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Research on Working Bodies of Hammer Crushers Employing the Finite Element Method

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***Abstract*. The present paper studies the issues of improving the reliability of the working bodies of hammer crushers. This machine is widely used for grinding grain material in animal husbandry and the processing industry. The main wear element of such crushers is the hammers and disks to which they are attached. To study the strength characteristics of these parts, a technique and algorithm for studying the stress-strain state of the hammer crusher disc employing the finite element method (FEM) using computer simulation software products were developed. The mathematical apparatus of finite element method simplifies the model construction where the stress-strain state must be explored. Finite element method provides solutions in the form of stress and deformation fields in almost any cross-section of structural parts. The express analysis module of the APM FEM COMPASS system was used as the software for this work. The implementation of finite element methodwill reduce the metal intensity of the equipment, increase the reliability of its operation and reduce the cost, improve the quality of the feed produced. The results of the study showed that the maximum stresses occur on the surface creating the internal holes in the place of attachment of the disc to the shaft, but the stresses that occur there remain within the normal range.**

Keywords: finite element method, hammer crusher, disc, strength characteristics.

I. INTRODUCTION

Hammer crushers [1-3] are widely used for feed grain grinding in livestock farms and feed mills. They are designed with maximum simplicity, flexibility, compactness, and reliability in the operation. Hammer crushers have a wide range of performances. One of the main elements of crushers is rotating discs.

The strength and durability of the discs determine the possibility of achieving high parameters of the machines and providing the necessary service life. But the fact is that traditional methods of calculating the strength and durability of rotating crusher parts can't provide further major improvements in this process [4, 5]. In this regard, the development of new methods for calculating the stress-strain state and the optimal size of working bodies for grinding grain feed machines, which have wider technological capabilities, lower energy intensity, metal intensity and provide good quality grinding, is an urgent task.

Currently, such basic machine parts as crusher shafts, shaft bearings, discs, hammers and their fastenings to the disk are calculated for strength in the process of designing structural elements of hammer crushers according to existing methods [6-11]. Strength calculations of machine parts are carried out in terms of the harshest working

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conditions. Harsh working conditions suggest the highest possible speed and strict recording of the oscillatory processes in individual parts.

The shaft of the crusher is calculated for strength, rigidity, transverse and twisting oscillations. The design or preliminary calculation of the shaft for strength is carried out according to bending and torsion deformations. The section dimensions of individual shaft units are determined in this calculation. The length of the shaft units is determined for design reasons, taking into account the most compact placement of parts. After the structural design of the shaft, the machines carry out a verification calculation whereby the safety margin coefficients in the most dangerous sections are determined. The structural dimensions of the disc are selected based on the conditions of placing the hammers and ensuring the minimum required circumferential speed of the hammer [6-8]. A test calculation for determining the actual stresses and safety factors in the process of calculating the strength of the disc material is carried out. The calculation of the suspension of the hammers, the thickness of the disk, the jumpers between the holes under the axes of the suspension and the outer disk is carried out based on the deformation of the cut and crumple.

The analysis of the calculation methods for the structural elements of hammer crushers shows that these calculations, based on safety margin coefficients have limitations. They don't allow to use effectively the optimal design methods, take into account the manufacturing quality of parts and implement CAD. The classical approach in strength calculations doesn't reveal the mechanism of destruction, which can be presented in terms of fracture mechanics with sufficient accuracy.

Therefore, it is necessary to use a refined method of strength calculation (the finite element method (FEM)) in the manufacture of the main elements of hammer crushers [12-17].

The purpose of the paper is to develop a technique and algorithm for studying the stress-strain state of the hammer crusher disc using computer modeling software products.

II. Materials and Methods

The advantages of finite element method can be represented when calculating the disc of a hammer crusher. For this purpose, we suggest using the Ascon APM FEM COMPASS express analysis module [18-21].

According to the accepted research methodology, the main stages of solving the problem with the help of finite element method are as follows:

1. The preparation of a geometric 3D model and material selection is carried out utilizing the COMPASS-3D system. We choose the material steel 45 with an allowable voltage of 200 MPa for the disc.

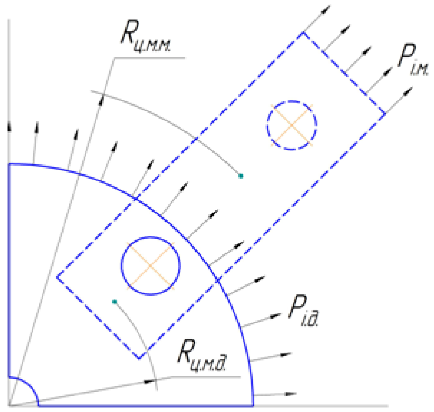

Fig. 1. Accounting scheme fourth disks of hammer crushers.

2. Analysis and determination of boundary conditions (fixation, loads). Fixing the disc sector is set by forming inner holes, in the place of its attachment to the shaft. Fixing and loads on the models are shown in Fig. 2.

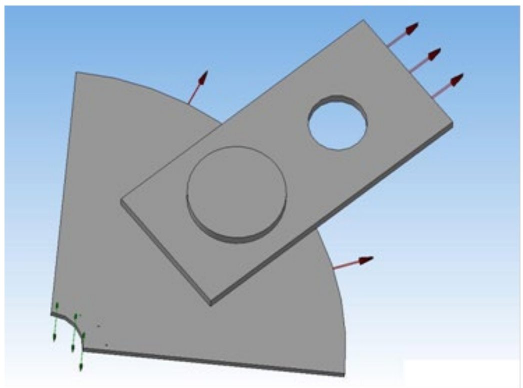

Fig. 2. Scheme of the fastening and loading models.

3. The generation of a finite element grid on a 3D model in APM FEM COMPASS is automatic, but the dimensions of the finite elements must be preset.
4. Selecting the desired type of calculation and configuring its parameters occurs in the APM FEM panel window. We select a static calculation.
5. Obtaining the results of automatic calculation in the form of a colour diagram of a deformed design model.
6. Analysis of the values of the main design characteristics (voltages, stock coefficients, displacements).

III. Results and Discussion

Centrifugal forces, the consequences of which are mechanical stresses, arise with the rotation of bodies in all elements of their volume. For each element of the volume of the body that rotates, a centrifugal force acts, $f_{ö} = \rho\omega^2 r$ where ρ is the specific weight of the material; ω is angular speed, r is the rotation radius. Speed n, rpm, is related to angular speed ω, rad/s, by the ratio $n = \frac{\omega}{2\pi}$. Since the elements of a rotating body, under the action of centrifugal forces, move in the body (within the elastic), each element is affected not only by centrifugal forces but also by the elastic forces of neighbouring elements. As a result, the distribution of mechanical stresses in a rotating body will depend on the shape of the body and elastic properties of the body μ (the modulus of volumetric elasticity (Poisson coefficient)).

The stress distribution in a disk of constant thickness is as follows [22-24]:

radial voltages (directed parallel to the radius):

$$\sigma_R = \frac{3+\mu}{8}\rho\omega^2\left(R^2 + R_0^2 - r^2 - \frac{R^2 R_0^2}{r^2}\right) \quad (1)$$

Tangential stresses (are directed perpendicular to radius):

$$\sigma_T = \frac{3+\mu}{8}\rho\omega^2\left(R^2 + R_0^2 - r^2\frac{1+3\mu}{3+\mu} - \frac{R^2 R_0^2}{r^2}\right) \quad (2)$$

where R is the external radius of the disk; R_0 is the inner radius of the disk; r is the current radius (Fig. 3. (it means that the axis of rotation of the disk coincides with the axes of the radii of the disk).

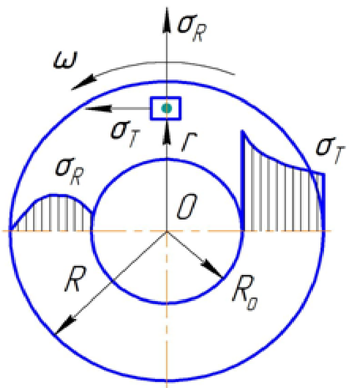

Fig. 3. Distribution radial and tangential stresses in rotating disk.

Equivalent stresses for plastic materials are determined by the fourth theory of strength, Von Mises criterion:

$$\sigma_e^{IV} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2} \quad (3)$$

Radial movement of the outer surface (deformation) of the disk of equal thickness from stresses is determined by the formulae:

$$\Delta R = \frac{\rho\omega^2 R^3}{4E}\left[1 - \mu + (3+\mu)\left(\frac{R_0}{R}\right)^2\right] \quad (4)$$

The disks of some machines, in addition to their inertial load, are additionally subjected to loads from the attached parts. For example, the centrifugal inertia forces of the hammers in hammer crushers are transmitted through the suspension axes to the disks, loading them at the radius of the axe installation. Distributing these loads evenly over the circumference of the specified radius, it can be assumed that in addition to the centrifugal forces of inertia, radial forces also act on the disk, evenly distributed over concentric ring sections of the radius of the axis installation [9].

As a result, the disk can be roughly viewed as loaded around the circumference by the following force factors: radial distributed forces of inertia, which arise in the disk itself and act in its middle plane and centrifugal forces of inertia of hammers, which act on the radius of installation of the axes.

Since the disc of a crusher with four hammers is a symmetrical design in configuration and loading, it is possible to consider the equilibrium of a quarter of the disk with one hammer (Fig. 1). Using the method of kinematics, we apply the force of inertia to the rim of the disk:

$$P_d^{in} = m_d \cdot \omega^2 \cdot R_{cms}$$

where m_d is the mass of a quarter of the disk; ω is angular speed; R_{cms} is the distance of the disk sector mass to the centre. We apply the force of inertia to the outer face of the hammer:

$$P_h^{in} = m_h \cdot \omega^2 \cdot R_{cmh}$$

where m_h is hammer mass; ω - angular speed; R_{cmh} is the distance of mass of the hammer to the centre.

For specified values $\omega = 314\ s^{-1}$, $m_d = 0{,}034$ kg, $m_h = 0{,}02$ kg, $R_{cms} = 0{,}064$ m, $R_{cmh} = 0{,}141$ m, we get such values of inertial forces: $P^{in}_{d.} = 214$ N, $P^{in}_{h.} = 284$ N.

When entering design data into the APM FEM COMPASS system, the finite element dimensions and other parameters of the geometric model (Fig.3) are set and the system automatically generates a finite element grid on the 3D model.

In a given system, the finite elements have the shape of a tetrahedron, and the number of elements in the thickness of the part should range from 4 mm to 6 mm. The thickness of the disk is 5 mm, so we take the height of the element at 1.5 mm. The finite element grid of the model is presented in Fig. 4.

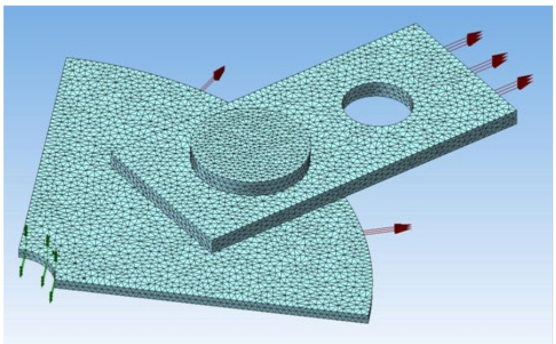

Fig. 4. Certainly element net to models.

As a result of the calculation, the diagrams of a deformed design model were obtained where the colour range depends on the level of stresses at a given place on the disk (Fig. 5). Viewing the results obtained and analyzing the values of the main design characteristics (stresses, reserve coefficients, movements) provide information for modifying the model based on the results of the calculations (you can change the geometric dimensions of the parts or material). Maximum stresses occur, as expected, on the surface creating an internal opening at the mounting point of the disc to the shaft. As the diagram (Fig. 5) shows, the voltage is normal.

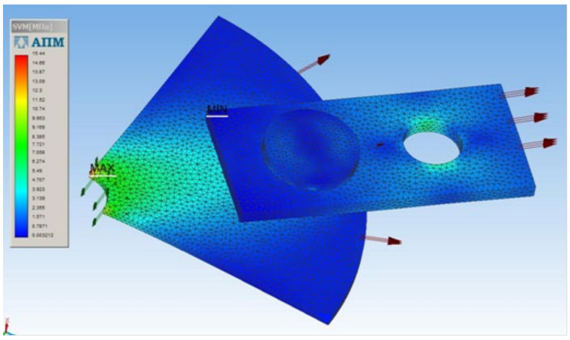

Fig. 5. Results of the calculation.

IV. CONCLUSIONS

The use of the mathematical apparatus of the finite element method simplifies the construction of a pattern where the stress-strain state must be explored. Finite element method provides solutions in the form of stress and deformation fields in almost any cross-section of structural parts. These advantages of the method have not been used in the design of hammer crushers up to the present time. Their implementation will reduce the metal intensity of the equipment, increase the reliability of its operation and reduce the cost, improve the quality of the feed produced.

The diagrams of the deformed design model obtained as a result of the study demonstrate the degree of stress at any point of the disk. According to the results of the study, peak stress values occur at the place of attachment of the disk to the shaft and in the places of the hammer holes. These peaks don't exceed the norm, but when changing the modes or operating conditions, as well as during grinding other material, the strengthening of the structure in these places may be needed.

REFERENCES

[1] S. Potapova. Klassifikatsia i otsenka izmel'chiteley zerna. MOTROL. Commission of Motorization and Energetics in Agriculture –2013. Vol. 15. No 3. 2013 pp.348-355

[2] V.V. Kirsanov, D.N. Murusydze, V.F. Nekrashevy. Mechanization and animal husbandry technology. Moscow KolosS, 2007. 584 p.

[3] V.I. Trukhachev, I.V. Kapustin, O.H. Angileev, V.I. Hrebennyk. Technologies and technical means in animal husbandry. StGAU Stavropol: AGRUS, 2005. 304 p.

[4] S. Yermakov, K. Mudryk, T. Hutsol. The analysis of stochastic processes in unloadingthe energywillow cuttings from the hopper. Environment. Technology. Resources. Rezekne, Latvia. Vol. III. 2019, pp. 249-252, https://doi:10.17770/etr2019vol3.4159.

[5] V. Ivanyshyn, S. Yermakov , T. Ishchenko. Calculation algorithm for the dynamic coefficient of vibro-viscosity and other properties of energy willow cuttings movement in terms of their unloading from the tanker. Renewable Energy Sources, vol. 154, E3S Web of Conferences. 2020, pp. 04005, https://doi:10.1051/e3sconf/202015404005.

[6] I.V. Demyanushko, I.A. Birger. Calculation of the strength of rotating discs. Moscow: Mashinostroenie, 1978. 247p.

[7] S.V. Kharlamov. Workshop on calculation and design of food production machines and devices. Leningrad: Agropromizdat. Leningrad Department, 1991. -256 p.

[8] V.I. Sokolov. Basics of calculation and design of machines and apparatus for food production: Moscow.: Mashinostroenie, 1983. – 447 p.

[9] M.F. Mykhalev, N.P. Tretyakov, A.I. Mylchenko, V.V. Zobnyn. Calculation and construction of machines and apparatus of chemical production: examples and tasks / Ed. Mykhaleva M. F. Leningrad: Mashinostroenie, 1984.

[10] S.Yermakov, T.Hutsol, V.Devin, S.Oleksiyko, P. Potapskyi. Effectiveness of cognitive digressions in classes of general technical disciplines in institutions of higher education of agro-technical direction.Engineering for rural development. 2022. pp.460-465 https://doi.org/10.22616/ERDev.2022.21.TF154

[11] S. Yermakov, T. Hutsol, S. Glowacki, V. Hulevskyi, V. Pylypenko. Primary Assessment of the Degree of Torrefaction of Biomass Agricultural Crops. Environment. Technologies. Resources. 2021. pp.264-267.https://doi.org/10.17770/etr2021vol1.6597

[12] O.V. Zhurbin, S.D. Chyzhiumov. Analysis of engineering structures by the finite element method: Textbook. Allowance. Komsomolsk-on-Amur: GOUVPO "KnAGTU", 2004. 157p.

[13] R. Gallagher. Finite element method: fundamentals. Moscow: Mir, 1984. 428 p.

[14] O. Zenkevich. Finite element method in technologyMoscow: Mir, 1975. 541 p.

[15] O. Zenkevich, K. Morgan. Finite elements and approximation. Moscow: Mir, 1986. 318 p.

[16] O. Zenkevich, I. Chang. The finite element method in the theory of constructions and mechanics of continuous media. Moscow: Nedra, 1974. 239 p.

[17] V.N. Vasilyeva. Introduction to the theory of the finite element method. Irkutsk, Irkut Publishing House. University, 1986.149p.

[18] A.N. Ivanov. Automated design and calculation of opto-electronic devices in CAD KOMPAS. Educational manual. St. Petersburg: NIU ITMO, 2012. 56 p.

[19] A. Gerasimov. Automation of work in KOMPAS-Grafik (+ CD-ROM). Moscow, BHV-Petersburg, 2010. 608 p.

[20] P. Talalai. Compass-3D V11 with examples (+ DVD-ROM). Moscow, BHV-Petersburg, 2010 616 p.

[21] N.V. Zharkov, M.A. Mineev, R.G. Why. Compass-3D V11. Full manual (+ DVD-ROM). Moscow, Science and Technology, 2010 688 p.

[22] H.S. Pisarenko. Resistance of materials. Kyiv: Higher school Main publishing house, 1979. 696 p.

[23] S.P. Fesik. Reference book on resistance of materials Kyiv: Budivelnyk, 1982. 280 p.

[24] V.I. Feodosyev. Resistance of materials. Moscow: Nauka, 1970. -544p.