

RESEARCH ON RELIABILITY OF PLOWS OPERATING IN MOUNTAINOUS CONDITIONS

Katsitadze J., Academician of the Georgian Academy of Agricultural Sciences, Ph. D., full professor;
 Kapanadze I., Ph. D. of Agricultural Engineering, assistant professor;
 Kutelia G., MS in Agricultural Engineering;
 Bidzinashvili I., BS in Agricultural Engineering.

Agricultural University of Georgia,
 David Aghmashenebeli Alley 140, 0159, Tbilisi, Georgia. E-mail: chokhadari@yahoo.com

Abstract: Characteristics of operational reliability of agricultural plows, operating in mountainous conditions were determined on the basis of theoretical and experimental studies. It is shown that these conditions adversely affect their workability, cause intense wear of working parts of plows, and lead to failures. For this purpose, special coefficient was introduced which takes into account the impact of mountainous conditions on reliability.

A structural-logical scheme for reliability calculations was determined, and at the level of invention, a fundamentally new plow with variable widths was developed, allowing a better use of its operation in the mountainous conditions.

KEYOBWORDS: RELIABILITY, PLOWS, FAILURE, STATE OF SERVICEABILITY, MODELING, RELIABILITY INDEX, LIFETIME, REDUNDANCY.

Among complex operations of cultivation of crops, plowing of the soil is the most important and labor-consuming operation which is carried out by plows.

Plows work in severe soil and climatic conditions - their working parts are affected constantly by sign-variable dynamic loadings, humidity of the soil and the abrasive particles in it, difficult relief configuration and exposition. During work in mountain conditions to these factors are added the small featured plots, inclination, a sinuosity of the processed soil and complication of maneuvering of plows in connection with deterioration of traction indicators of tractors. The specified factors cause intensive wear of working parts, reduction of their durability and, as a result, both gradual, and sudden refusals. The latter cause idling of plows, violation of agrotechnical terms of plowings and reduction of a crop of agricultural production. Therefore, increase of reliability of agricultural plows is very important problem of world significance which solving will give big economic effect.

We developed the general technique for calculation of indicators of reliability of agricultural machinery [1,2] and continued developing this technique achieving our own method of calculation of reliability of plows which considers the specific of work in mountain conditions and nature of connection of their elements in the structural and logical scheme (SLS).

We entered special coefficient K - which considers influence of mountain conditions on indicators of reliability of plows.

$$K = \frac{\overline{P(H)}}{P(H)} \dots (1)$$

Where $\overline{P(H)}$ - the probability of no-failure operation (PNFO) of plows during the work in mountain conditions.
 $P(H)$ - (PNFO) in flat conditions.

Our research [3,4] showed that this coefficient fluctuates in limits

$$K = 0,74 - 0,80.$$

Further, for calculation of reliability, we made the structural and logical scheme of plows which considers reservation by means of the additional case (fig. 1).

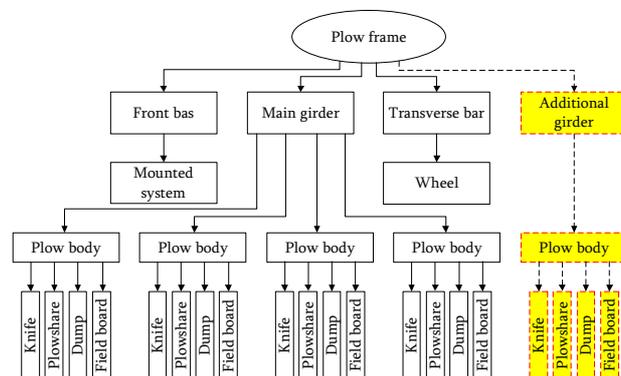


fig.1 The structural and logical scheme of a plow for calculation of reliability.

Theoretical prerequisites and sequence of calculation of reliability of machines depending on a type of connection of elements are described in detail in our work [2]. Our calculations showed that the use of the reserve case increases the probability of no-failure operation of plows by 8-10 percent.

Generally VBR of plows can determine be by a formula:

$$P(t) = K \cdot P_1(t)P_2(t) \dots (2)$$

$P_1(t)$ - PNFO at sudden refusals;

$P_2(t)$ - PNFO at gradual refusals.

Our theoretical and experimental studies [5,6] showed that in most cases $P_1(t)$ - is described by the exponential law, and $P_2(t)$ - by normal distribution. Then (3) the equation will be:

$$P(t) = K \frac{e^{-\lambda t}}{\sigma \sqrt{2\pi}} \int_0^{\infty} e^{-\frac{(t-T)^2}{2\sigma^2}} dt \dots (3)$$

σ - average quadratic deviation of an indicator reliability;

\overline{T} - Mathematical Expectation of time of non- failure work, h.

t - operating time of a plow, h.

λ - failure rate, h^{-1} .

For probabilistic and statistical modeling of the general characteristics of indicators of operational reliability of the plows, working in mountain conditions, field observations were made by the technique developed by us. For collecting of the statistical materials in special journals were fixed the main indicators of operational reliability - time between failures, an operating time between refusals, a type and group of complexity of refusals, an idle time and restoration, dynamics of wear of working parts and others. Experimental research was conducted in mountain areas of Racha-Lechkhumi and Samskhe-Javakheti regions of Georgia (Ambrolauri, Oni, Tsageri, Adigeni, Akhalkalaki and Akhaltsikhe areas).

After mathematical processing of statistical data, the empirical frequency of refusals of plows and frequency (statistical probability, table.1) were determined.

Table 1.

Statistics of refusals of plows

output (in ha) before failures, interval a...b	middle of the Interval H_i , ha	empirical frequency m_i	statistical probability w_i
10...14	12	53	0,33
14...18	16	33	0,21
18...22	20	23	0,14
22...26	24	20	0,13
26...30	28	13	0,08
30...34	32	10	0,06
34...38	36	5	0,03
38...42	40	3	0,02

Number of intervals of refusals:

$$K = 1 + 3,2 \cdot \lg \cdot N \dots (4)$$

where N – is a quantity of refusals for. N=160, we get

K=8.

Width of the interval $h = 4$ ha ... (5)

Further, general characteristics of the distribution of refusals were determined:

- Average value

$$\bar{H} = \sum_{i=1}^k w_i h_i = 19,3 \text{ ha} \dots (6)$$

- Dispersion

$$D = \sum_{i=1}^k (H_i - \bar{H})^2 w_i = 55 \text{ ha}^2 \dots (7)$$

- Average deviation

$$\sigma = \sqrt{D} = 7,45 \text{ ha} \dots (8)$$

- Variation coefficient

$$V = \frac{\sigma}{\bar{H}} = 0,39 \dots (9)$$

- Failure rate

$$\lambda = \frac{1}{\bar{H}} = 0,05 \text{ ha}^{-1} \dots (10)$$

Density of distribution of refusals (differential function of distribution) was determined by formula

$$f(H) = \lambda e^{-\lambda H} = 0,05 \cdot e^{-0,05 \cdot H_i} \dots (11)$$

Results of calculations of this indicator are presented in table 2.

Tab. 2

Indicators of distribution of refusals of plows

output (in ha) before failures, interval a...b	middle of the Interval H_i	empirical frequency m_i	frequency W_i	Distribution density(H) (empirical)	Distribution density(H) (theoretical)
10...14	12	53	0,33	0,083	0,027
14...18	16	33	0,21	0,053	0,023
18...22	20	23	0,14	0,035	0,018
22...26	24	20	0,13	0,032	0,015
26...30	28	13	0,08	0,020	0,012
30...34	32	10	0,06	0,015	0,010
34...38	36	5	0,03	0,008	0,008
38...42	40	3	0,02	0,005	0,007

The value of the variation coefficient was assumed to be have exponentially.

Integrated function of distribution of refusals of plows and probability of non-failure operation are [4] respectively equal:

$$F(H) = 1 - e^{-0,05 \cdot H_i} \dots (12)$$

$$P(H) = 1 - F(H) = e^{-0,05 \cdot H_i} \dots (13)$$

These indicators were defined after mathematical processing of statistical data on refusals of the plows working in mountain conditions.

Special attention was paid to types of refusals of plows. Their analyses showed that the percentage was the following:

- Design refusals -18%,
- Industrial refusals -37%,
- Operational refusals -45%.

Integrated function of distribution and probability of no-failure operation of plows were also defined.

In fig. 2 . graphical Interpretation of the results of calculations are given.

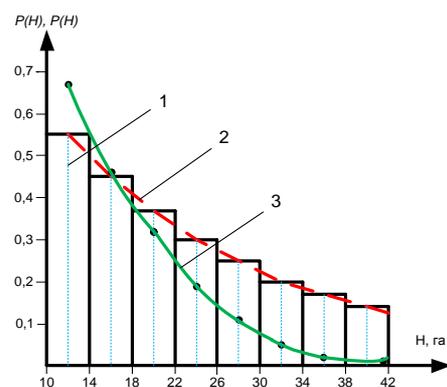


Fig. of 2 Schedules of probability of no-failure operation of plows
1 Histograms, 2 Polygon, 3-Theoretical curve.

Validation of the mathematical model using Kolmogorov criteria showed that the coincidence probability of theoretical and experimental results is $p(\lambda) = 0,54$.

Our further research was directed on the development of constructional actions for increase of reliability of plows taking into account reservation. At the level of the invention it was developed and made a plow with a variable width of capture. Existing similar designs have a shortcoming which comes from a difficult design of the mechanism of capture width variation. Operators are compelled

to perform additional works manually that complicates a plow unitization with a tractor.

At the level of the invention [6] we developed, made and tested an original plow with a variable width of capture which differs from others with simplicity of a design, convenience in operation and with increase in reliability. In addition it has a reserve element case of a plow (fig. 3).

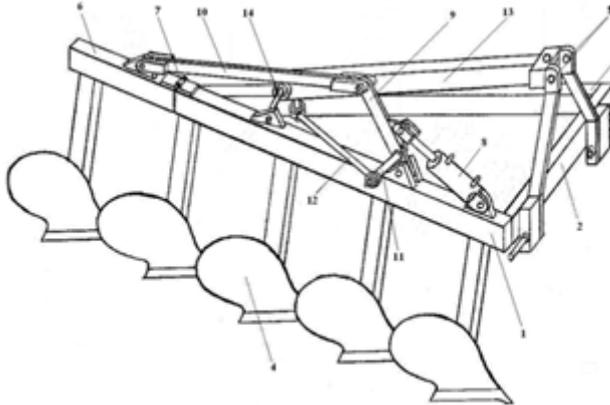


Fig. 3. Plow with a variable width of capture.

1-main beam. 2-front bar. 3-cross bar. 4-case of a plow. 5-hinged system. 6-additional beam. 7- hinge. 8- hydraulic cylinder. 9-yoke. 10-lever. 11-lever. 12-traction. 13-mobile bar. 14-oval axis.

The plow with a variable width of capture is aggregated with a tractor hinged system. For change of width of capture the operator directly in a cabin turns on the lever and oil with a high pressure moves in a hydraulic cylinder which rod moves a yoke and the lever. As a result of it, the additional beam together with the reserve case falls down and holds working position. At the same time by means of the lever the mobile bar moves on an oval axis that promotes increase in width of capture of a plow.

The carried-out field tests showed working capacity and high reliability of the plow developed by us with a variable width of capture which qualitatively carried out soil plowing in the mountain regions of Georgia.

Conclusions

- 1 . The technique for calculation of indicators of reliability of plows taking into account mountain working conditions is developed.
- 2 . The structural and logical scheme of a plow for calculation of reliability is made and probabilistic and statistical modeling of indicators of operational reliability is carried out.
- 3 . At the level of the invention is developed and tested the plow with a variable width of capture which differs from the similar plows by simplicity of a design and convenience in operation.

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