13, 25	45	55 / 75
	Varioprofi							
	6165 classic	1,20x0,6-1,65	2,20	Proficut, 4		0, 14	70	59 / 80
	6200 classic	1,20x0,6-2,0	2,20	Proficut, 4		0, 14	70	81 / 110
	6165 L SC	1,20x0,6-1,65	2,20	Proficut, 4		0, 14, 25	70, 45	59 / 80
	6200 L SC	1,20x0,6-2,0	2,20	Proficut, 4		0, 14, 25	70, 45	81 / 110

Table 2

Technical characteristics of roll balers with a grinding device, that form rectangular packs

Firm (country)	Model	Width and diameter of rolls, m	Pick-up width, m	Feeding rotor (number of teeth)	Length and diameter of the rotor, m	Number of knives	Theoretical cutting length, mm	Required power, kW / hp
Claas (Germany)	**Quadrant**							
	2100 RC	0,80x0,70	2,10	RotoCut, 4	0,80 / -	8 / 16	47	73 / 100
	2200 RC/FC	1,20x0,70	2,10	RotoCut, 4 FineCut, 4	1,20 / -	25(0,6,13, 25) 49	45 20	92 / 125
	3200 RC/FC	1,20x0,70	2,10	RotoCut, 4 FineCut, 4	1,20 / -	25(0,6,13, 25) 49	45 20	-
	3400 RC	1,20x1,0	2,35	RotoCut, 4	1,30 / 0,86	25(0,12,13,25)	45	-
Krone (Germany)	**Big Pack**							
	890 XC	0,80x0,90	1,95	X-Cut, 3	0,80 / 0,55	16	44	95 / 130
	1270 XC	1,20x0,70	2,35	X-Cut, 3	1,20 / 0,55	26	44	100 / 136
	1290 XC	1,20x0,90	2,35	X-Cut, 3	1,20 / 0,55	26	44	112 / 152
	1290 HDP XC	1,20x0,90	2,35	X-Cut, 3	1,20 / 0,55	26	44	147 / 190
	12130 XC	1,20x1,30	2,35	X-Cut, 3	1,20 / 0,55	26	44	140 / 190

The main unit of these machines is a shredder of sliding cutting, the feeding device of which can be made (Fig. 5) in the form of a chain-finger conveyor, an eccentric reel with controlled rakes (rake) or a rotor.

Table 3

Technical characteristics of pick-up trucks with a grinding device

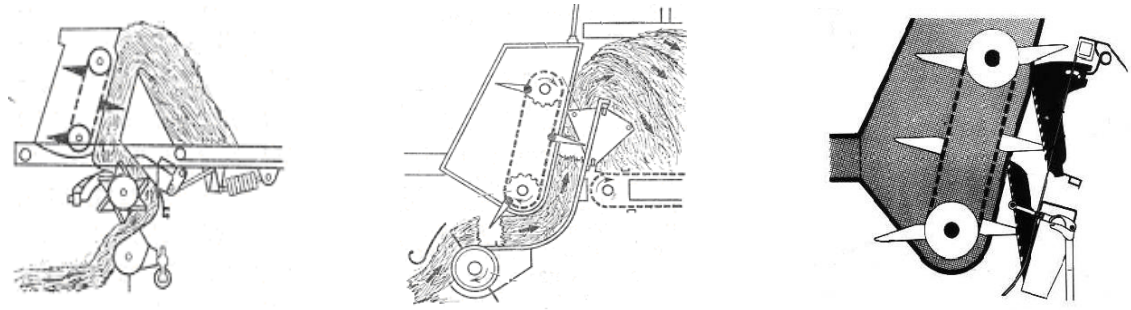
Firm (country)	Model	Trailer capacity, (DIN 11741/ dry mass) m^3	Pick-up width, m	Feeding device, (type; length, m)	Feeding rotor (diameter, mm; number of teeth in a circle)	Number of knives	Theoretical cutting length, mm	Required power, kW / hp
1	2	3	4	5	6	7	8	9
Claas (Germany)	**Cargos**							
	9400	38 / 76	2,0	Rotary; 1,58	860; 9	40	38	
	9500	44 / 88	2,0	Rotary; 1,58	860; 9	40	38	
	9600	50 / 100	2,0	Rotary; 1,58	860; 9	40	38	
Krone (Germany)	**Titan**							
	4/32 L	22 / 32	1,6	4 rakes; 1,47	- ; 4	0,4,9,18,35	40	37 / 50
	6/40 L	26,5 / 40	1,7	6 rakes; 1,47	- ; 6	0,4,9,18,35	40	60 / 80
	6/40 GL	26,5 / 40	1,7	6 rakes; 1,47	- ; 6	0,17,18,35	40	60 / 80
	6/48 GL	30,5 / 48	1,7	6 rakes; 1,47	- ; 6	0,17,18,35	40	66 / 90
	6/42 GD	26,5 / 42	1,7	6 rakes; 1,47	- ; 6	0,17,18,35	40	66 / 90
	AX							
	250 L	25 / 44	1,8	Rotary; 1,557	760; 8	0,16,32	45	59 / 80
	250 GL	25 / 44	1,8	Rotary; 1,557	760; 8	0,16,32	45	59 / 80
	250 D	25 / 44	1,8	Rotary; 1,557	760; 8	0,16,32	45	59 / 80
	250 GD	25 / 44	1,8	Rotary; 1,557	760; 8	0,16,32	45	59 / 80
	280 L	28 / 48	1,8	Rotary; 1,557	760; 8	0,16,32	45	66 / 90
	280 GL	28 / 48	1,8	Rotary; 1,557	760; 8	0,16,32	45	66 / 90
	280 GD	28 / 48	1,8	Rotary; 1,557	760; 8	0,16,32	45	66 / 90

continuation of table 3

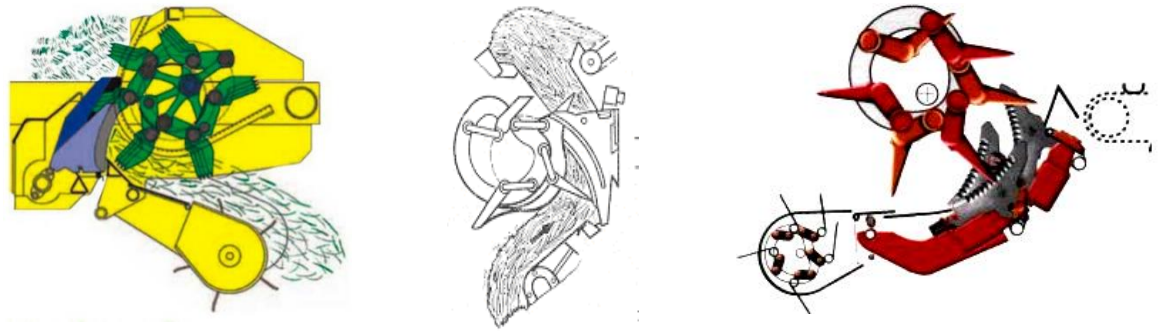
Firm (country)	Model	Trailer capacity, (DIN 11741/ dry mass) m^3	Pick-up width, m	Feeding device, (type; length, m)	Feeding rotor (diameter, mm; number of teeth in a circle)	Number of knives	Theoretical cutting length, mm	Required power, kW / hp
1	2	3	4	5	6	7	8	9
	MX							
	310 GL	31 / 50	1,9	Rotary; 1,64	880; 8	0,20,21,41	37	88 / 120
	310 GD	31 / 50	1,9	Rotary; 1,64	880; 8	0,20,21,41	37	88 / 120
	350 GL	35 / 56	1,9	Rotary; 1,64	880; 8	0,20,21,41	37	92 / 125
	350 GD	35 / 56	1,9	Rotary; 1,64	880; 8	0,20,21,41	37	92 / 125
	ZX							
	350 GL	33 / -	2,1	Rotary; 1,84	880; 8	0, 23 / 46	7 4 / 37	95 / 130
	350 GD	33 / -	2,1	Rotary; 1,84	880; 8	0, 23 / 46	7 4 / 37	95 / 130
	400 GL	38 / -	2,1	Rotary; 1,84	880; 8	0, 23 / 46	7 4 / 37	105 / 143
	400 GD	38 / -	2,1	Rotary; 1,84	880; 8	0, 23 / 46	7 4 / 37	105 / 143
	450 GL	43 / -	2,1	Rotary; 1,84	880; 8	0, 23 / 46	7 4 / 37	118 / 160
	450 GD	43 / -	2,1	Rotary; 1,84	880; 8	0, 23 / 46	7 4 / 37	118 / 160
	550 GL	53 / -	2,1	Rotary; 1,84	880; 8	0, 23 / 46	7 4 / 37	140 / 190
	550 GD	53 / -	2,1	Rotary; 1,84	880; 8	0, 23 / 46	7 4 / 37	140 / 190
Pottinger (Austria)	**FARO**							
	3500 LD	35	1,85	Rotary	750, 7	27	51	
	4000 LD	40	1,85	Rotomatik, 1,43	750, 7	27	51	
	4500 L	45	1,85	Rotomatik, 1,43	750, 7	27	51	
	6300 L	63	1,85	Rotomatik, 1,43	750, 7	6	210	
	8000 L	80	1,85	Rotomatik, 1,43	750, 7	6	210	
	EUROPROFI							
	4000 LD	40	1,85	Rotor, Euromatik	800, 8	31	45	
	45000 LD	45	1,85	Euromatik	800, 8	31	45	
	5000 LD	50	1,85	Euromatik	800, 8	31	45	
	TORRO							
	4500 LD	45	1,85	Rotor, Powermatik,	800, 8	39	35	
	5100 LD	51	1,85	Powermatik, 1,45	800, 8	39	35	
	5700 LD	57	1,85	Powermatik, 1,45	800, 8	39	35	
	JUMBO							
	6000 LD	60	2,0	Rotor. Powermatik	800, 8	45	34	
	6600 LD	66	2,0	Powermatik, 1,63	800, 8	45	34	
	7200 LD	72	2,0	Powermatik, 1,63	800, 8	45	34	
	8000 L	80	2,0	Powermatik, 1,63	800, 8	45	34	
	10000 L	100	2,0	Powermatik, 1,63	800, 8	45	34	
	JUMBO COMBILINE							
	6000 LD	60	2,0	Rotor., Powermatik	800, 8	45	34	
	6600 LD	66	2,0	Powermatik, 1,63	800, 8	45	34	
	7200 LD	72	2,0	Powermatik, 1,63	800, 8	45	34	

The use of a chain-finger conveyor (Fig. 5, a), inclined above the sorter in combination with knives with a straight blade set at an angle to the direction of movement allows you to apply the mass to a given height, and simultaneously cut it. However, such a design due to the contradictions between the reduction of the cutting length and the increasing force of elongation of the chain, has not found its further development.

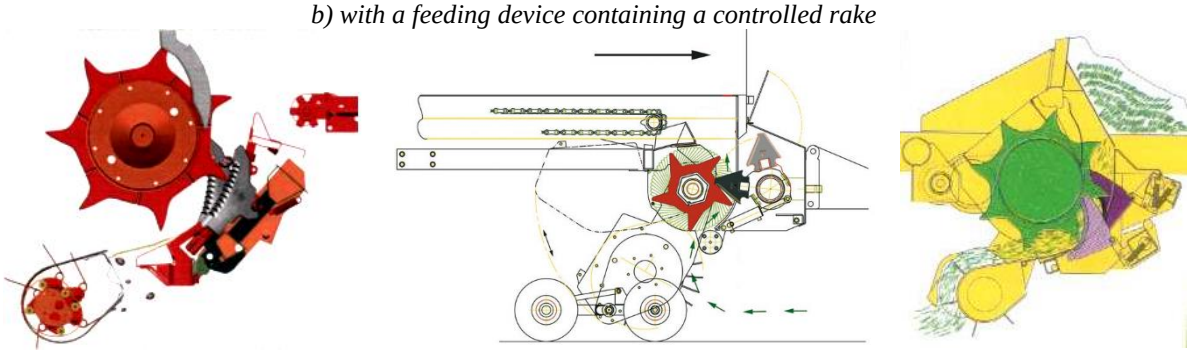
The rake feeding device (fig. 5, b) is designed in the form of a double eccentric reel with rakes at one of the ends of which there are arms with rollers which move on guides of the special form. Possibility of the directed action controlled by use of a guide track of a rake allows to capture reliably weight in a zone of action of the sorter and to push it with pressing on height of a body of the vehicle. The curved trajectory of the rake base ensures sliding cutting facilitates the use of flat knives with a crescent-shaped blade. In addition, it is possible to install more knives in this mechanism, which allows you to reduce the cutting length of the grass mass.



a) with a chain-finger conveyor of the feeding device



b) with a feeding device containing a controlled rake



c) with a rotary feeding device

Fig. 5. Constructional and technological schemes of bitumen-knife shredding machines

Krone uses a rake feeder (Fig. 6) with a width of 1.47 m with 4 and 6 controlled rakes, which are shifted relative to each other along the device (Table 3) in the Titan trolleys [12]. Double fingers (teeth) with a radial displacement, forming two sections are placed on each of the rakes. The central control system from Krone allows the use of knives 0, 4, 9, 18 and 35 knives, and therefore quick and easy adjustment of the cutting length. The theoretical cutting length with 18 knives involved reaches 80 mm, with 35 - 40 mm. The Titan cutting mechanism contains passive plate knives arranged in two rows [12].

Fig. 6. Scheme of the shredding device with controlled rakes of Titan trolleys

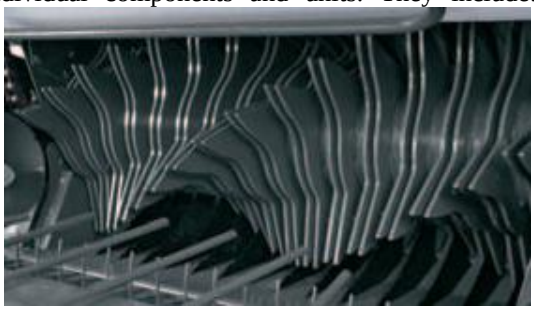
Fig. 7. Form of the feeding device Supermatic trolleys Boss junior and Boss LT

Similar in design grinders are used in pick-up models Boss junior, Boss LT (Fig. 7), Euroboss and Primo of company Pottinger (Austria) (Table 3) [16].

Rake feeders for shredding machines of these pick-up trucks are high-performance devices, however, given the complexity of its design, metal content, pulsating power loads, rapid wear of components moving on treadmills, the rotary feeder has become widely used in modern designs of trolleys-pickers-conveyors (Fig. 5, c).

Machines of different foreign companies, based on the same functional purpose, in general arrangement are close to each other and differ only in the design of individual components and units. They include: a frame, a trailer, a running gear, a sorter, a shredder, a body, an unloading device, which may additionally contain a dosing device for unloading fodder in the feeder. Pick-up trucks are not manufactured in Ukraine.

In modern models a simpler and more reliable rotary feeder is used (Fig. 5, c). It is a cylindrical drum on the surface of which curved fingers are fixed, thus forming a star-shaped shape. The number of fingers around the circumference of the drum varies from 2 to 9 depending on the diameter. This design of the feeder allows it to be used not only in pick-up trucks, but also in balers. In them, the stem mass is selected from the roll by a sorter and is fed into the area of rotation of the fingers of the rotary feeder.

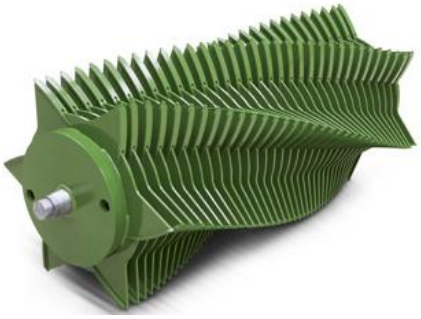


Form of the feed rotor Roto Cut baler Variant 380 RC by Claas

Form of the feed rotor Fine Cut baler Quadrant 3200 FC by Claas

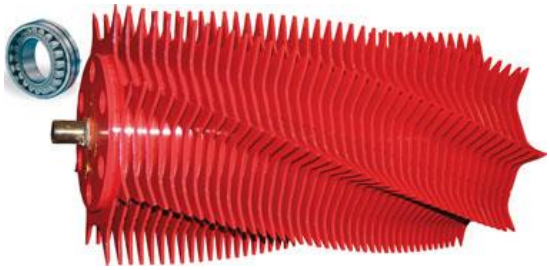
Form of the feed rotor of the baler Quadrant 3400 RC by Claas

Form of feed rotor Multi Cut baler Round Pack1250, 1550 by Krone



Form of the feed rotor of a pick-up truck AX by Krone

Form of the feed rotor CropCutter of a pick-up truck BigBaler 1290 by New Holland



Form of the feed rotor Powermatic Jumbo of a pick-up truck by Pottinger

Form of the feed rotor of a pick-up truck Caras 9400 by Claas

Fig. 8. Versions of feed rotors of pick-up trucks and balers

Then it is captured by a pair of fingers and stretches along the forming channel on the plate knives. Then the crushed stem mass is pushed into the pressing chamber of the baler or into the trailer of the pick-up truck.

The considered shredding machines with rotary feeder of foreign pick-up trucks and balers of such firms as Pottinger, Claas, Krone, Deutz Fahr [10-14, 16] and others are similar in general execution and differ only in design features of units and working bodies. Thus, their rotary feeder (Fig. 8) differs in length and diameter, the number of rows of fingers by their design (finger length and shape of the working surface line) and the method of attachment to the drum. For most models, the rotor contains a built-in reverse mechanism, which is used in the case of clogging.

As for the cutting mechanism, in all models, without exception, the knives are lamellar and installed in one or two rows (Fig. 9, 10). Arc-shaped knives have individual protection against breakage in case interference of foreign objects [17]. The execution of plate knives of foreign manufacturers, which are used in balers or pick-up trucks, is shown in Fig. 11.

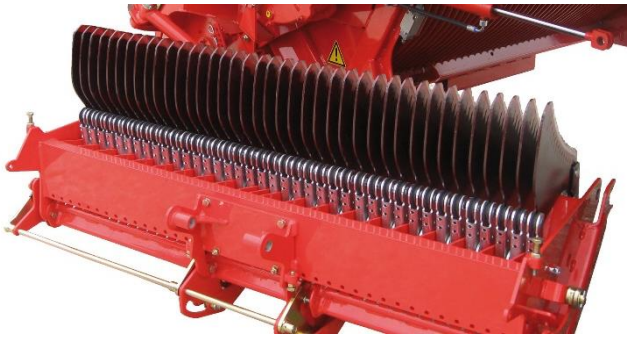


Fig. 9.
Cutting mechanism of the Pottinger Torro 5100 LD pick-up truck

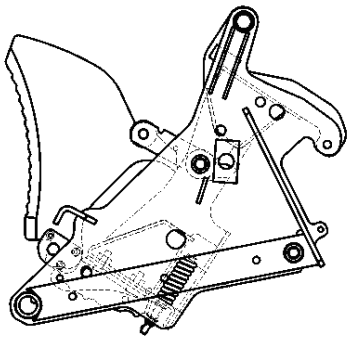


Fig. 10. Scheme of the cutting mechanism

Claas (Germany) uses Roto Cut and Fine Cut shredders (Fig. 8) for harvesting hay and haylage in the Variant, Rollant and Quadrant balers, the feed rotor of which contains 4 rows of spirally mounted fingers, works in pairs with 14 and 16 knives (for Variant and Rollant) and 6, 13, 25, and 49 knives for Quadrant (Table 1) [11]. The Fine Cut system, which is equipped with a cutting mechanism with 49 knives, has an estimated cutting length of 20 mm [11].

а) Pottinger, Rollprofi 3200

б) TP-F-45

в) Krone AX/MX

Fig. 11. The appearance of plate knives

The feed rotor of the baler crusher Quadrant 3400RC (Fig. 8) with a length of 1.3 m and a diameter of 86 cm is the largest rotor on the market [11]. With 9 rows of fingers it is possible to make about 28000 cuts a minute with cutting length of 45 mm (tab. 2).

The feeding device of the AX, MX and ZX models of Krone trolleys is made in the form of a rotor with a diameter of 760 mm and 880 mm, respectively (Fig. 8), with a working grip length of 1.57 m (for AX models), 1.64 m (for MX models) and 1.84 m (for ZX models), which is driven by a closed gearbox (Table 3). For all the models (AH, MX and ZX) the rotor has 8 gripping teeth, each subsequent row of which is offset from the previous by 2.7o, 2.1o and 1.9o, respectively, forming a spiral arrangement (Fig. 12) [18].

Fig. 12. Location of teeth on AH (25 mm) and MX (17 mm) Krone pick-up truck

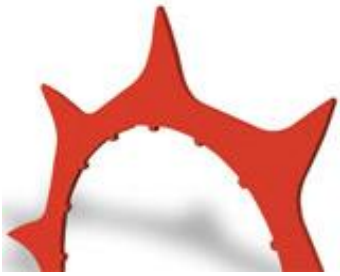


Fig. 1.13. Toothed disc of Rotomatic feed rotor of Pottinger pick-up truck

As for Pottinger pick-up trucks, they use rotary feeders Rotomatik, Euromatik and Powermatik (Fig. 8) [16] on models Faro, Europrofi, Torro, Jumbo and Jumbo Combiline [19]. In general, they are similar to each other and differ only in structural differences (Fig. 13).

Malone (Ireland) produces five models of Trojan MT [20] pick-up trucks with a capacity of 35 to 62 m3. The rotary feeder, which contains 5 rows of fingers 6 mm thick, interacts with the cutting mechanism, which has 35 and 44 plate knives. This design of the shredder allows you to get a cut grass mass of 35 and 40 mm.

Ross (Italy) offers pick-up trucks of CT series with a trailer capacity of 38, 48 and 60 m 3, which contain a shredding machine with a rotary feeder [21]. A distinctive feature of the device (Fig. 14) is that the flow (transportation) of grass mass from the pick-up takes place on the front part of the rotor. The rotor with a working length of 2.0 m contains 5 rows of fingers paired on the drum with subsequent displacement relative to each other, forming a spiral. The fingers interact with the cutting mechanism, which has 18 lamellar knives arranged in a row, which have the shape of segments, which allows the use of oblique cutting.

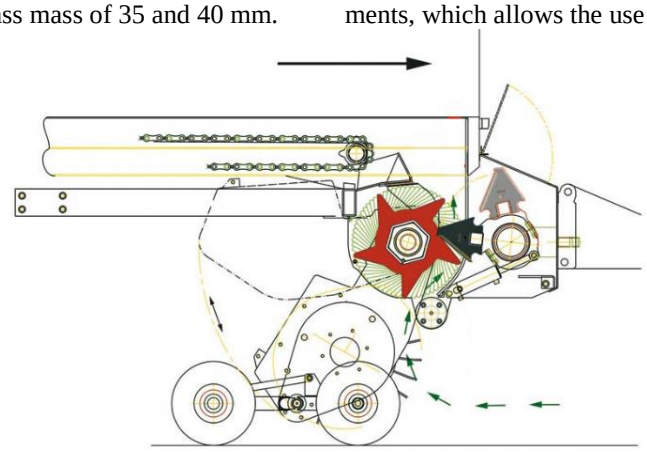


Fig. 14. Scheme of the feeding device with the feed rotor of the pick-up trucks Roc ST 360, 348, 238

The advantage of the considered constructive-technological scheme of carts-pickers is assignment of the pick-up trucks in transport position under a trailer body (fig. 14) that promotes convenient movement and moving of the unit on rough surface.

The disadvantages of the shredding machines are caused by energy losses, which are caused by the magnitude of the cutting force and the friction of the grass mass on the side surfaces of flat knives. The blades of such knives have a curved shape, and the cutting edge is located on the inner surface of the knife. This design of the knives makes it difficult to maintain the sharpness of the blade during operation.

Conclusions. Thus, the shredding machine is the main and quite energy-intensive working unit of the forage harvester, the design of which determines the technological scheme of the combine as a whole, as well as the location of its main components. Among the main features of shredding machines the following can be noted:

1. Most high-performance forage harvesters (over 75%) use a two-section closed and open drum shredder with a V-shaped arrangement of knives. In combines of small and medium productivity, the diameter of the drum is in the range of 400-800 mm, width - 400-700 mm, speed - 800-1100 rpm. The cutting speed is 28-40 m/s. Increasing the width of the drum allows you to increase the cross-sectional area of the receiving neck, and thus increase the productivity of combines.

2. The disk shredder is installed mainly on trailed and semi-mounted forage harvesters, as well as machines that are aggregated with universal energy means, where their use is determined by the design of the combine as a whole. The diameter of the disk, at the end

points of the knives, varies from 670 to 1200 mm, the speed of the most distant points of the knives from the axis of rotation - 35-52 m/s, the minimum cutting speed - 8-12 m/s.

3. Rotary shredding machine, along with such advantages as simplicity, reliability and versatility, has a significant energy consumption (up to 8 MJ/t), low productivity (up to 1.5 ha/h) and low cutting quality. The diameter of the rotor with knives varies from 500 to 820 mm in width up to 2.0 m. The rotor speed varies from 1100 to 1600 rpm, the blade speed - from 36 to 60 m/s. The blades of knives, as a rule, are parallel to the axis of rotation of the rotor and in the process provide chopping. To improve the quality of grinding in series with the rotary shredder a drum or disk shredder is installed.

4. The energy consumption of the technological process of grinding-transporting the mass is reduced, the reliability of the apparatus is increased by using bitumen-knife shredding machines, which carry out multi-plane cutting at a speed of 4-8 m/s. Such devices are used in construction and technological schemes of balers and pick-up trucks of such well-known foreign firms as: Pottinger, Mengele, Taarup (Denmark), Far, Claas, Krone, Deutz Fahr (Germany), New Holland, Case, John Deere (USA) and others. Their feeding device which can be executed in the form of the chain-finger conveyor, an eccentric reel with the controlled rakes (rake) or a rotor. In modern models the simpler and reliable rotary feeding device is used representing the cylindrical drum on which surface curved fingers are fixed , thus forming an asterisk. The number of fingers on the circumference of the drum varies from 2 to 9 depending on the diameter. Rotary feeder from different manufacturers differs in length and diameter, the number of rows of fingers, their design (finger length and the shape of the line of the work surface) and the method of attachment to the drum. For most models, the rotor has a built-in reverse mechanism, which is used in the case of clogging.

As for the cutting mechanism, in all models, without exception, the knives are lamellar and installed in one or two rows. Arc-shaped knives have individual protection against breakage in the event of foreign objects.

Further study of the features of the grinding machines of forage harvesters should be aimed at determining the quality indicators in the process of cutting stem materials.

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