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STRUCTURAL-PARAMETRIC JUSTIFICATION OF THE SLEWING UNIT OF AN EXCAVATOR SWING MECHANISM AND EVALUATION OF MATERIAL COMPATIBILITY

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Abstract. This article presents a structural-parametric analysis of the slewing unit of an excavator swing mechanism and evaluates its main geometrical parameters and material properties. The study used the assembly drawing of the swing mechanism, working drawings of the base, cover, and internally toothed ring gear, catalogue data for three-row roller slewing bearings, and the results of spectral analysis of the ring gear material. The analysis showed that the swing mechanism is a large-sized annular support unit. Its main parameters were determined as follows: the maximum diameter of the base component is **2460 mm**, the number of holes in the base is **76**, the number of holes in the cover is **78**, the module of the internally toothed ring gear is **m = 14**, and the number of teeth is **z = 149**. The calculation-based evaluation showed that the pitch diameter of the ring gear is approximately **2086 mm**, while the circular pitch of the teeth is **43.98 mm**. The comparison with standard roller supports of the **2240 class** showed that the existing structure has a high level of compatibility in terms of external dimensions. The results of spectral analysis of the ring gear material confirmed that the sample corresponds to **40Kh steel**. Based on the obtained results, it was determined that the efficiency of the swing mechanism depends not on a separate type of support element alone, but on the mutual compatibility of structural geometry, mounting scheme, and material suitability.

Keywords: excavator, swing mechanism, slewing unit, internally toothed ring gear, structural analysis, parametric evaluation, roller support, mounting scheme, 40Kh steel, material compatibility.

Аннотация. В данной статье проведен конструктивно-параметрический анализ опорно-поворотного узла механизма поворота экскаватора, а также

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оценены его основные геометрические показатели и свойства материала. В исследовании использованы сборочный чертеж механизма поворота, рабочие чертежи деталей основания, крышки и внутреннего зубчатого венца, каталожные данные трехрядных роликовых опорно-поворотных подшипников, а также результаты спектрального анализа материала зубчатого венца. В результате анализа установлено, что механизм поворота представляет собой крупногабаритный кольцевой опорный узел. Его основные параметры определены следующим образом: максимальный диаметр детали основания составляет **2460 мм**, количество отверстий в основании — **76**, количество отверстий в крышке — **78**, модуль внутреннего зубчатого венца — **m = 14**, число зубьев — **z = 149**. Расчетная оценка показала, что делительный диаметр зубчатого венца составляет приблизительно **2086 мм**, а окружной шаг зубьев — **43,98 мм**. Сравнение со стандартными роликовыми опорами класса **2240** показало, что существующая конструкция имеет высокую степень соответствия по внешним габаритным размерам. Результаты спектрального анализа материала зубчатого венца подтвердили, что образец соответствует стали **40Х**. На основе полученных результатов установлено, что эффективность механизма поворота зависит не только от отдельного типа опорного элемента, но и от взаимного соответствия конструктивной геометрии, монтажной схемы и пригодности материала.

Ключевые слова: экскаватор, механизм поворота, опорно-поворотный узел, внутренний зубчатый венец, конструктивный анализ, параметрическая оценка, роликовая опора, монтажная схема, сталь 40Х, соответствие материала.

Annotatsiya. Mazkur maqolada ekskavator aylanish mexanizmining tayanch-burilish uzeli konstruktiv-parametrik jihatdan tahlil qilindi hamda uning asosiy geometrik ko‘rsatkichlari va material xususiyatlari baholandi. Tadqiqotda aylanish mexanizmining yig‘ma chizmasi, asos, qopqoq va ichki tishli venets detallarining ishchi chizmalari, uch qatorli rolikli tayanch-burilish podshipniklari katalog ma’lumotlari hamda tishli halqa materiali bo‘yicha spektral tahlil natijalaridan foydalanildi. Tahlil natijasida aylanish mexanizmi yirik gabaritli halqasimon tayanch uzeli ekani aniqlandi. Uning asosiy parametrlari quyidagicha belgilandi: asos detalining maksimal diametri **2460 mm**, asosdagi teshiklar soni **76 ta**, qopqoqdagi teshiklar soni **78 ta**, ichki tishli venets moduli **m = 14**, tishlar soni **z = 149**. Hisobiy baholash natijasida venetsning boshlang‘ich diametri taxminan **2086 mm**, tishlar aylana qadami esa **43,98 mm** ga teng ekani ko‘rsatildi. **2240 klass** standart rolikli tayanchlar bilan o‘tkazilgan taqqoslash mavjud konstruktsiya tashqi

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gabaritlar bo‘yicha yuqori moslikka ega ekanini ko‘rsatdi. Tishli halqa materiali bo‘yicha spektral tahlil natijalari namunaning **40X po‘latga** mos kelishini tasdiqladi. Olingan natijalar asosida aylanish mexanizmining samaradorligi faqat tayanch elementning alohida turiga emas, balki konstruktiv geometriya, montaj sxemasi va material mosligining o‘zaro uyg‘unligiga bog‘liq ekani aniqlandi.

Kalit so‘zlar: ekskavator, aylanish mexanizmi, tayanch-burilish uzeli, ichki tishli venets, konstruktiv tahlil, parametrik baholash, rolikli tayanch, montaj sxemasi, 40X po‘lat, material mosligi.

INTRODUCTION.

In modern mining and construction machinery, the excavator swing mechanism is considered one of the most critical units. The function of this unit is not only to ensure the rotation of the upper platform, but also to safely withstand the axial, radial, and overturning loads generated during operation and to distribute them uniformly across the supporting elements. Therefore, the base, cover, internally toothed ring gear, and slewing bearing included in the swing mechanism must operate together with high accuracy.

According to the drawings and systematized parameters, the maximum diameter of the base component in the considered unit is **2460 mm**, with **76 holes of Ø26 mm**. The cover contains **78 holes of Ø26 mm**, while the internally toothed ring gear has a module of **m = 14** and a number of teeth of **z = 149**. These indicators confirm that the unit is designed as a large-sized structure intended to operate under heavy-load conditions.

In practice, when improving such units, the main issues are often the type of support element, the operational reliability of the ring gear, and the compatibility of the housing components. However, in many cases, the problem is not limited only to the selection of the bearing type. In fact, the efficiency of the slewing unit is determined by the rigidity of the annular housing, the arrangement of the mounting holes, the torque transmission capacity of the ring gear, and the suitability of the material for operating conditions. From this point of view, this article evaluates the slewing mechanism as an integrated structural system and substantiates the geometrical and material compatibility of its individual elements.

The main parameters of the internally toothed ring gear in the considered unit deserve special attention. The module **m = 14** and the number of teeth **z = 149** indicate that the mechanism is intended for transmitting high torque. Under such conditions, the load acting on the support zone also increases, and local stresses may occur in the bearing raceways, support rings, and fastening zones. Therefore, when evaluating the design, not only torque transmission but also the degree of uniform load distribution along the support contour is an important criterion. In

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particular, the presence of numerous holes in the base and cover shows that the design aims to increase mounting rigidity and create stable clamping along the ring.

Along with structural evaluation, material selection is also of particular importance. Spectral Analysis Report No. **447-25** for the ring gear indicates that the sample material is **40Kh steel**, containing **0.40% carbon**, **0.29% silicon**, **0.76% manganese**, **0.92% chromium**, **0.017% phosphorus**, and **0.015% sulfur**. These indicators were assessed as complying with the requirements of **GOST 4543–2016**. The results show that the ring gear material satisfies practical requirements in terms of mechanical strength and wear resistance. Therefore, in the evaluation of the swing mechanism, a materials science approach is necessary together with structural-parametric analysis.

The purpose of this article is to analyze the structural-parametric configuration of the slewing unit of an excavator swing mechanism, systematize its main geometrical parameters, determine its compatibility with a series of standard roller slewing bearings, and evaluate the suitability of the ring gear material for the selected design.

Through this approach, the main structural factors that ensure the optimal operation of the unit are identified.

MATERIALS AND METHODS.

The assembly drawing of the swing mechanism, working drawings of the base, cover, and internally toothed ring gear, the catalogue of three-row cylindrical roller slewing bearings, the **GOST 3722–2014** standard for steel balls, and the spectral analysis report of the ring gear material were used as the main sources in the study. The research object was the excavator swing mechanism, while the research subject was the structural, mounting, and material parameters of its slewing unit.

At the first stage of the work, a structural-geometrical analysis was carried out. In this stage, the annular shape of the base and cover components, mating diameters, number of mounting holes, and supporting surfaces were examined. The following parameters were systematized: an outside overall dimension of **2460 mm** and **76 holes of Ø26 mm** for the base, **78 holes of Ø26 mm** for the cover, and **m = 14** and **z = 149** for the internally toothed ring gear. At this stage, the structure was evaluated as a large-sized unit with a multi-point fastening scheme.

Table 1.

Main parameters of the updated swing mechanism

Parameter	Value
Maximum diameter of the base component	2460 mm
Number of holes in the base	76 holes, Ø26 mm

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Number of holes in the cover	78 holes, Ø26 mm
Module of the internally toothed ring gear	m = 14
Number of teeth	z = 149
Ring gear material	40Kh steel
Closest standard support class	2240

At the second stage, compatibility with standard sizes was analyzed. For this purpose, large-sized variants of the **130, 131, and 133 series** from the catalogue of three-row cylindrical roller slewing bearings were considered. In particular, the main dimensions of the **130.45.2240**, **131.45.2240**, and **133.45.2240** standard sizes were analyzed. For these variants, the outside diameter is specified as **2461 mm**, the inside diameter as **2019 mm**, the overall height as **231 mm**, with **60 mounting holes of Ø33 mm** and **M30 mounting threads**. These values were compared with the external dimensions shown in the drawings of the existing unit, and the compatibility of the standard size was evaluated.

At the third stage, a materials science analysis was carried out. The chemical composition data from Test Report No. **447-25** for the ring gear material were summarized, and their compliance with the standard range for **40Kh steel** was checked. In the evaluation, the percentage values of carbon, silicon, manganese, chromium, phosphorus, and sulfur were accepted as the main criteria. At this stage, the material of the component was considered sufficiently justified for use in the structure.

At the fourth stage, an auxiliary comparative approach was applied. Based on the **GOST 3722–2014** standard for steel balls, the accuracy grades, diameter deviations, and hardness requirements were summarized as standard quality indicators of ball supports. These data were used not for direct new calculations, but to strengthen the conclusions related to the load-receiving scheme and structural solutions in the slewing unit.

RESULTS

The conducted analysis showed that the considered variant of the swing mechanism is formed as a large annular slewing unit. The large-diameter configuration of the base and cover components, the large number of mounting holes, and the location of the internally toothed ring gear in the central part of the unit indicate that a structural scheme intended to distribute the load along the ring in the support zone was selected.

This result confirms that the structure is designed to operate not locally, but along the entire contour.

Formula 1. Pitch diameter of the internally toothed ring gear

$$d = m \cdot z$$

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Where:

- **d** — pitch diameter, mm
- **m** — module
- **z** — number of teeth

d=14x149=2086mm

The pitch diameter, which is one of the main geometrical parameters of the internally toothed ring gear, is determined by the module and the number of teeth:

$$\mathbf{d = m \cdot z}$$

As a result of the calculation, this diameter was found to be 2086 mm. The systematization of the main parameters showed that geometrical compatibility is well maintained in the unit. The fact that the maximum diameter of the base component is 2460 mm, while the outside diameter of the roller supports of the 2240 class in the standard catalogue is 2461 mm, indicates practical compatibility. The difference here is minimal, which means that the slewing unit can be brought close to a standard size. In addition, the parameters D1 = 2395 mm and D2 = 2085 mm given for the 131.45.2240 and 133.45.2240 variants in the catalogue show functional similarity with the annular support contour of the existing structure.

The results obtained for the mounting scheme were also positive. The presence of 76 holes in the base and 78 holes of Ø26 mm in the cover indicates that the unit has a high fastening density. In the catalogue roller supports, 60 holes of Ø33 mm and M30 threaded joints are provided. This difference shows that the considered structure is not a direct copy of the catalogue variant, but a modernized unit with its own fastening scheme. At the same time, the large number of holes gives a useful result in terms of creating uniform clamping along the ring and increasing the rigidity of the housing.

The parametric analysis of the internally toothed ring gear confirmed its leading role in torque transmission. The module **m = 14** and the number of teeth **z = 149** showed that the transmission is designed to receive high loads and torques. In this case, the large module has a positive effect on the strength of the tooth contact zone, while the relatively large number of teeth helps to improve the smooth operation of the swing mechanism. On this basis, the ring gear was evaluated not only as a transmission element, but also as a central component that directly affects the operation of the entire slewing unit.

Formula 2. Compatibility coefficient of outside diameters

$$K_D = \frac{\mathrm{Dk}}{\mathrm{Ds}}$$

Where:

- K_D — diameter compatibility coefficient

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- D_k — diameter in the structure
- D_s — standard support diameter

Calculation:

$$K_D = \frac{2460}{2461} = 0.9996$$

The compatibility coefficient between the outside diameters of the structure and the standard roller support is **KD = 0.9996**, which indicates a very high level of geometrical compatibility.

Formula 3. Relative deviation

$$\Delta D = \frac{|Dk - Ds|}{Ds} \cdot 100\%$$

Calculation:

$$\Delta D = \frac{|2460 - 2461|}{2461} \cdot 100 = 0.04\%$$

As a result of the calculation, it was determined that the relative deviation between the outside diameters is only **0.04%**. This indicates that the existing structure is very close to the series of standard roller supports.

The results of the material analysis showed that the selected **40Kh steel** for the ring gear corresponds to the standard composition. The values of **0.40% carbon**, **0.92% chromium**, and **0.76% manganese** indicate the material's suitability in terms of strength and heat treatment. The low content of phosphorus and sulfur reduces the risk of brittleness. As a result, the ring gear material was found to be practically justified for the operation of the structure under high-load conditions.

Table 3.

Chemical composition of the ring gear material

Element	Content, %
C	0.40
Si	0.29
Mn	0.76
Cr	0.92
P	0.017
S	0.015

As a result of the auxiliary comparative analysis, it was determined that although the standard requirements for ball elements are very precisely regulated, the main advantage in the considered large-sized unit depends on geometrical compatibility and the load distribution scheme.

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In other words, within the framework of this study, the main result was the conclusion that the efficiency of the slewing unit is determined more by the structural compatibility of the entire unit than by the accuracy of an individual element.

DISCUSSION.

The obtained results showed the need for a systematic approach to the evaluation of the slewing unit of the excavator swing mechanism. While the first article mainly focused on the comparative characteristics of ball and roller supports, this study considered structural-parametric compatibility as the central issue. This approach made it possible to explain the efficiency of the unit not only by the type of supporting element, but also by the combined operation of the housing, ring gear, and mounting scheme.

The large number of mounting holes in the annular housing elements and the large support diameters increase the rigidity reserve of the structure. This is especially important when overturning moments and uneven loads occur in the swing mechanism. Therefore, it is appropriate to consider the base and cover not merely as auxiliary components, but as active structural elements that redistribute the load. From this point of view, the mounting scheme in the considered unit makes a significant contribution to the overall stability of the slewing unit.

The determination of compatibility with the catalogue of standard roller supports increases the practical value of this modernization. The almost complete correspondence of the external dimensions with the **2240 class** standard sizes shows that the structure can be brought closer to a standardized industrial series. This is useful in the subsequent stages in terms of using ready-made standard solutions, ensuring spare parts supply, and simplifying maintenance. Such a result indicates that the modernized unit is also convenient from the point of view of manufacturing and operation.

Table 4.

Comparison of the parameters of the structure and the standard roller support

Indicator	Investigated structure	Standard roller support (2240 class)
Outside diameter	2460 mm	2461 mm
Internal/geometrical main zone	approx. compatible in the range of 2086–2019 mm	2019 mm
Height	structural according to the drawing	231 mm

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Number of main holes	76	60
Number of holes in the cover	78	60
Module of the internally toothed ring gear	14	depends on the catalogue type
Number of teeth of the internally toothed ring gear	149	depends on the type

When the parameters of the internally toothed ring gear, namely **m = 14** and **z = 149**, are considered together with the standard composition of **40Kh steel**, it can be seen that the unit's ability to transmit torque and resist wear is sufficiently justified.

The main scientific and practical aspect here is that both the structural parameters and the material indicators should not be evaluated separately, but as a complex integrated system. This comprehensive approach constitutes the main difference between the present article and the first article.

CONCLUSION.

The structural analysis showed that the base and cover components of the swing mechanism form a large-diameter support zone and serve to distribute the load uniformly along the ring through numerous mounting holes. Such a structural solution creates favorable conditions for the use of a roller slewing bearing. This is because, in a roller-type scheme, the load is effectively received in several directions and is better compatible with this design. As a result, a reduction in deformation in the support zone and an increase in overall stability can be expected. The parameters of the internally toothed ring gear also confirm that the modernized unit is intended for severe operating conditions. The fact that the module is equal to **14** and the number of teeth is **149** indicates that the swing mechanism has the ability to transmit high torque. Under such conditions, the load acting on the supporting element also increases. Therefore, the use of a roller bearing that receives the load over a wider contact surface is considered structurally justified.

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