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EVALUATION OF RELIABILITY OF SORGHUM HARVESTER

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ABSTRACT

Based on the results of experimental studies of single-module attachment harvester headings sorghum and other crops and with radically new threshing and separating device inertial-type, thestripper reliability combine as a whole and its major systems are defined. Thus, the time to failure of sorghum harvester is 87.22 hours and availability factor is 0.985. It was revealed that limitings of the combine reliability are: Maize, threshed grain handling system in a combine hopper module. The decrease in the reliability of these systems failures and malfunctions is influenced by belting included in their design. During the study were recorded 41 failure of belt transmission. It was determined that 89% of failures occur due to loss of required belt tension and its delayed service. To increase the reliability of systems limiting sorghum harvester it is possible due to maintenance belt drive transmission throwers grain beater ramjet remote threshing chamber at intervals of 90 m ± 20% and the drive of the cutting apparatus reapers at intervals of 45 m ± 20%.

Keywords: MTBF, reliability, sorghum harvester, uptime.

INTRODUCTION

Harvesting of cereal, headings and other crops is the final, difficult, time-consuming and most important stage. Cleaning efficiency is largely determined by the duration of the works. However, downtime harvesters only due to technical reasons reach 12-15% of the shift time. At the same time the period between failures and other domestic grain harvesters under ordinary operation sometimes reaches 80 hours.

Total downtime combines, including sorghum harvest, for technical reasons, is largely determined by the level of reliability. However, the assessment of the reliability of sorghum harvester with a radically new design threshing and separating device stripper inertial-type and its main systems has not yet been carried out.

The more efficient use of sorghum harvester, resource efficient implementation of its systems and components, detection and early prevention failures maintenance plays a major role. We have adopted an interim system maintenance sorghum harvester new design that does not allow realizing the full inherence in the development of individual resource systems, assemblies and components combine. For example, the share of belt drives accounts for a large number of failures and faults combine some of which may be prevented by timely and quality service.

Therefore, to improve the utilization of sorghum harvester, reducing the cost of their operations, increase productivity per hour and the main shift time and a substantial reduction of crop losses there is a need to enhance their reliability by improving the maintenance of belt drives with an individual approach to each of them.

MATERIALS AND METHODS

The purpose of research is an assessment of the reliability of the main systems of sorghum harvester and determining the frequency of service belting. We used an experimental method with the processing of statistical data.

RESULTS AND DISCUSSIONS

In Volgograd State Agricultural University sorghum harvester with a fundamentally new threshing and separating device inertial stripper type has been developed. Patented is the modification hinged single and multi-module sorghum harvest combine [4, 5], as well as a multi-trailer [6].

All developed harvesters are similar and include: energy means 1 (Figure-1), one or more modules 2, attachment 3, 4 header, grain silos 5, 6 grain transportation system, transporter plants 7, 8 trolley, electrical 9 and signaling.

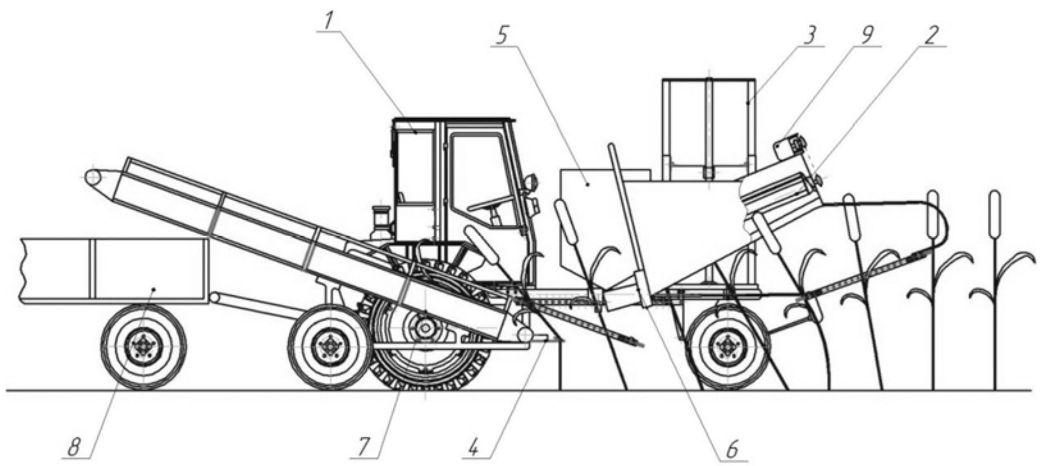

Figure-1. Driving a single-module attachment sorghum harvester.

Module sorghum harvester (Figure-2) includes direct flow outrigger threshing chamber 1,normalizer 2, an intermediate conveyor 3, synchronizing the transmission 4.

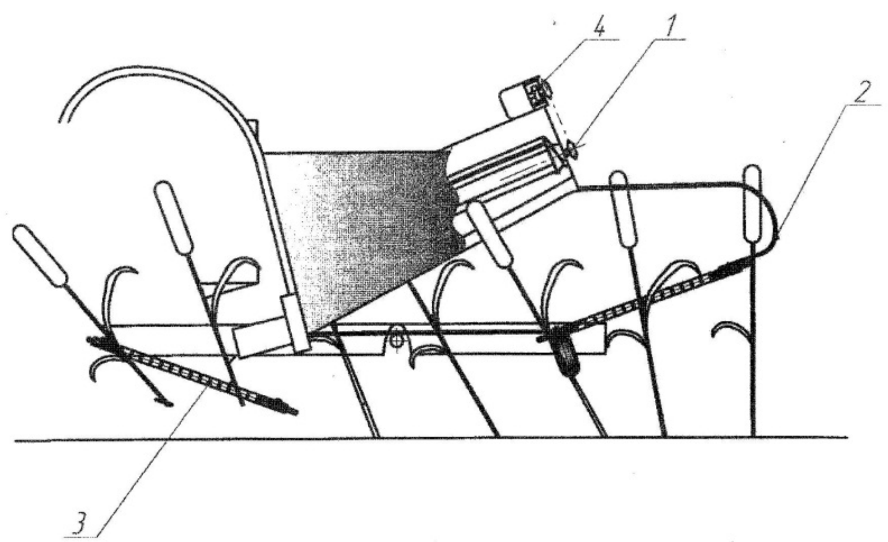

Figure-2. Module outline sorghum harvester.

The main working bodies of once-through remote cameras are threshing beater.

The threshing and separating device inertial stripper type we used to conveying gap beater plate [7].

One module combine threshes one row of plants to root using slotted beater made under patent [7]. If one uses slotted beater manufactured according to the patent [8], one module can thresh two rows of plants.

The number of modules for sorghum harvester are optimized [3].

Each module operates feeder grain threshing area in the hopper and stacker stem.

Grain transport system can be based on the use of the throwers fan type, screw conveyors, pneumatic devices [9].

To improve the quality of the grain harvest, sugar sorghum and broomcorn, high reliability and adaptability of sorghum harvester design sorghum harvester one uses multi-stage telescopic attachment [10].

Harvester operates as follows. When cleaning, for example broomcorn Sorghum plants picks up the normalizer 2 (Figure-2) and tilts them, setting broom plants perpendicular to the plane of the right-beater threshing accurate remote camera 1. Plants threshed. Threshed grain transportation system 6 (Figure-1) is fed into the hopper 5 processor.
Sorghum harvester threshes crop on the vine.

Threshed plants are cut header 4 and placed on the conveyor 7 plant, which supplies them to trailed carriage 8. The hydraulic hitch 3 allows the direct-flow threshing outrigger camera module 2 to the desired height thrashing. The cutting height is also adjustable to header plants.

Base and power means a single-module attachment sorghum harvester modification 2014 is self-propelled chassis of T-16M. For trailed and mounted multimodular sorghum harvesting combines can use the type of tractor MTZ-82.1, K-744R2, and others.

The level of reliability of a single-module attachment sorghum harvester is estimated by statistical method based on the results of the continuous timing of his work during harvesting in the sorghum broomcorn fields of Svetloyarsky district (Volgograd region).

In assessing the reliability of sorghum harvester conventionally it has been dissected into its component systems. List of the components of sorghum harvester systems is presented in Table-1. It is known that the reliability of individual system affects the reliability of the machine as a whole [1, 2] and failure in one system results in the machine inoperable.

Calculation of reliability of all systems performed by MTBF (t_{oi}), as well as the coefficient of preparedness (Kg_i).

MTBF sorghum harvester was determined by the equation (1):

$$t_o = 1/(\sum 1/t_{oi}) \quad (1)$$

The availability of each system and of the combine a whole was calculated, respectively, by the equations (2) and (3):

$$Kg_i = t_{oi} \ / \ (t_{oi} + t_{вi}) \quad (2)$$

Where
$t_{вi}$ – the duration of the recovery system uptime

$$Kg = 1 \ / \ \{1 + \sum[(1/Kg_i) - 1]\} \quad (3)$$

The estimated values of the coefficients system availability sorghum harvester after treatment statistical-based Information obtained as a result of experimental studies are presented in Table-1.

Table-1. Values of the reliability of sorghum harvester.

No.	Name system	t_{0i}, h	$t_{вi}$, h	Kg_i
1	Power Tool	Indicatorsnot determined		
2	Module	700	2.5	0.996
3	Suspension	924	0.9	0.999
4	Reaping part	252	0.9	0.996
5	Grain silos	1965	1.2	0.999
6	The system of grain transportation	575	1.0	0.998
7	Plants Conveyor	1128	0.8	0.999
8	Cart	1113	1.6	0.999
9	Electricals and alarm	1049	0.8	0.999

From Table-1 is clear that the limiting of the reliability of sorghum harvester is: maize, threshed grain handling system in a combine hopper module.

Calculations by the equation (1) defined the MTBF single-module attachment sorghum harvester in actual use (without taking into account the level of reliability of energy resources). It is equal to 87.22 h. According to the equation (3) calculated the value of the coefficient of readiness. Kg = 0.985 kg.

Thus, studies have shown that the level of reliability of a single-module attachment sorghum harvester in actual use is quite high, but the level of reliability of some of its systems need to be improved.

Studies have shown that the reliability of limiting systems sorghum harvester is largely determined by the level of reliability of belt drives. For belt drives used by us in knife drive harvesters, Throwers of grain transportation system threshed grain into the hopper and combine beater threshing ramjet remote camera module.

Research sorghum harvester new construction carried out for 3 harvesting seasons. The evaluation results MTBF t_o belting of sorghum harvester are presented in Table-2. Table-2 calculated values are given as the standard deviation σ and coefficient of variation υ MTBF investigated belting.

Table-2. MTBF belting.

Name of the drive	MTBF, h	t_o, h	σ, h	υ
The cutting apparatus reapers	4, 13, 37, 53, 58, 60, 65, 73, 79, 93, 98, 126, 130	68.385	27.216	0.398
Throwers of grain	60, 77, 83, 90, 95, 98, 106, 112, 114, 117, 123, 124, 137, 143, 148, 166, 168	115.350	29.529	0.256
Beater	52, 88, 92, 97, 101, 105, 108, 109, 121, 134, 157	105.818	77.416	0.732

The results showed that during the observation recorded were 41 failures of belt transmission. It was determined that 86% of failures occur due to loss of time specified operating instructions combine belt, and its untimely service. For these reasons, there was the decrease of the belt from the pulleys, while sorghum harvester stopped, wore a belt on pulleys and adjust its tension was performed. Other failures belting is due to gaps and bundles of belts associated with their aging.

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The number of refusals belting average per season, per one processor was 14 and the mean time between failures made 96.5 h. The lowest MTBF has a belt drive transmission header cutterbar (t_o= 68.385 h).

To improve the reliability of belt drives possible solutions to this goal were offered:

a) Definition of each individual belt drive frequency of maintenance.
b) Equipment of each belt drive signaling easing the tension.
c) Change the value of the limit of the maximum belt tension.

All our proposed ways to increase uptime belt drives can be realized under ordinary operation sorghum harvester.

In order to establish the individual service intervals belting sorghum harvester should be aware of the probability of failure-free operation. The probability of failure-free operation is one of the main indicators of the reliability assigned to a given operating time.

To probabilistically assess the reliability of the above indicator one is to use the distribution function $P(t)$ and the probability density function failure $f(t)$.

By using the information data statistical series of developments to refusal of belting investigated sorghum harvester were compiled. Subsequently, all the MTBF values were grouped into slots whose number is determined depending on the $n_y = \sqrt{n}$ (here n – the total number of points of information). When the number of points in each slot information is taken into account, the statistical number should be not be less than 5.

Δt_o interval is determined by the equation (4):

$$\Delta t_o = (\Delta t_{omax} - \Delta t_{omin}) / n_y \quad (4)$$

Where

Δt_{omax}, Δt_{omin}- the maximum and minimum values of MTBF belt drive shown in the statistical seriesΔt_o

Table-3 shows the calculation of indicators of reliability belting sorghum harvester.

The density function and the probability of failure of belt transmission are determined by dependencies:

$$f(t_o) = n_i / n\Delta t_o \quad (5)$$

Where

n_i – the number of failures in a given interval

$$P(t_o) = (n - \sum n_i) / n \quad (6)$$

Where

$\sum n_i$– the number of failures before the i –th developments

Table-3. The values calculated indices of reliability belting.

Interval groups, h	Δt_{oi}	n_i	$\sum n_i$	$f(t_{oi})\ 10^{-2}$	$P(t_o)$	t_{oi}	$\ln t_{oi}$	$-\ln t_{oi}$	$\ln\lvert-\ln P(t_{oi})\rvert$	$P(t_{oi})$	$f(t_{oi})\ 10^{-2}$
Knife drive header											
0…35	35	2	2	0.440	0.846	17.5	2.86	0.167	-1.789	0.884	0.954
36…70	35	5	7	1.100	0.461	52.5	3.96	0.774	- 0.256	0.511	1.005
71…105	35	4	11	0.879	0.153	87.5	4.47	1.877	0.630	0.229	0.593
106…140	35	2	13	0.440	-	122.5	4.81	-	-	0.084	0.262
141…175	35	-	-	-	-	157.5	5.06	-	-	0.026	0.009
Drive grain throwers											
0…35	35	0	0	0	1.0	17.5	2.86	0	-	0.999	0.017
36…70	35	1	1	0.168	0.941	52.5	3.96	0.061	- 2.780	0.943	0.402
71…105	35	5	6	0.840	0.647	87.5	4.47	0.435	- 0.831	0.661	1.201
106…140	35	7	13	1.176	0.235	122.5	4.81	1.448	0.370	0.220	1.044
141…175	35	4	17	0.672	-	157.5	5.06	-	-	0.019	0.183
Drive beater											
0…35	35	0	0	0	1.0	17.5	2.86	0	-	0.999	0.020
36…70	35	1	1	0.260	0.909	52.5	3.96	0.095	- 2.350	0.932	0.501
71…105	35	5	6	1.300	0.454	87.5	4.47	0.790	- 0.236	0.582	1.441
106…140	35	4	10	1.039	0.091	122.5	4.81	2.397	0.874	0.125	0.848
141…175	35	1	11	0.260	-	157.5	5.06	-	-	0.034	0.049

According to the Table-3 histograms density function $f(t_o)$and the probability of failure of $P(t_o)$ belting are as follows (Figure-3).

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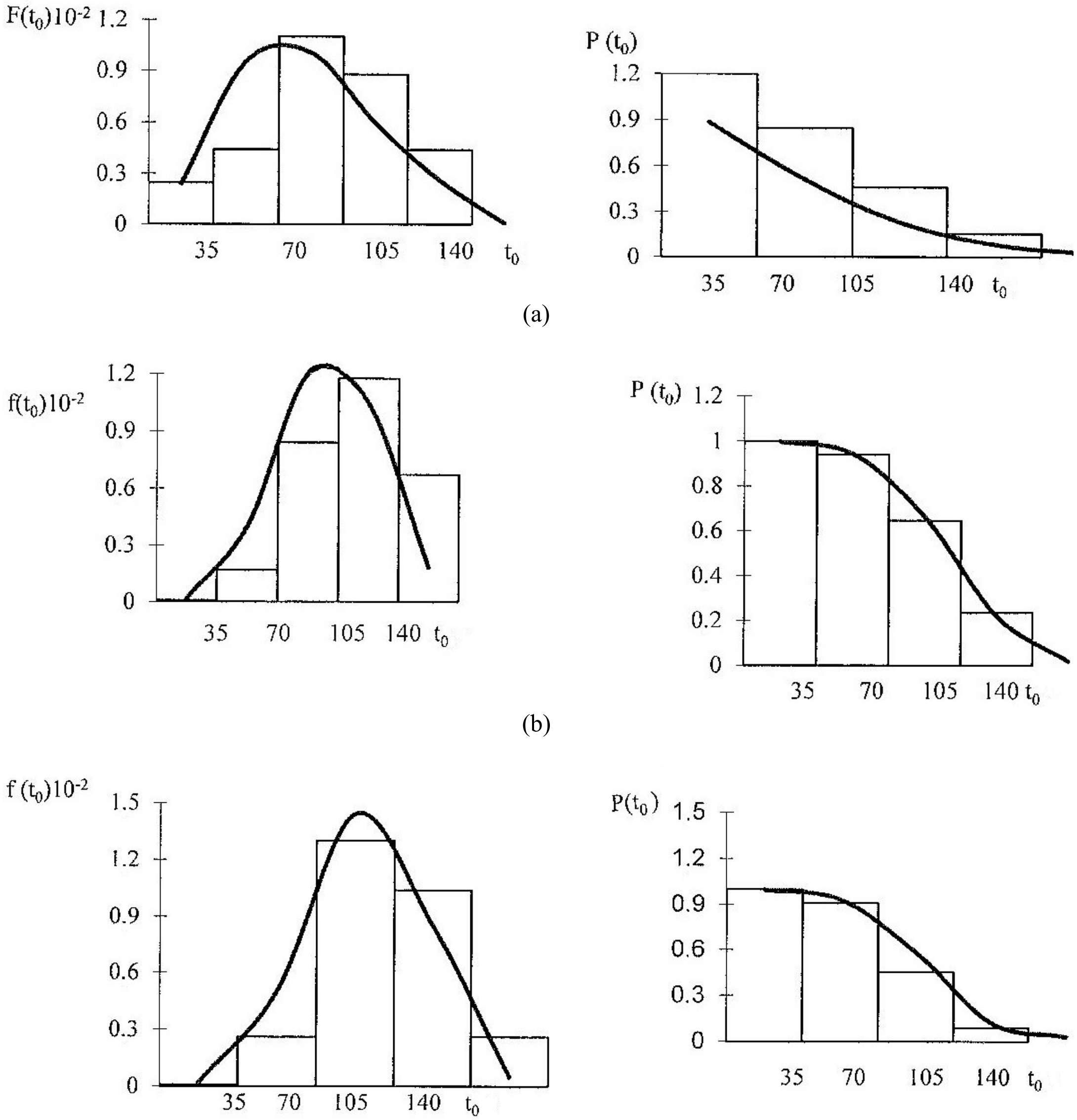

(c)

Figure-3. Probability density functions and uptime belting: (a) knife drive header, (b) drive grain throwers,(c) drive beater.

View graph of the function $f(t_o)$shows that this function is distributed, or exponential, or Weibull, or under the law of Rayleigh. Weibull distribution law, as is known, is more general, because it has two parameters *a* and *b*, at which it is possible to evaluate the variation range of statistical parameters, moreover, with b = 1 this coincides with an exponential law, for b = 2 - Rayleigh law, and when b = 2.5…3.5 is close to normal. Therefore, in subsequent calculations, we have used the Weibull law. Weibull parameters are defined graphically.

For belting sorghum harvester values of the Weibull distribution law are pre-presented in Table-4.

Table-4. Calculated values of the Weibull distribution law.

Name of transfer	*a*	*b*
Knife drive header	68	1.54
Drive grain throwers	110	3.84
Drive beater	102	4.00

Harmonization of experimental data with the theoretical distribution law is known, it is possible according to the criteria of the Kolmogorov, χ^2 and ω^2. However, Kolmogorov is applicable only to continuous random variables if parameters are checked by theoretical law previously known. In our case, its use is not possible.

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To match the experimental data with the theoretical law studies at agricultural machines most commonly is used the criterion of consent χ^2. Table 5 is a calculation criterion χ^2. According to the Table-5 is determined:

$$\sum\chi^2 = \sum(n_i - n_{mi})^2 / n_{mi} \qquad (7)$$

Where

$n_{mi} = n \{F(t_{ki}) - F(t_{ni})\}$

Table-5. Calculation criteria χ^2.

Interval groups, h	n_i	$(t_{ki} – c)/a$	$F(t_{ki}) - F(t_{ni})$	n_{mi}	$(n_i - n_{mi})^2/n_{mi}$
Knife drive header					
0…35	2	0.10	0.10	1.30	0.377
36…70	5	0.50	0.40	5.20	0.008
71…105	4	0.75	0.25	3.25	0.173
106…140	2	0.91	0.16	2.08	0.003
141…175	0	0.98	0.09	1.17	1.17
					$\sum\chi^2 = 1.731$
					$P(\chi^2) \approx 0.42$
Drive grain throwers					
0…35	0	0.159	0	0	0
36…70	1	0.477	0.07	1.19	0.030
71…105	5	0.795	0.28	4.76	0.012
106…140	7	1.114	0.49	8.33	0.212
141…175	4	1.432	0.16	2.72	0.602
					$\sum\chi^2 = 0.856$
					$P(\chi^2) \approx 0.68$
Drive beater					
0…35	0	0.172	0	0	0
36…70	1	0.515	0.07	0.77	0.069
71…105	5	0.858	0.34	3.74	0.424
106…140	4	1.201	0.46	5.06	0.222
141…175	1	1.544	0.13	1.43	0.129
					$\sum\chi^2 = 0.844$
					$P(\chi^2) \approx 0.66$

According to the calculated values $\sum\chi^2$ and taking into account the number of degrees of freedom r ($r = n_y - s$, s = 3 - the number of required connections) $P(\chi^2)$ is defined - probability of coincidence of the experimental data with Weibull. It was believed that if $P(\chi^2) > 0.1$ selected to align the theoretical law of distribution is suitable.

The results of calculations (Table-5) showed a fairly good consistency of the experimental data with the theoretical law of the Weibull distribution.

By law Weibull parameters calculated failure probability density function $f(t_o)$ and the state probability $P(t_o)$:

$$f(t_0) = \frac{b}{a}(\frac{t_0}{a})^{b-1}\exp\left[-(\frac{t_0}{a})^b\right];$$

$$P(t_0) = \exp\left[-(\frac{t_0}{a})^b\right] \qquad (9)$$

The calculated values of $f(t_o)$ and $P(t_o)$ are shown in Table-3 and shown in Figure-3.

The resulting values of the Weibull distribution law we used to determine the frequency of maintenance of all investigated belting by operating sorghum harvester combine to the point of time when the limit is equal to the probability of failure (R_n). The calculation is performed by the equation (10):

$$t_n = a\sqrt[b]{-\ln(1-R_n)} \quad (10)$$

Table-6 contains the maintenance intervals studied belting hours main job sorghum harvester hectares and harvested area - S at the maximum probability of failure (Rn = 0.2). This data is used to limit loosening of the belt, that is when the belt tension goes beyond the recommended time instruction manual approval, and the area, removes single module half sorghum harvester in 1 hour time S_{bsc}= 0.4 ha/h.

Table-6. The values of t_n and S for belting sorghum harvester.

Name of transfer	t_n, h	S, ha
Knife drive header	25.66	39.27
Drive grain throwers	74.42	113.86
Drive beater	70.09	107.24

Presented in the Table-6 data on harvested area - S indicates that the transmission belt drive throwers grain beater comply temporary operating instructions for the frequency of maintenance TO-1, at 90 ha of harvested area.

Limit weakening of belt drive transmission is achieved in header cutterbar to the timing of maintenance TO-1. This maintenance-free belt drives earlier.

In general, the increase in t_n to the standard value is possible by adjusting the difference between the maximum (top) H_{max} and minimum (lower) H_{min} limits belt(H_{max} - H_{min}). But since H_{max} determines the durability of the belt based on its loading, then an adjustment is only possible by changing the lower limit value H_{min} belt in the direction of tightening the limits of regulation. However, belt drive transmission cutterbar header decrease tolerance for the amount of deflection of the belt at a certain force is almost impossible. This is due to the fact that for the belt drive belt deflection tolerance is recommended only 1 mm. In this regard, it is necessary to change the frequency of maintenance belt drive transmission cutterbar header from 90 hectares harvested area to 45 hectares of ± 20%.

Experimental studies of belting knife drive harvesters, throwers of grain and direct-flow bypass beater threshing chamber single-module attachment sorghum harvester combine with the recommended maintenance intervals showed that the failure of these programs between the periodic maintenance due to the weakening of the belts have been recorded.

CONCLUSIONS

The level of reliability of a single-module attachment sorghum harvester in a real operation is quite high: MTBF is 87.22 hours and availability factor - 0.985. Increased reliability limiting systems combine sorghum harvester achieved by maintenance belt drive transmission throwers grain beater ramjet remote threshing chamber at intervals of 90 m ± 20% and the drive of the cutting apparatus reapers - at intervals of 45 m ± 20%.

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REFERENCES

[1] Gubsch M. 1972. Zu einigen Aspekten in der Mahdrescherentwicklung. Agrartechnik. 3: 122-125.

[2] Nath S., Johnson W.H., Milliken G.A. 1982. Combine loss model and optimization of the mashine System. Transactions of the ASAE. 25: 308-312.

[3] Ryadnov A.I., Fedorova O.A. 2014. Rationales for the number of modules combine with threshing and separating device inertial-type stripper. Basic Research. 11: 1010-1014.

[4] Ryadnov A.I., Sharipov R.V., Semchenko A.V. 2011. Harvester industrial crops. The patent of the Russian Federation № 2421974, A01D 41/08; applicant and patent holderVolgograd State Agricultural Academy - № 2010100341/21; stated 11.01.10; published 27.06.11, bulletin № 18.

[5] Ryadnov A.I., Sharipov R.V., Semchenko A.V. 2013. Sorghum harvester. The patent of the Russian Federation № 2498553, A01D 37/00; patent holders: Ryadnov A.I., Sharipov R.V., Semchenko A.V. - № 2012103615/13; stated 10.06.12; published 20.11.13, bulletin № 32.

[6] Ryadnov A.I., Sharipov R.V., Semchenko A.V. 2013. Trailing sorghum harvester. The patent of the Russian Federation № 2496296, A01D 41/04, A01D 41/12; patent holders: Ryadnov A.I., Sharipov R.V., Semchenko A.V. - № 2012109041/13; stated 11.03.12; published 27.10.13, bulletin № 30.

[7] Ryadnov A.I., Skvortsov A.K., Sharipov R.V., Ileneva S.V. 2003. Slit beater with conveying plate. The patent of the Russian Federation № 2199203,A01D 41/08; applicant and patent holder-Volgograd State Agricultural Academy-№ 2000128584; stated 15.11.2000; published 27.02.03, bulletin № 6.

[8] Ryadnov A.I. 2014. Beater threshing and separating device. The patent of the Russian Federation № 2535255, A01F12/18/; applicant and patent holder-Volgograd State Agrarian University - №

2013133173/13; stated 16.07.2013; published 10.12.14, bulletin № 34.

[9] Ryadnov A.I. 2014. Substantiation of is constructive-technological scheme of air conveyor grain harvester sorgouborochnogo. Proceedings of lower Volga agro-University complex: science and higher education. 3(35): 200-205.

[10] Ryadnov A.I., Sharipov R.V. 2014. Analysis of the types of devices mounted module sorghum harvester. Modern problems of science and education. 3(35): 190-195.