Results of flaw detection of parts of the «shaft - pinion bushing» connection of agricultural machinery reducers

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Abstract. The article has devoted to solving an urgent problem related to the fault detection of the main parts of gearboxes. A study of the dimensions of new and worn parts, forming the connection «shaft - pinion bushing» Ø40N7/k6 in the gearboxes of agricultural machines had carried out. It was found that the defect in size is 12.45 %, and the defect in shaft size is 8.69 %. It had found that the greatest wear of the holes when reaching 0.082 mm, about 19 % of the gears must be replaced due to the excess of the inner diameter, the shafts wear up to 0.12 mm and about 23 % of the shafts have rejected. It has shown that a transitional fit is assigned in the new joint, as evidenced by the presence of both clearances and interferences, and interferences predominate. The defect to the left of the span of a fit is 0.91 % and to the right is 0.47 %. This indicates that all new holes and shafts can be allowed for assembly, including those provided by defect, but as a result, there will be practically no defect in the joints. When joints have formed from worn parts, above 25 % of rejects at the maximum clearance, therefore, flaw detection and complete control in this case are necessary.

1. Introduction

Domestic machines for the agro-industrial complex have a lower level of reliability than foreign ones and, because of this, more often require repair actions, so control during repair should play a crucial role [1,2]. During operation, most of the critical joints of machines are subject to wear, there is an increase in gaps [3,4] and there is a dynamic change in the tightness in the seats of various assembly units and aggregates [5,6], the sealing units wear out and lose their properties [7,8]. Insufficient accuracy of the equipment used in mechanical engineering, and outdated technologies, in comparison with foreign production, are the main reasons for quality assurance problems. To increase the accuracy, selective assembly methods [9, 10] and new methods for increasing the durability of joints [11, 12] have used. Therefore, the process of defecation is so important, where a decision is made to accept or reject worn parts [13]. The process of defect detection and control during the repair of machines should be carried out with competent metrological support [14, 15] and with the use of quality control tools [16].

In agricultural machinery, gearboxes are very widespread, where keyway connections are used in the connections of gears with shafts [17]. The accuracy standards of fixed cylindrical joints with a key were analyzed in [6], and a new method for calculating such landings was developed and proposed [18]. But in operation there are reducers with key connections, which use fit with a clearance or interference, so the study of their wear and further use is an urgent task.
2. Research objectives and methods

The purpose of the research is an experimental assessment of the maximum clearance in the «shaft-gear sleeve» connection when using used and new parts in the process of repairing agricultural machinery gearboxes.

Theoretical and experimental methods had used in the research. Methods of probability theory and mathematical statistics had used to process the experimental data. The reliability of the calculation results has guaranteed by the use of standard methods of statistical data processing and the use of modern software.

3. Research results and analysis

As the objects of research, the details of the «shaft – gear sleeve» connections Ø40H7/k6, installed on the universal gearbox H 090.20.000 of the Mosselmash plant, had selected. The parameters of the studied parts have shown in table 1.

| Table 1. Parameters of the parts forming the connection «shaft-gear sleeve» gearbox H 090.20.000. |
|---------------------------------------------------------------|
| **Detail** | **Controlled parameter** | **Size designation** | **Maximum dimensions, mm** | **Tolerance T, µm** |
|-----------|-----------------------|---------------------|-------------------------|-------------------|
| Shaft     | Outer diameter of the gear surface | k6 | 40.018 | 40.002 | 16 |
| Gear      | Internal diameter of the basement surface | 40H7 | 40.025 | 40.000 | 25 |

Measuring instruments for micrometry and defectation were selected in accordance with the requirements for measurement error according to GOST 8.051-81. The shaft was measured with a lever bracket SR-50, and the hole-with an inside caliper of increased accuracy NI-50, the description of the measuring instruments is presented in the table 2.

| Table 2. Metrological characteristics of measuring instruments. |
|---------------------------------------------------------------|
| **Measuring instrument** | **Symbol name** | **Effective range, mm** | **Division price, mm** | **Error of measurement, mm** |
|--------------------------|-----------------|------------------------|------------------------|-----------------------------|
| Indicator inside caliper | NI-50-0.001     | 18-50                  | 0.001                  | ±0.002                      |
| Bracket lever arm        | SR-50-0.002     | 25-50                  | 0.002                  | ±0.002                      |

As a result of the quality study, 20 pieces new connections «shaft-gear sleeve» Ø40H7/k6, installed on the universal gearbox H 090.20.000 revealed that the dispersion of the inner diameter of the gear and the outer diameter of the shafts obeys the law of normal distribution. The hole size defect is 12.45 % and the shaft size defect is 8.69 %. After the study of 48 pieces of worn holes and shafts, it had revealed: the greatest wear of holes is up to 0.082 mm, about 19 % of gears are subject to replacement during repair due to exceeding the internal diameter; the shafts wear down to 0.12 mm and about 23 % of the shafts have rejected, table 3.

| Table 3. Parameters for the disassembly of the inner diameter of the gear and the outer diameter of the shafts. |
|---------------------------------------------------------------|
| **Distribution parameter** | **Symbol name** | **Inner diameter of the gear new** | **Inner diameter of the gear worn out** | **Outer diameter of the shaft new** | **Outer diameter of the shaft worn out** |
|--------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Arithmetic mean, mm      | X               | 40.0095         | 40.033          | 40.012          | 40.012          |
Standard deviation of a measurement result, mm $\sigma$ 0.00755 0.05546 0.00424 0.0384
Scattering zone, mm $\omega$ 0.04531 0.33276 0.02544 0.2304
Shift value, mm $c$ -0.003 +0.002
Risk factor (incorrigible defect) $t_1$ 1.26 0.87/1.14a 2.36 0.73/0.99a
Risk factor (correctable defect) $t_2$ 2.05 – 1.42 –
The probable percentage of the defect that can be corrected, % $Q_{cd}$ 10.38 – 0.91 –
Probable percentage of an uncorrectable defect, % $Q_{uncd}$ 2.07 19.22/12.71a 7.78 23.27/6.11a
Total defect, % $Q_d$ 12.45 – 8.69 –

* - the first digit is for the permissible size limit when mating with used parts; the second digit is for the permissible size limit when mating with new parts, table 3.

The parameters for making a decision on the suitability of each of the parts for further operation are presented in table 4.

Table 4. Connection defect parameters «shaft-gear sleeve».

| Parameter Description | Dimension, mm | Conclusion |
|-----------------------|---------------|------------|
| Gear shaft H 090.20.000: wear of the gear surface | $40^{+0.018\ +0.002}$ | 39.985 | 39.97 | Repair |
| Gear H 090.20.601: wear of the surface under the shaft | $40^{+0.025}$ | 40.04 | 40.05 | Repair |

Data on the formed clearances and interferences in the connection of new shafts and holes, as well as on the clearances in the connection of worn-out parts, but allowed for further operation, are presented in table 5.

Table 5. Connection parameters of new parts and parts approved for further operation.

| Fitting parameters | Symbol name | Connecting parts |
|--------------------|-------------|------------------|
| Standard deviation of a clearance (interference), mm | $\sigma$ | 0.00866 | 0.06745 |
| Maximum clearance, mm | $S_{max}$ | 0.025 | 0.065 |
| Maximum interference, mm | $N_{max}$ | 0.018 | – |
| Medium clearance, mm | $\bar{S}$ | –0.0025 | +0.021 |
| Risk factor (interference) | $t_1$ | 2.37 | – |
| Risk factor (clearance) | $t_2$ | 2.60 | 0.65 |
| The probable percentage of the defect (interference), % | $Q_{cd}$ | 0.91 | – |
| The probable percentage of the defect (clearance), % | $Q_{uncd}$ | 0.47 | 25.78 |
| Total defect, % | $Q_d$ | 1.38 | – |
Based on the data presented (table 5), it can be concluded that a transition fit has assigned in the new connection, as evidenced by the presence of both clearances and interferences, and interferences prevails, since the average interferences with a minus sign. The defect to the left of the span of a fit is 0.91 % and to the right – 0.47 %. This indicates that all new holes and shafts can be allowed to be assembled, including those that turned out to be defective, but as a result, there will be practically no defect in the joints.

When forming joints from worn parts, more than 25 % of defects are observed in the maximum clearance, so defecation and continuous control are necessary in this case.

4. Conclusions
A study of the dimensions of new and worn parts, forming the connection «shaft - pinion bushing» Ø40N7/k6 in the gearboxes of agricultural machines had carried out. It was found that the defect in size is 12.45 %, and the defect in shaft size is 8.69 %. It had found that the greatest wear of the holes when reaching 0.082 mm, about 19 % of the gears must be replaced due to the excess of the inner diameter, the shafts wear up to 0.12 mm and about 23 % of the shafts have rejected. It has shown that a transitional fit is assigned in the new joint, as evidenced by the presence of both clearances and interferences, and interferences predominate. The defect to the left of the span of a fit is 0.91 % and to the right is 0.47 %. This indicates that all new holes and shafts can be allowed for assembly, including those provided by defect, but as a result, there will be practically no defect in the joints. When joints have formed from worn parts, above 25 % of rejects at the maximum clearance, therefore, flaw detection and complete control in this case are necessary.

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